UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

ASSESSMENT OF QUALITY ASSURANCE PRACTICES OF CONCRETE PRODUCTION BY CONSTRUCTION FIRMS IN GHANA

DANIEL MENSAH

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8171760009

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 requirements for the award of the Master of Philosophy (Construction Technology) degree

JUNE, 2020

DECLARATION

STUDENT'S DECLARATION

I, DANIEL MENSAH, declare that this Dissertation, except for quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my original work, and it has not been submitted, either in part or whole, for another degree in the University of Education, Winneba or elsewhere.

SIGNATURE: ….……………………...

DATE …………………………. …….

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work were supervised under the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

NAME: DR. NONGIBA A. KHENI

SIGNATURE …………………………….

DATE ……………………………………..

ACKNOWLEDGEMENTS

My heart is full of praise to God Almighty for sustaining my life and steering me in this academic pursuit. I am grateful to God for directing me to the production of this long essay. A document of this nature could not have been completed without the support, encouragement, technical and professional guidance of some individuals whose efforts and contribution have to be acknowledged.

My sincere thanks and grateful thoughts go to Dr. Nongiba A. Kheni, my supervisor and a senior lecturer, University of Education, Winneba Kumasi Campus, who read the manuscripts and a lot of useful suggestions and corrections were made.

Another appreciation and thanks go to Mr. Isaac Ofori headteacher of Kwadaso S.D.A Junior High School Kumasi, for his immense contributions towards achieving this dissertation. I also thank Madam Aku Duku Judith an I.C.T. tutor at Effiduasi Senior High Technical School for typing the whole work.

My last appreciation is extended to my family members who are diverse ways contribution towards my training at the University.

DEDICATION

I dedicate this work to my dear wife Portia Peprah and my two children Christian Kwamena Mensah and Nana Aba-Ahema Mensah, whose toil has brought me this far.

TABLE OF CONTENT

CONTENT **PAGE**

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

ABSTRACT

Globally, failure of mass and reinforced concrete structures are frequently reported in the mass media. In Ghana, the failure of concrete structures is a yearly experience with dire consequences. Generally, the causes of failures include; lapses in design and construction, change in intended usage and deterioration of materials and components. To a large extent, the poor quality of concrete remains a significant issue. The aim of the study was to explore the implementation of quality assurance practices in the production of concrete by construction firms in Ghana and develop strategies for effective quality assurance in concrete production. The study adopted a cross-sectional descriptive survey design. The target population of the study comprised construction project team professionals in D1K1 construction companies within the Greater Accra Region. A structured questionnaire was used to collect data from construction project team members namely; Project Managers, Project Engineers, Site Engineers, Quality officers, works superintendents and site supervisors. Systematic random sampling was adopted to select the construction professionals covered in the survey using the sampling frame compiled for the list of the construction professionals. A sample size of ninety-five (95) was selected using Cochran's formula and a response rate of 77% was achieved. The data collected was analyzed using descriptive statistics, cross-tabulations, chi-square and analysis of variance (ANOVA). The findings reveal effective quality assurance practices to include; the design of concrete products to fit use or purpose, production of concrete products to specifications and standards, a strict regime of supervision by experienced personnel, striving for excellence, adherence to the information contained in drawings and evaluation of performance requirements. It found that all construction project team members as respondents have a fair knowledge about the elements of quality assurance practices in concrete production. The major challenges faced by companies in their quest to ensure quality assurance practices included; difficulty to keep permanently employed key site operatives for concrete operations due to financial constraints, inappropriate use of construction materials in their right proportions, and difficulty getting certain skilled personnel for a specific task. It further revealed materials in the concrete mix must be free from impurities, be well-graded aggregates and required proportions of water-cement ratio should be used in an attempt to implement quality assurance practices. In conclusion, constructors and construction project team members in the construction industry must appropriately develop programs and principles that will necessarily ensure effective quality assurance practices in all types of projects. It, therefore, recommended that the implementation of formal quality management systems by all construction companies must be encouraged by the management of companies.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Concrete is the major component of most of our infrastructural facilities today in the 21st century because of its versatility in use. Concrete is the most widely used man-made material on earth (Lomborg, 2001). According to the Cement Association of Canada, twice as much as the total of all other building materials, amounting to about 3.8 billion cubic meters is used globally every year. (Ecosmart, 2018). In Ghana, as a result of the various efforts by the previous and current government advocating for foreign investors, for instance, the oil and gas industry, the construction and service sector covers more than 50% of the nation's output (Granado, 2015).

Increasingly, there is massive infrastructural development in Ghana as a result of the discovery of oil and gas and rapid urbanization, the country is embarking on several high rise buildings mostly reinforced concrete structures. However, despite the predominant manufacture of concrete products and construction of reinforced concrete structures, the quality of infrastructure falling below desirable levels and often described as "crumbling infrastructure" (Meyer, 2002). Many concrete structures have suffered a lack of durability which affects the gross national output of the sector in many nations (Mehta & Gambhir, 2004; 2013). In this regard, pertinent research questions arise such as; what are the quality assurance practices adopted by construction companies? And what are the key constraints to the adoption of proven quality assurance practices in the construction industry?

Neville and Brooks (2010) suggested that, over the past ten years, a good number of concrete structures have exhibited signs of distress even though they are within their design life suggesting plausible compromise in the quality 'of the production process of such structures. In Ghana, there are several reports of concrete structures failing while still under construction (Bediako & Smith-Asante, 2015). The failure of concrete is not limited to Ghana and reverting examples around across Sub-Saharan Africa. Notably in Nigeria, Anosike and Boampong (2011; 2015) reported several cases of concrete failures that bring to question the quality of supervision and the production process of building and civil engineering structures.

According to Navy et al. (1997) the fact that the correct constituent of material is chosen for a particular concrete does not guarantee the sufficient condition for the production of high-quality concrete. Navy et al. (1997) opined that the materials must be appropriately proportioned; the concrete must be mixed, placed and cured properly to achieve enhanced quality and improved life span of concrete. Neville and Brooks (2010) assert that the large incident of failure of concrete structures such as buildings, bridges, pavements in recent years is an indication that the construction firms do not know enough about how high-quality concrete is achieved. The failure of concrete structures can be mild with visible cracks and deflections or severe, leading to partial or total collapsed of the structure during the construction or after the construction stage.

Quality Assurance practices have been successful in the manufacturing industry and in most cases, however, any institution or organization that relies on success for the sustainability of the organization can adopt the same. The construction industry has some key differences compared to the manufacturing industry. This creates some challenges. The construction industry can also benefit if these quality assurance management practices are considered (Ashford, 1989). Enhancing quality assurance management practices in the construction industry mean improving, maintaining and ensuring that, the required standards are obtained to meet the customer satisfaction that will later bring about sustained competitiveness and financial survival (Tan & Rahman, 1989). From the engineering point of view “quality carries the concepts of compliance with a defined requirement of value for money, fitness for purpose or customer satisfaction". This implies that to achieve quality for a product, certain basic things need to be done to attain the level of quality that is intended for. There exist a lot of literature on enhancing quality assurance of concrete production and placement (Chudley & Greeno, 2008; Macomer & Nelson, 2006; Shetty 2005; Neville & Brooks, 2010). The literature also talks about management practices important for the success of projects (Ashford, 1989; Garvin, 1984; Pyzdek & Keller, 2013; Juran & Godfrey, 1999). Besides, there are guides on quality management for concrete works such as ACI 122R and ISO 9001. However not much can be found in the literature with specific reference as to the enhancement of quality assurance management practices of concrete production by construction firms in Ghana.

1.2 Statement of the Problem

Quality assurance of concrete production is a major key to successful product demand in the construction industry and the ultimate quality of concrete structure depends on the qualified people to construct it (ACI Manual, 1994 part2). Also concrete can become quality material when the ingredients are properly sourced and selected as well as its production is also under-regulated standard and practice procedure. The lack of quality assurance of concrete products are considered as a threat to the future of concrete by the public (Mehta, 1997). To the engineer and designer, deterioration of concrete poses severe challenges (Davidovits, 1988). Deterioration of concrete has been widely researched Litvan & Brickley (1987); Germick (1989): Khanna et al. (1988): Shayan & Quick (1982) as cited by Mehta (1997).

Improper management of concrete production to enhance its quality results in shoddy works, delays' and abandoned projects in the construction industry. To a contractor, non-conformance can yield penalties as well as cost, time burdens for rework, which can be converted into productivity loss (Bactikha, 2000). For the past decade, the construction industry has been criticized for its bad performance and productivity concerning other industries in Ghana in terms of quality concrete production. Overgbile (2012) revealed that over the past 10years, the incident of building collapse in Nigeria has become alarming and does not show any sign of abating.

Similarly, in Ghana, incidences of failures of a structure are linked to bad concrete practice in our major cities such as Accra, Kumasi, Techiman, among others. The Melcom building near Achimota in Accra collapsed in November 2012 which killed (14) people and injured several other people is a typical example associated with bad concrete production practices and poor design. The Grand View Hotel building at NII-Boi Town also in Accra, collapsed in March 2014 and recorded four (4) deaths. The investigation conducted revealed that the three-story building that collapsed at Asafo in Kumasi in October, (2017) was also a result of the structural failure; thus sub-standard concrete and steel bar reinforcement were cited (yen.com.gh). Similarly, Osei (2005) found that a lot of concerns have been raised over the quality of construction projects being executed by local contractors in Ghana.

Several factors have been attributed to the lack of quality of concrete production. However, Allen (2005) asserted that the immediate mechanism may be due to chemical reactions or corrosion of the reinforcement but, in many of the cases, the fundamental causes can be traced back to poor workmanship, or unrealistic detailing.

Tasker, (1985) also opined that most defects in concrete are caused by ignorance of the correct use of the consistency, lack of adequate concrete cover and curing requirements. This brings to the topic “enhancing quality assurance management practices of concrete production by construction firms in Ghana”. The concept of quality has been transitioned through quality inspection, quality control, quality management and finally to total quality management (Dahlgaard et al., 2007).

Construction stakeholders play different roles to achieve a successful project especially those which involve much concrete works. In concrete production, the construction team members need to follow quality assurance practices to produce the desired concrete product that could withstand the test of time. This study, therefore, seeks to find out how quality assurance of concrete production is maintained at the various work sites.

1.3 Aim and objectives of the Study

The aim is to examine the implementation of quality assurance practices in the production of concrete by construction firms in Ghana and develop strategies for effective quality assurance in concrete production. The specific objectives are as follows:

- 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.

1.4 Research Questions

Based on the aim and the review of related literature, pertinent research questions are posed as follows:

- What are the effective quality assurance practices of concrete production by construction companies in Ghana?

- What is the contractors' knowledge of elements of quality assurance in concrete works in Ghana?
- What are the challenges of quality assurance practices facing the construction companies in the production of quality concrete in Ghana?
- What are the practical measures for the implementation of quality assurance in concrete works?

1.5 Significance of the Study

This research is valuable to local building contractors to understand the benefit of quality concrete control production with particular focus on quality assurance policies implementation and develop strategies for effective quality assurance of concrete production.

1.6 Scope / Delimitation

The study was focused on in-situ concrete works both on site and in the yard. This is because ready mixed concretes is of high quality or undergo strict quality control checks at the point of production as compared to that of site production of concrete as well as yard production of concrete. The study was limited to D1K1 contractors in the Greater Accra 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 Limitation of the Study

The limitation of the research is selected towns and cities in the Greater Accra Region of Ghana. With the study population chosen, it would not reflect the majority situation in the country. The dissertation has been designed to examine and assess the implementation of quality assurance practices of concrete production by construction companies registered with the Greater Accra Region of Ghana.

1.8 The Organization of the Study

The study consisted of six chapters namely: chapter one consisted of an introduction, background to the study, statement of the problem, aim of the study, research questions, scope/delimitations of the study, limitation of the study and significance of the study. Chapter two discussed a related literature and overview of concrete works and quality assurance management practices. Chapter three also addressed the philosophical stance of the researcher and the methods that were used. Research design, sampling techniques and data collection methods that were adopted were also discussed. Chapter four involve the presentation results and analysis of the study. Chapter five focused on the discussions of the findings or results. The summary of findings, conclusions and recommendations were discussed in chapter six.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter is divided into three sections: the first section looked at the concept of quality, their various definitions and their usefulness in the recent trends in concrete works. The second section was the quality management of concrete works. The final section was an overview of concrete works.

2.2 Construction Projects

According to the Charted Institute of Building C.I.O.B (2019) construction projects are a series of related tasks which when they are carried in the correct order will lead to the completion of the project. In the fields of building construction and architecture, construction projects involve the process that consists of tangibly assembling an infrastructure or building construction projects incorporate numerous mini-projects. A construction project is not a single activity, larger-scale construction projects require human multitasking in most instances, these construction projects are managed by a project manager. Also, these types of larger construction projects are supervised by a design engineer, a construction engineer, a certified project architect. Construction projects are sometimes referred to as a "project" that organized process of constructing, renovating, refurbishing etc. a building structure or infrastructure (C.I.O.B, 20019). For construction projects to be executed in cost-efficient manner, effective planning is required. Any construction management team involved with the design and execution of the infrastructure must implement various safety measures and analyze the overall cost of the project to ensure that work-related injuries or financial troubles are not met. C.I.O.B (2019) opined that the project may be public or private.

A "public project" is one that is financed by the government. These include major infrastructure works such as roads, bridges, dams, railway, tunnels and so on.

A "private project" is one that is financed, controlled, or commissioned by a private party, i.e. one that is not the government. Private parties can include individuals, corporations, charities, privately founded institutions, schools, hospitals and so on.

Stringent planning is required in all construction projects because of the in a variable environment and financial impact they will possess.

As a result of inherent traits, all construction projects to be successful, require exhaustive planning revolving around the following elements: the availability of building materials, logistics, scheduling a budget, construction site safety, bidding and the inconvenience the project will impose on the general public.

Rodriguez (2019) outlined ten (10) of the largest construction projects in the world.

- Al Maktoum International Airport, Dubai - which extends over more than 21 square miles. The facility is designed to handle 200 wide-body aircraft at a time.
- Jubail II, Saudi Arabia - which is a 22-year long industrial city project that began its second phase in 2014 with an $11 billion expansion.
- Dubailand - Dubai- wait Disney world can fit three times inside the Dubailand complex with 278 square meters.
- International Space Station Space - The ISS circles the earth every 92 minutes. It is created by a consortium of 15 nations and fire space agencies.
- South-North Water Transfer Project - China
- London cross rail project - the first underground train system
- High-Speed Railway California - work on California's high-speed train began in 2015 and is scheduled for completion in 2029.

- Chuo Shinkansen - Japan- it is officially called Linear Chuo Shinkansen. Japan newest high-speed rail line.
- Beijing Airport - China
- Great man-made River project Libya

Figure 2.1: A construction Project

Source: (Lagasse, 2018)

2.2.1 Materials in Construction Projects

Any construction project is a very important thing as it ensures that you are getting the dream construction of your home or office completed as per your requirements (Kumari, 2017). Kumari added that each construction project is unique and you need to make sure that you are getting high-quality construction materials. A wide range of building materials is available for the construction of buildings and structures. The proper selection of materials to be used in a particular building or structure influences the original cost, maintenance ease of cleaning durability and of course, appearance. (Kumari, 2017)

Kumari (2017) argued that it is vital to have a team of experts on board who will be able to help you ascertain your needs and get the best materials. Construction materials are the items, articles, or material supplied or consumed in the construction works. Kumari outlined five (5) steps to be taken in choosing the best constructional materials.

- Know the type of project - It is very important to know the type of project you are working on. He said that if you have a team of professionals working with you, it is a very good idea to communicate with them.
- Test the climate conditions of the area - The climatic conditions of the area that you are working in is a very important part of the project. For instance, the type of construction materials like magnesite bricks for the steel plant that you use in the project depends widely on the climate that you are getting the building constructed as well as the mixing of concrete on site.
- Research about the construction material options - When you know the nature of your project and the climate you are functioning in; you need to research the type of material that you can make an intelligent choice.
- Create a list of things you need - Once the whole process of selection is done, make a list of all things that you do not purchase in excess.
- Get expert advice - It is always a good idea to work with experts when you are getting something constructed. Kimathi (2016) claimed that the majority of structures worldwide are made concrete. In concrete coarse aggregate usually takes up the largest portion of a concrete composition.

  Aggregate is also used for both rigid pavement roads as well as for asphalt concrete roads (flexible). Sankara and Rushikesh (2018) outlined some basic materials used in construction projects. These are:
- Cement

- Sand
- Lime
- Hard broken stone jelly
- Bond stone
- Bricks
- Steel rods
- Paints
- Binding wire
- Concrete admixtures
- Structural steel sections
- Timber
- Ceramic files
- Plastic etc.

A wide range of building materials is also available for the construction of buildings and structures. The proper selection of materials to be used in a particular building or structure can influence the original cost, maintenance; ease of cleaning, durability and of course appearance. Construction materials are the items, articles, or material supplied or consumed in the construction works. Some of the major construction materials used wood, timber, sandstones etc.

- **Wood**

Wood is a commonly used material in many parts of the world because of its reasonable cost, ease of working, attractive appearance and adequate life if protected from moisture and insects (Dhanani, 2015). However, the forest is a valuable natural resource that must be conserved, particularly in areas with marginal rainfall.

As good material as wood may be, there are regions where other materials should be considered first, simply on a conservation basis. Wood for the building is available from many different species with varying characteristics.

Some species are used in the form of small poles from light construction, while other species are allowed to mature so that timber (lumber in many countries) may be sawn from the large logs. Early settlers in North America used wood to build log cabins since it was more efficient than transporting other materials from Europe (Rosmanitz, 2013). Wood is reliable that houses built over 800 years ago are still standing today. (Hoib, Hansen & Nybakk, 2015).

In buildings and rural structures, wood is often used in the form in which it has grown, i.e. round poles. In some areas where enough trees are grown on the farm or local forests, wooden poles can be obtained at a very low cost. These poles have many uses in small buildings construction, such as columns for the load-bearing structure, rafters, trusses, and purlin. Sticks and thin poles are often used as wall material or as a framework in mud walls. Where straight poles are selected for construction, it is easy to work with round timber as with sawn timber. However, somewhat crooked poles can also be used if they are turned and twisted and put into positions in which the effects of the bends are unimportant, Round timber is generally considered stronger than sawn timber of the same section area because the fibres in round timber are intact.

- **Cement**

Cement is water-based binder used to bind other building materials together (Zentner, 2019). It is used in the production of mortar and concrete during the construction process. Concrete, on the other hand, is a material used in construction, made by mixing aggregate (i.e. different types of sand and gravel), cement, small stones, and water. He is of the view that cement is one of the most common construction ingredients among others because of its ability to hold the structures together. Sankaran (2018) also opined that cement is the best material for making cement concrete for foundations; Rcc works; brick masonry works; flooring works; waterproof works; etc. Comparing to the usage of lime for making mortar, cement used works will save a lot of time in construction activities (Sankaran, 2018).

2.2.2 Concrete Production in Construction Projects

Concrete is the most widely used man-made material in the world; in many ways, concrete forms the basis of our modern society (Mindess, 2008). Almost every aspect of our daily lives depends directly or indirectly on concrete. Concrete can be used for roads, bridges, runways, dams, water conduits, and buildings of all types and so on. Mindess report that because concrete is ubiquitous we tend to take it for granted. The general view of concrete can be expressed by often quoted "you mixed with cement, gravel, water and it gets hard'. He added that several forces are driving this resurgence in the cement and concrete industry much more sustainable. A challenge for the entire concrete industry is to improve the sustainability of concrete structures (Geiker, 2008). Sustainable development is defined by the world business council for sustainable development (W.B, C.D) as "Forms of progress that meet the needs of the present without compromising the ability of future generations to meet their needs". Geiker is of the view that self-compacting concrete SCC containing a large amount of powder and in some countries, the powder is mainly cement. He said that SCC potentially improves productivity, work environment and the quality of hardened concrete.

Figure 2.2 Honeycomb concrete blocks

Source: (Adom Super Blocks, 2020)

Figure 2.3 Culverts under construction

Source: (Taysec Construction, 2019)

2.2.2.1 In-Situ Concrete Production

In situ is a Latin phrase that is commonly used in the construction industry to mean "On-site", "In position" or "In place" Chartered Institute of Building (CIOB, 2019). According to (CIOB, 2019), in-situ concrete production refers to work which is carried out on the construction site itself in the finished position as opposed in an off-site location as with fabrication or pre-assembly techniques. It's further added that, the most common use of the term "In situ" concerning concrete with components such as slabs, beams and piles being described as cast in situ to distinguished them from precast concrete components that are manufactured off-site. In situ concrete production also dates way back to the discovery of concrete by the Romans. It involves the use of large quantities of water on a building site because fresh concrete cannot be workable if it loses moisture (Allen, 1985). Concrete masonry construction (CMC) also falls under the category of in situ construction. Taylor (1997) describes concrete blocks as precast members and goes on to say these can be factory manufactured or site cast. Despite this argument concrete masonry construction involves large quantities of water on site. Allen (1985) explains that mortar is much as part of masonry units themselves. It accounts for 20% of masonry work and it can only be used when it is wet and fresh. This statement confirms that CMC is a wet system. Collum (2017) reports that in-situ concrete is poured out in its permanent location and offers a much more robust solution. For example, its reinforcement bars are assembled first, then shuttering of formwork erected around them and finally concrete poured into whatever space remains. Once the concrete has cured and set the formwork can be removed when the concrete has achieved its maximum strength. Over the years in-situ concrete construction has evolved from plain and reinforced concrete in the first half of the nineteenth century (Allen, 1985) to pre-stressed concrete in the first half of the twentieth century (Taylor 1977). Despite having undergone such evolution, In situ construction had to adapt to various changes to compete with other systems of construction such as steel and precast construction.

There has been extensive prefabrication of reinforcing steel, mechanization of finishing operations, reusable formwork and many other techniques (Allen, 1985).

Generally, in-situ Construction techniques tend to be more labour and time-intensive, however, they are more flexible in response to changes that may arise on-site (CIOB, 2019).

2.2.2.2 Offsite Concrete Production

Striving to deliver value and quality is at the heart of how we approach our civil and structural design (Civic Engineers, 2018). It is for this reason that we have been championing off-site construction and pursuing innovations in penalized and modular technology. Offsite construction (OSC) is used in construction as a means of improving quality and increasing efficiency (Constructing Excellence, 2004). Offsite Construction (OSC) offers a new construction approach by moving the building construction process away from the job site into a controlled factory environment (Jiang et al. 2018). Though OSC is still at the early stage of its application in developing countries (e.g. China) Hong (2018), this emerging construction technique has stimulated wide public attention due to its potential advantages in achieving better project performance, such as reducing project duration and minimizing construction waste. Multiple studies have compared the performance between OSC and conventional construction methods in terms of cost Hong (2018), energy performance and overall sustainability of the process (Kamali & Hewage, 2017). OSC involves the modularity of construction products, which is related to design, manufacture, supply chain, and the life cycle assessment (Sonego, 2018). These contemporary construction issues comprise of Building information modeling (BIM), integrated project delivery (IPD), and environment.

2.3 Concept of Quality

Quality Concept is therefore aimed at "conforming to the standards and specifications of a product", this is in turn, impelled quality engineers in manufacturing industries to implement the method of "inspection" to control the quality of manufacturing product (Yang, 2017). Yang further added that "quality assurance" was "users oriented" implying that the production processes the fitness for purpose of use based on its functions" and hence quality is zero defects and meeting the specifications 100%" (Yang, 2017).

2.3.1 Quality

Quality is a much more complicated term than it appears. Dictionary definitions are usually inadequate in helping quality professionals understand the concept (Sower, 1999). Sower said that every quality expert defines quality in somewhat different ways. He claimed that the word "quality" is no simple endeavor. There are a variety of perspectives that can be taken in defining quality. E.g. customers' perspective and specification-based perspective. According to the American Society of Civil Engineers (2005) as cited by Ali (2016) quality is defined as meeting the legal, aesthetic and functional requirements of a project. These requirements may be simple or complex, or they may be stated in terms of the result required or as a detailed description of what is to be done. Several definitions exist for quality and none is universally accepted as the ultimate (Pyzdek, 2003). The definition of quality in the construction industry is different from that of the manufacturing sector Rumane 2011, cited by Ali (2016). This is as a result of construction not repetitive in nature compared to manufacturing or the service sector (Rumane, 2011). ISO (1994) cited by Chung (1999) defines quality as "the totality of characteristics of an entity that bear on its ability to satisfy stated or implied needs".

Table 2.1 Definition of Quality by different authors

1. Philip B. Crosby	"conformance to requirements"
2. W. Edward Deming	"quality should be designed into both process and product"
3. Armand V. Feigenbaum	"best for customer use and selling price"
4. Joseph M. Juran	"quality is fitness for use"
5. Kaoru Ishikawa	"quality of the product as well as the sales service, quality management, the company its self and human being"
6. John S. Okland	"quality is meeting customer requirements."

Source: (Rumane, 2011 as cited by Ali 2016)

Gavin (1984) cited by Sower (1999) also outlined five definitions of quality

- Transcendent - Quality is universally recognizable, it is related to comparison of features and characteristics of a project.
- A product based - "Quality is precise and measurable variables"
- User-based - quality is "fitness for intended use"
- Values-based - "Quality is defined in terms of cost and prices". Sower (1999) explains that it provides performance at an acceptable price or conformance at an acceptable cost.
- Manufacturing based - "Quality as conformance to specification" Parry (2018) claimed that John Ruskin, the Victorian art critic, suggested that "Quality never an accident, it is always the result of intelligent effects". In other words, quality does not just happen, we have to work for it.

International Standard Organization (ISO) 9000:2005 - Fundamentals & Vocabulary defines quality as "the degree to which a set of characteristics fulfill requirements".

2.3.2 Quality Management

Quality management is the act of overseeing all activities and tasks needed to maintain a desired level of excellence (Barone, 2019). Barone (2019) asserts that quality management includes the determination of a quality policy, creating and implementing quality planning and assurance and quality control and quality improvements. In general quality management focuses on long-term goals through the implementation of short-term initiatives (Barone, 2019). In the construction industry quality is defined as maintaining a quality standard that meets customer satisfaction Chen-ken and Hanuzah (2011) and which subsequently make the company financially viable to survive competition in the market, thus it leads to long term competitiveness and survival of organizations (Chen-ken & Hanuzah, 2011; Haris et al., 2013; Juran & Godfrey, 1999). The use of quality management concepts has an influence cost-effectiveness of projects and positive results in terms of project performance and the view of supported research Rumane (2011) and cited by Ali (2016). "the application of quality management systems in managing a process to achieve maximum customer satisfaction at the lowest overall cost to the organization whilst containing to improving process". The concept of quality management which emerged after the second world war strives to develop initiatives that systematically engage the entire workforce to achieve quality. Extension of these concepts led to the development of total quality.

2.3.2.1 Quality Control and Quality Assurance

Quality control QC is a set of activities for ensuring quality in production. The activities focus on identifying defects in the actual products produced (Singh, 2018). Sigh stated that Quality control QC aims to identify and correct defects in the finished product. "It is therefore a reactive process." According to Sigh (2018), Quality Assurance can be defined as a set of activities for ensuring quality in the processes by which products are developed. Sigh added that Quality Assurance aims to prevent defects with a focus on the process used to make a product. It is a "proactive process". Certain industries have viewed quality control as a contractor responsibility and quality assurance as to the consultant's responsibility Fick et al (2012), however, a more comprehensive approach is to consider quality control as an element of quality assurance means ensuring that things are done according to the plans, specifications and permit requirements. The concept of quality assurance is an approach to ensure that a whole organization is involved in producing high-quality outcomes in everything they do. Arutso (2019) claimed that quality control signifies those specific tests and inspections made by the material producer that determine the acceptability of a product.

Quality Assurance QA is taking no means to complete the program performed by the purchaser that includes not only quality control function (Arutso, 2019). There is standing controversy on who should provide quality assurance for concrete construction Arutso (2019), however, Arutso asserts that there are three parties involved in providing Quality Assurance in concrete construction (Arutso, 2019). These are Owner, Architect/Engineer and Contractor. Quality Control (QC) is the part of quality management that ensures products and services comply with requirements (CIOB 2019). CIOB is of the view that one way of controlling quality is based on inspection or verification of finished products.

Figure 2.4: The relationship between Quality Management, Quality Assurance and Quality Control

Source: (Bennett n.d)

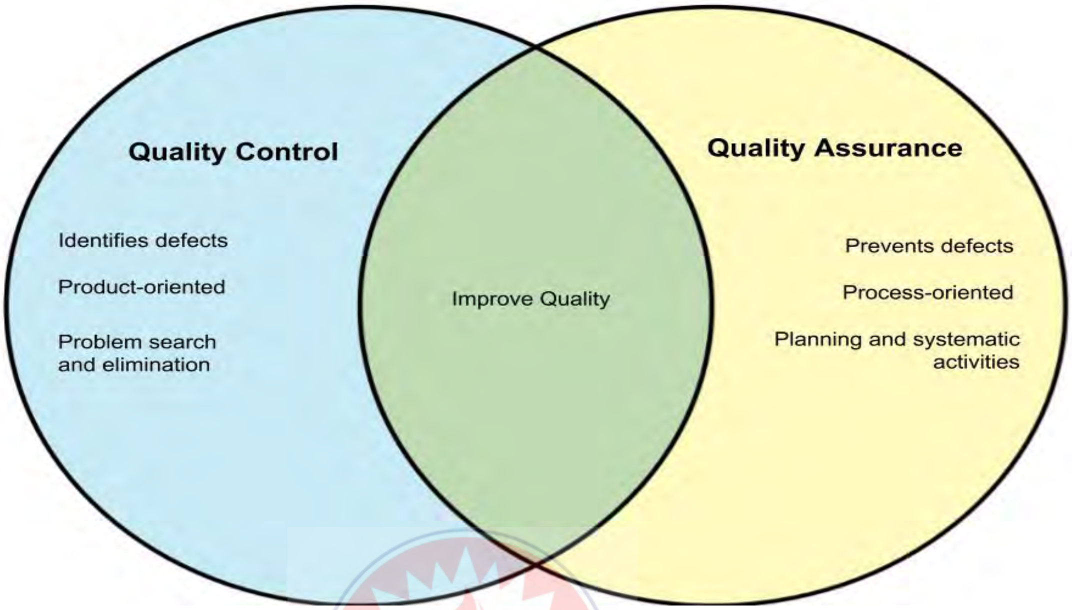

Figure 2.5: How Quality Assurance and Quality Control improves Quality

Source: (Bennett n.d)

2.3.2.2 Quality System

A quality system is formally described as the organizational structure, responsibilities, procedures, processes and resources for implementing the management of quality (Study notes, 2019), however many manufacturing and service enterprises have their quality system certified against a recognized quality management standard commonly one of the international ISO 9000 standards. Such standards lay down a generic element of good business practice that enterprises must implement and follow to gain certification. It is often the case today that organization are required to be certified against a particular standard for a contractual or regulatory reason (Study note 2019).

According to ISO (1994) as cited by Chung (1999) quality system is a framework for quality management and it embraces organizational structure, processes needed to implement a quality management system. The purpose of a quality system is to satisfy the requirements of quality management and assuring customers of the quality products (Gartenstein, 2018)

2.3.2.3 Quality Standard

A product is said to be of quality if it is free from any manufacturing defect deficiency or significant variations. To do so certain specific standard, needs to be set so that uniformity is achieved in the entire set of products being manufactured. The standard defined should be such that the features and specifications offered by the product should be capable to meet the implied need of the product.

The quality standard is an objective measure of fitness for purpose for the provision of goods or services, in a commercial or public sector context. They include durability, consistency, environmental (e.g. emissions), or performance measures (Craig, 2018). Craig added that quality standards are established variously by industry groups, government or consumer representative association, and there are often mechanisms for independent assessment by regulatory bodies with statutory (food or fire safety standards) legal (professional registration or industry guarantee compliance), or simply trade association backing. Limbachia (2016) lists some of the benefits of international standards to an organization as follows:

i. Improve company and product quality
ii. Increase customer satisfaction
iii. Through quality objectives and procedures, management and employee should be able to focus on what's important.

For customer:

i. Products with improved quality and reliability
ii. Timely delivery

iii. Data production

iv. Third-party adults help to ensure a proper verification process in place.

2.4 Determinants of Quality of Concrete

Quality Concrete must be durable, perform satisfactorily in service be cost-effective and safe. (Ozyildrim, 2011) Quality alluded to earlier on has several definitions. Arditi and Gunaydin (1997) define quality in construction as "meeting the legal, aesthetic and functional requirement of a prospect." The authors further note that because some of the definitions such as aesthetic subjective, it generates a lot of disagreement as to what quality is coupled with the fact that there are different players involved in the construction industry who interpret quality differently. Concrete manufacturing uses raw materials such as sand and rocks which constitute approximately 65% to 75% of the concrete's total volume as well as water cementitious material and different additives that represent the remaining volume. Thus, at the global level, this means a demand for several million tons of raw materials that are processed annually (Becker 2013; Sabay et al., 2015). However, despite the evident importance of these materials, sometimes the manufacturing, placement, or curing procedures are not adequate, thereby affecting concrete performance and quality. The factors influencing its quality may be classified into materials, labor, methods, machinery and environment. Concerning the first factors, the researcher of (Chan et al., 2003) mentions that it is necessary to know and control the characteristics of the aggregates such as the size absorption percentage and the shape coefficient, since they determine the workability of fresh concrete. Likewise, the fact of knowing the attributes like texture, bond capacity and mineral composition which significantly increase the transition zone, allows determining whether the mechanical strength of concrete will be affected or not. As for the mixing water Rodriguez et al. (2012) indicated that if potable water is not available on the site, it is possible to use water with considerable chemical loads as long as the reduction of the compressive strength of the concrete does not exceed 10% maximum, compared with concrete made of the same material but mixed with potable water.

Regarding the labor factor, which generally implies long working days in the construction sector, research made in the United States by (Gillen & Gittleman, 2013) concluded that the workers' physical exhaustion is intensified by the fact that they are often exposed to direct sunlight which makes them vulnerable to high temperatures and put at risk their health, thereby reducing productivity at work. Lit et al. (2016) used regression models to analyze the impact of the hours of the day (by the effect of the temperature) on workers productivity in reinforced concrete works and they concluded that the temperature does have negative effects on the direct working time and positive effects on the idle time.

Furthermore, for each additional Celsius degree of temperature, the direct working time decrease by 0.57% and the idle time increases by 0.74%. Additionally, age has a negative influence on productivity, while the experience and the body mass index of the worker have a positive impact. Consequently providing adequate working conditions can improve the productivity which is reflected upon the good quality of the works. About the machinery the study of a walker walker (1986) indicated that the placement of premixed concrete requires specialized equipment and tools, intending to minimize the variation in the quality of the product during the casting stage.

Concerning this subject, Navarrete and Lopez (2016) modeled the separation of the aggregate from the mortar through concrete stability analysis and they found that the tendency of concrete to remain uniform can be mainly controlled by the mix design. Moreover, Banfillet et al. (2011) analyzed how the vibration speed of the concrete mix affects its performance in terms of fluidity, concluding that the operational range increases as yield strength reduces and plastic viscosity increase.

Finally, Safwawi et al. (2005) studied the application of vibration on the concrete, with the introduction of superplasticizers, demonstrating that the segregation tendency decreases in this type of mix, due to the strengthening agent. Formwork is another relevant aspect regarding the machinery and tools used for concrete placement. Zhang et al (2016) studied the main factors acting on the lateral pressure of the formwork and they found that the casting speed, the vibration mode and setting of concrete can influence the pressure; the collapse risk may increase if these aspects are not properly controlled.

Finally, about the environmental factor, the temperature when casting plays an important role. Starting with 23°C, the researcher (Burg, 1996) demonstrated that concrete setting decreases or increases by 20mm per every 10^0C of temperature. Increase or decrease respectively. Furthermore, there is a 50% variation in the setting time for every 10^0C change in temperature. As for the design strength development, concrete cured at a temperature of 23°C developed a strength at 7 days, similar to the strength developed by concrete cured for 3days at a temperature of 32^0C.

2.4.1 Technical Variables

It is evidence that quality concrete can be achieved when the right ingredients are used in the right quantities and proportions, the processing and placement methods and finally the quality management practices adopted. Most national codes of practice on concrete construction contain clauses for ensuring the durability of concrete structures (CPWD, 2002). Other codes such as ACI 311.IR, ACI 201.2R-01 etc. describe good concrete practices and guides to durable concrete.

2.4.2 Environmental Variables

The world needs an environmentally friendly material because of the desire to reduce CO^2 emissions, save emissions, save nonrenewable energy resources, provide aesthetically pleasing and healthy surroundings and at the same time minimize waste (Bremner, 2001). Fortunately, we have just such a material- concrete and most of the essential research has been done to enable concrete to fill this role. The environmental problems with concrete will be discussed next in order of decreasing importance according to my perception of the problems they create.

- CO_2 emissions - the most serious problem with our industry is that it is a major CO_2 emitter causing global warming when every CO_2 emitted about 0.5 tones come from the composition of the limestone and balance is generated by the power plant supplying the electricity to turn the Kiln and ball mills to grind the cement plus the fuel to fire the kiln (Bremner, 2001). All other generation such as operating read mix trucks adds only a minor to the CO_2 emissions.

  Bremner further explained that conventional concrete mixtures (ie not using fly ash, slag, or silica fame), about 480kg of CO_2 is emitted per cubic meter of concrete or 20kg of CO_2 per 100kg of concrete produced.
- Visual Pollution - Visual pollution resulting from quarries used to gain raw material for cement production or for obtaining sand and gravel can be sculptured to meet natural topography and when abandoned can be planted with vegetation that can make them blend in with natural surroundings (Bremner, 2001). Bremner continued to say that, unfortunately, most quarries have a long life and any attempt to sculpture the topography for visual effect is counterproductive to the efficiency of the quarrying process. The most effective end-use might be for educational or recreation purposes with special attention being paid to public safety (Bremner, 2001).
- Traffic congestion - Traffic congestion in the delivery of the cement and ready-mix concrete is being mitigated by using large energy-efficient vehicles with appropriate

attention to noise suppression and dust to tolerate the placing of the ready-mix plant closed to where concrete is needed thereby reducing traffic (Bremner, 2001).

- Noise pollution - Noise pollution is normally a public concern as the cement plant is usually placed at a distance from habitation. The ready-mix plant, if it wishes to be located near to its customers must be greatly concerned about noise pollution. At the construction site, the use of superplasticizers to produce high slump concrete that requires a maximum of vibration has greatly reduced the problem of on-site noise.
- Adverse health effects - currently the health of employees is being affected by the increased chromium content in the cement is mostly derived from the burning of waste products.
- Water pollution - on average each ready-mix truck returns about a one-half cubic meter of cement per day (Bremner, 2001). Bremner goes on to say that, after this concrete is discharged there is still about 300kg of solids (cement, sand and stone) that is washed out with about 1000 litres of water (Bremner, 2001).

2.4.3 Managerial Variables

Managerial variables can be defined as those institutional variables relating to project management and other soft variables of project design and implementation, which include the efficiency and effectiveness of the supply chain, the characteristics of an agency’s culture, and the capacity of an adopting agency to adapt to and to manage change (IGI Global, 2019). The top management has the responsibility of providing a quality policy, setting out its commitment and quality objectives which need to apprehend into reality to get quality concrete. They have the responsibility of creating organizational chart indicating the responsibility and inter-relationship.

Management must provide all the necessary resources at the right time, organize training and lead in the communication of quality objectives throughout the organization (Chung, 1999). Management must also ensure that customer requirements are understood and resources provided to meet the needs (ACI 121R-08, 2008).

2.5 Quality Management Practices in Concrete Production.

According to Ferguson and Clayton (1998) "Quality Management practices is a practice covering activities necessary to provide quality in the work to meet the project related policies procedures requirements. Quality management practices involve establishing project-related policies, procedures standards, training, guidelines and system necessary to produce quality. Design professionals and constructors are responsible for developing an appropriate program for each project. Quality management practices protects against quality problems through early warning play an important role in the prevention of both internal and external problems".

Establishing the project requirements for quality begins at project inception. As opined by Artidi and Gungydin (1997), a careful balance between owner's requirements of the project cost and schedule, desired operating characteristics, materials of construction etc. And the design professional's need for adequate time and budget to meet those requirements against economic considerations and in some cases, against the chance of failure.

Sisay (2017) is of the view that the quality of a finished concrete structure is affected by the freshly mix concrete and standard of workmanship in handling compacting, finishing and curing the concrete. Sisay further said that the standard of workmanship throughout the concreting operations is therefore extremely important in the construction of a good quality concrete structure. He reported that to improve the quality of concrete the producers need to put all factors that affect the concrete Quality Management System (QMS) and adhere to it. a quality management system establishes company policies and goals and set actions and responsibilities for individuals within an organization about quality (Sisay, 2017).

2.5.1 Reactive Quality Management in Concrete Production.

Building a culture of quality depends on reactive and proactive functions, processes, and workflows in the organization. However, the best approach to attain quality has always been debatable.

- The reactive Approach deals with the problems once they arise or being encountered, without proper planning on how to, what to, when to and whom to report (proactive).
- Proactive Approach- Includes planning for the future, taking into consideration the potential problems that on occurrence may disturb the orders of processes in the system. It is about recognizing the future threats and preventing them with requisite actions so that you do not end up getting into bigger trouble (Qualityze.com, 2019). According to Singh (2018), Quality Control (QC) is a "reactive process" therefore reactive quality management in concrete production can be defined as the quality management that compromises the activities of inspecting, testing, or checking a concrete product to ensure it meets the requirement or standard. Prasad (2018) outlined four (4) characteristics of reactive quality management as shown in table

2.2 . Table 2.2. Four characteristics of reactive quality management

Proactive Quality management	Reactive Quality Management
1. Probable trouble spots are diagnosed and investigate before advancement towards the next step.	Mistakes are considered as and when observed.
2. Checklist investigation authorizes people like a foreman to carry out an effective analysis.	A site manager has to keep all construction know-how in his/her mind or on paper.
3. Implementation of quality checks process to homogeneous methodology.	Inconsistent quality check.
4. On-time inspection by a relative person on the site on work completion.	Fewer inspections take place.

Source: Prasad (2018)

Reactive Quality Management of concrete production is the part of quality management that ensures products and services comply with requirements (CIOB, 2019). It is a work method that facilitates the measurement of quality characteristics of a unit, compares them with the established standards and analyses between the results obtained and the desired results to make decisions which will correct any differences.

Technical specifications define the type of controls that must be carried out to ensure the construction works are carried out correctly. They include not only the products and materials but also the execution and completion of the works.

C.I.O.B continued to explain that, one way of controlling quality is based on the inspection or verification of finished products. The aim is to filter the products before they reach the client so that products that does not comply with the requirements are discarded or required. They further explained that this reception control is usually carried out by people who were not involved in the production activities, which means that cost can be high and preventative activities and improvement may not be effective. It is a final control, located between producer and client, and although it has the advantage of being impartial, it has a large number of drawbacks such as slow information flows, and that the inspectors are not familiar with the circumstances of production and are not responsible for the production quality (CIOB, 2019).

2.5.2 Planned Quality Management in Concrete Production.

Construction quality management involves the implementation of the execution of a planned sequence of events to ensure a certain level of performance is attained by a structure Building & construction Research & consultancy (BCRC, 2019). BCRC further explained that, if a quality management plan is developed and executed in an acceptable way it can;

1. Reduced material waste.
2. Ensure smooth cooperation between the construction team and project management.
3. Keep construction cost down.
4. Improve durability by minimizing the cost of the structure after construction.

The above is true for all structures and is particularly pertinent for concrete construction. The project quality management plan (QMP) guidance document provides information about concrete material related quality assurance (QA) and quality control (QC) practices for the Bureau of Reclamation Construction projects with significant concrete features (Von Fay, 2015).

2.5.2.1 Control Charts

According to the American Society for Quality ASQ (2019) the control chart can be defined as a graph used to study how process changes over time. Data are plotted in time order. (ASQ) further explained that the control chart always has a central line for the average, an upper line for the upper control limit, and a lower line for the lower control limit. These lines are determined from historical data. ASQ further asserts that by comparing current data to these lines, you can conclude whether the variation is consistent (in control) or is predictable (out of control), affected by special causes of variation.

Control charts are a process behaviour chart and in statistical process control, it is a tool used to determine if a manufacturing or business process is in a state of statistical control. If the analysis of the control chart indicates that the process is currently under control (i.e. is stable, with variation only coming from sources common to the process) then no corrections or changes to process control parameters are needed or desired.

In addition, data from the process can be used for the future performance of the process. If the charts indicate that the monitored process is not in control, analysis of the chart can help determine the sources of variation, as this will result in degraded process performance (William, 2006).

Control charts are typically used for time-series data, though they can be used for data that have logical comparability (Poots & Woodcock, 2012). This means that you want to compare samples that were taken all at the same time or the performance of different individuals. However, the type of chart used to do this requires consideration.

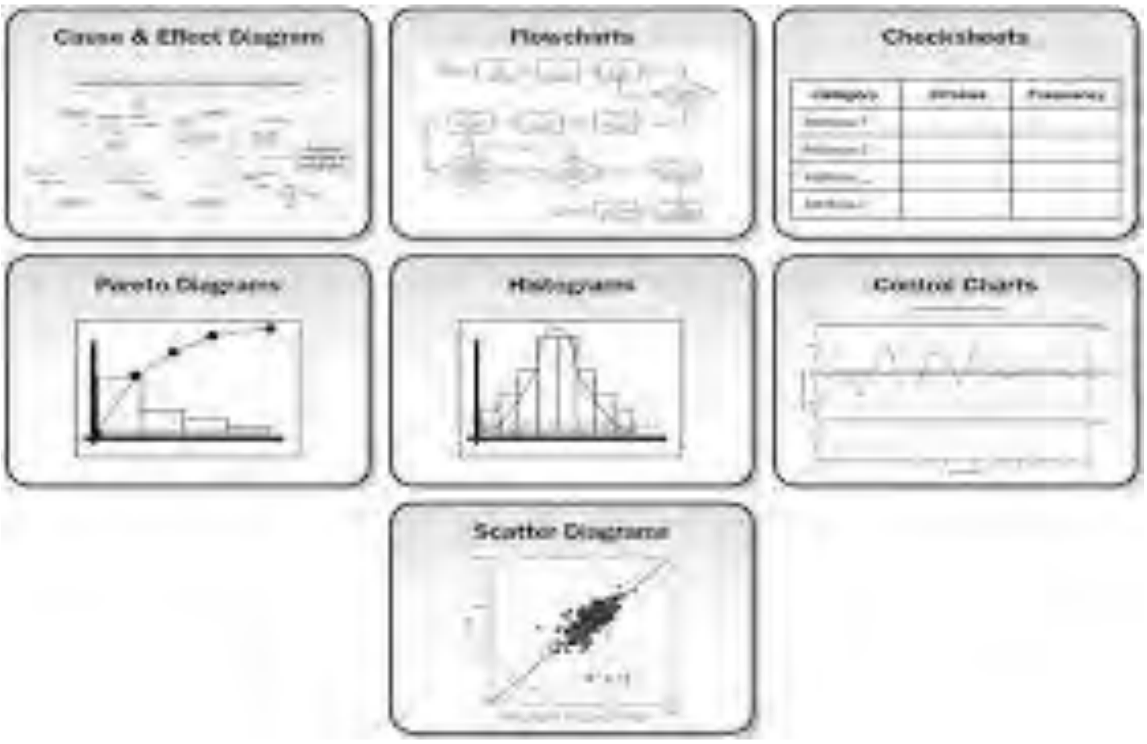

Figure 2.6 The Seven Basic Quality Tools

The Seven Basic Quality Tools are:

1. Cause and Effect Diagram
2. Pareto diagrams
3. Process Maps
4. Histograms
5. Control Charts
6. Scatter Plot or Diagram
7. Check Sheets

2.5.2.2 Monitoring in Concrete Production.

One of the most important things to know during a construction project is the strength and maturity of concrete at any given time (Pepin, 2017). Pepin also said that contractors have traditionally relied on lengthy break tests performed in laboratories to gather this data, but in recent years, new technology has emerged to enable contractors to gather concrete strength and maturity in place and in real-time.

Smart sensors for concrete temperature and maturity testing have been around since November 2015 and have enabled engineers, contractors and construction workers to cut down on time and resources needed to conduct proper strength and maturity tests (Pepin, 2017). Wireless concrete temperature sensors like SmartRocks2 remove a lot of the hassle present on job sites. These sensors allow you to gather strength, maturity and temperature, data in-place in real-time, eliminating the need to wait long periods for laboratory-based brake test results. The elimination of time and resources needed for break tests means contractors save on laboratory cost and can move on to the next step of the projects as soon as optimal concrete strength and maturity has been reached (Pepin, 2017)

Pepin is of the view that In situ Concrete maturity data is important to predict the early age strength gain of concrete, which is directly related to the hydration temperature history of cementitious paste.

Concrete can be monitored by using "Cusum system". Cusum system is a practical means of meeting the requirements of concrete (CCI, 1996). In general, the Cusum system measures performance relative to design intentions. It compares results with target values and checks whether they are consistent with intended and required levels. The Cement and Concrete Institute (CCI) explained that the Cusum system is used for monitoring trends in mean strength, standard deviation and the relationship between early-age and 28-day strengths.

The Cusum system has the following advantages over other systems:

- The Cusum system is more sensitive in detecting changes of the magnitude experienced with concrete production.

- Reliable decisions can be made on fewer results.
- The trend of results can be identified from the general slope of the graph.
- The slopes of the graph can be used to determine the magnitude of properties (ie mean strength and standard deviation).
- Positions of changes in the slopes of graphs indicate approximately when changes occur (CCI, 1996).

2.6 Best Practices of Quality Management

A well-run Quality Management System (QMS) brings the entire company together to solve problems, standardize processes and meet the demands of the customer and regulatory agencies (TrustArc, 2017).

Colton (2012) outline 8 key best practices of quality management:

- Align Enterprise Quality Units Strategic Goals and Initiatives.
- Establish structures and resources to get the desired results.
- Create supporting policies, procedures, and tools- not mandates.
- Select, define, and standardize quality measures across the enterprise.
- Allow business unit leaders to establish performance targets for enterprise quality measures.
- Report quality measures at least quarterly.
- Design quality measures to focus on value-added quality activities and core strategic objectives.
- Use measures to promote a culture of quality. The practices above can help organizations as they form new processes and generate support for quality improvements.

2.6.1 Applicability of Best Practices of Construction Industry.

Best practices cannot be ignored when talking about concrete production made by the construction industry. It plays a very crucial role in the production of concrete by these construction companies. Though contracts and subcontracts and sub-subcontracts, the general contractor ends up delegating responsibility for quality. In the 1980s came the advent of the construction management project delivery system whereby construction management firms emerged as entities not responsible for design and construction, but performing only managerial functions on behalf of the owner from the inception phase to the completion of the construction phase (Phang & Hui 2004).

Many manufacturing and service enterprises have their quality systems certified against a recognized quality management standard, commonly one of the international ISO 9000 standards. Such standards lay down generic elements of good business practice that an enterprise must implement and follow to gain certification. It is often the case today that organizations are required to be certified against a particular standard for contractual or regulatory reasons.

According to Obrien (1989), one way in which more attention will be given to quality control is the development of a project quality control plan. Presently, testing and inspection requirements are scattered throughout the contract specifications. To develop a firm plan, the testing and inspection requirements can be combined into new division of the specifications. This would emphasize quality control and provide an organized location in which all quality control issues are identified to bidders. As part of the quality control plan, how the construction manager will apply quality control procedures should be described to the bidders; this will permit them to assign appropriate costs to the testing procedures.

Alexander (2008) reports that when describing best practices the term Quality Assurance (QA) and Quality Control (QC) are frequently used interchangeably. Since quality control is part of quality assurance, maintaining a clear destination between them is difficult, but important. Quality Assurance is all plan and systematic actions necessary to provide adequate confidence that a structure, system, or component will perform satisfactorily and conform to the project requirements. On the other hand, Quality Control is a set of specific procedures including planning, coordinating, developing, checking, reviewing, and scheduling the work. The quality control function is closest to the product in that various technologies and activities are used to monitor the process and to pursue the elimination of sources that lead to unsatisfactory quality performance (Wick & Veilleux, 2003).

Most design related quality assurance and quality control activities are covered by a design organizations standard office procedure. Developing and monitoring the activities within the quality assurance program in the construction phase is the responsibility of either the designer or the construction management firm depending on the project delivery system in use.

Kado (2010) asserted that, although there are such laws and regulatory organizations and their manuals, yet shortcomings persist in the construction industry. Also, Bamisile (2004) observed that "in certain instances, unqualified persons prepared architectural and engineering designs and/or working drawings are poorly prepared even in some cases without drawings number and the name of the designer or drawn by column completed not to talk about the name of the person that checked the drawings before they are issued for construction".

Also, some of the drawings are uncoordinated, grossly inadequate for construction specifications are not used by the design team in many instances they are left to quantity surveyors to write. References are often made to certain standards and codes of practice without the writer having seen a copy of them before. Their current status and relevance to specific projects are also hardly checked. In conclusion, Bamisile (2004) remarked that "one could say that the design team has not yet adopted any quality culture in their contribution to the production of buildings in Ghana"

2.6.2 The Process of Concrete Production

Before it can become a driveway, patio, or foundation, concrete must be combined from a mixture of sand, aggregate, or gravel, Portland cement and water. Once these ingredients are mixed, the wet concrete product is poured in a form that serves as mold Taylor (2017), within a short time, the concrete becomes solid.

Today's final concrete products are smooth, strong and can withstand massive pressure. Historically, however, the earliest forms of concrete were a combination of mud, sand, water and perhaps some straws and the mixture was applied to twig structures to form huts. In the 1800s, the development of Portland cement, a form of powdered limestone, resulted in a much stronger concrete mixture (Taylor, 2017). D'Antyono (2017) also said that concrete is a useful material that is used in many situations. It is often laid directly on the ground as a floor or base.

Brainkart (2018) opined that good quality concrete is essentially a homogeneous mixture of cement, coarse and fine aggregates and water which consolidates into a hard mass due to chemical action between the cement and water. Each of the four constituents has a specific function. The coarse aggregate acts as a filler, the fine aggregate fills up the voids between in conjunction with water acts as a builder. Brainkart added that most of the properties of the hardened concrete depend on the care exercised at every stage of the manufacture of concrete. A rational proportioning of the ingredients of concrete are the essence of the mix design. However, it may not guarantee having achieved the objective of the quality control work. Quality control aims to ensure the production of concrete of uniform strength from batch to batch. This requires some rules to be followed in the various stages of concrete production and is discussed as follows (Brainkart, 2018).

The stages of concrete production are:

- Batching or measurement of materials.
- Mixing
- Transporting
- Placing
- Compacting
- Curing
- Finishing

Batching of Materials

For good quality concrete, proper and accurate quality of all the ingredients should be used. The aggregates, cement and water should be measured with an accuracy of 3% of batch quality and 5% of batch quality. There are two prevalent methods of batching materials, volume batching and weigh batching. For most important works weight batching is recommended.

Mixing

i. Hand mixing
ii. Machine mixing
iii. Iii Tilting mixers
iv. Non- Tilting mixers
v. Reversing drum mixer
vi. Pan-type or stirring mixer

vii. Transit mixer

Charging the Mixer and Mixing Time

The order of feeding the ingredients on to the mixer is as follows:

About 25%of the water required for mixing is first introduced into the mixer drum to prevent any sticking of cement on the blades and the bottom of the drum. Then the ingredients are discharged through the skip. In the skip, the order of loading should be to half the coarse aggregate and then half the fine aggregate and over this total cement and then the balance aggregates. After discharging the ingredients into the drum, the balanced water is introduced.

Brainkert explained that the poor quality of concrete is obtained if the mixing time is reduced. On the other hand, if the mixing time is increased it is uneconomical. However, it is found that if the mixing time is increased to 2 minutes the compressive strength of concrete produced is enhanced and beyond this time the improvement in compressive strength is significant (Brainkart, 2018).

Transporting

Concrete should be transported to the place of deposition early without the loss of homogeneity obtained at the time of mixing. A maximum of 2 hours from the time of mixing is permitted if trucks with agitator and 1hour if trucks without agitators are used transporting concrete.

Some methods of transporting concrete are as below:

a. Mortar pan
b. Wheelbarrow
c. Chutes
d. Dumper

e. Bucket and ropeway

f. Skip and hoist

g. Pumping

Placing

To achieve quality concrete, it should be placed with utmost care securing the homogeneity achieved during mixing and avoidance of segregation in transporting. studies have shown that a delayed placing of concrete results in a gain in ultimate compressive strength provided the concrete can adequately be compacted. For dry mixes in a hot weather delay of the half to 1 hour is allowed whereas for wet mixes in cold weather it may be several hours.

Compaction

After the concrete is placed at the desired location, the next step in the process of concrete production is compaction. Compaction consolidates fresh concrete within the moulds or frameworks and around embedded parts and reinforcement steel. A considerable quantity of air is entrapped in concrete during its production and there is possible partial segregation also. Both of these adversely affect the quality of concrete. Compaction of the concrete is the process to get rid of the entrapped air and void elimination of segregation occurred and to form a homogeneous dense mass. The compact of concrete can be achieved by the following:

- Hard compaction
- Compaction by vibration
- Needle vibrator
- Formwork vibrator

- Compaction of spinning
- Compaction by Jolting
- Compaction by rolling

Curing

Curing cement gains strength and harden because of the chemical reaction between cement and water. This chemical reaction requires moisture, favourable and time referred to as the curing period. Curing freshly place concrete is very important for optimum strength and durability. Sufficient water should be made available to concrete to allow it to gain full strength. The process of keeping concrete damp is known as curing.

Concrete may be kept moist in several ways. The method consists of either supplying additional moisture to concrete during the early hardening period by ponding, spraying, sprinkling, etc., or by preventing loss of moisture from concrete by sealing the surface of the concrete by a membrane formed by curing compounds. The following are some of the prevalent methods of curing.

- Water curing
- Steam curing
- Curing by infrared radiation
- Electrical curing
- Chemical curing (Brainkart, 2018)

Finishing

Concrete is used because of its high compressive strength. However, the finish of the ultimate product is not that pleasant. In the past couple of decades, efforts have been made to develop surface finishes to give a better appearance to concrete surfaces and are as follows.

- Formwork finishes

- Surfaces treatments
- Applied finishes (Brainkart, 2018)

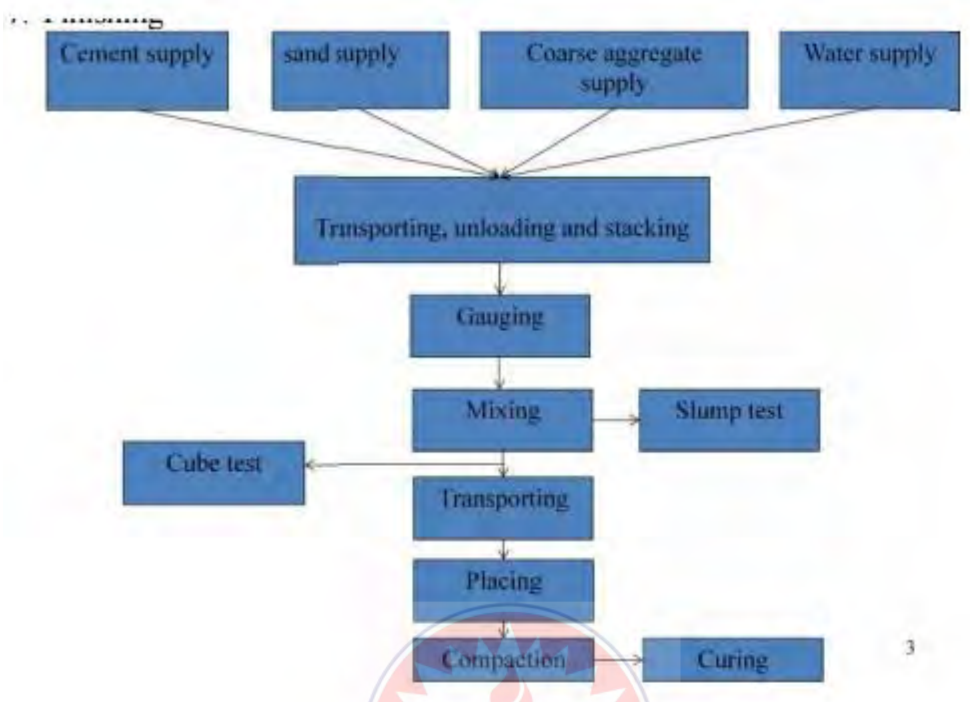

Figure 2.7 A Chart showing the process of making concrete

Source: (Brainkart, 2018)

2.7 Factors Affecting the Adoption of Best Practices in Concrete Production

Concrete is generally produced in batches at the site with the locally available materials of variable characteristics. It is therefore likely to be variable from one batch to another (Alam, Habib, Seikh & Hasan, 2016). The magnitude of this variation depends upon several factors, such as:

a. Variation in the quality of constituents materials;
b. Variation in the mix proportions due to batching process;
c. Variation in the quality of batching and mixing equipment available;
d. The quality of overall workmanship and

e. Supervision at the site. Moreover, concrete undergoes several operations, such as transportation, placing, compacting, and curing.

During these operations, considerable variations occur partly due to the quality of plant-available and partly due to differences in the efficiency of techniques used (Alam et al 2016). Thus there are no unique attributes to define the quality of concrete entirely. Under such situations, concrete is generally referred to as being good, fair, or poor quality.

This interpretation is subjective. It is, therefore, necessary to define the quality in terms of desired performance characteristics, economics, aesthetics, safety and other factors. Due to large number of variables influencing the performance of concrete, quality assurance is an involved task.

Alam et al. (2016) explain the above factors affecting the adoption of best practices in concrete production as follows:

Materials

For uniform quality concrete, the ingredients (particularly the cement) shall preferably be used from a single source. When ingredients from different sources are used, the strength and other characteristics of the materials are likely to change and therefore, they should only be used after proper evaluation and testing.

- **Cement**

Cement is any material that harden and becomes strong adhesive after application in plastic form. Cement is the binding constituent of concrete. Similar types of cement from different sources and at different times from the same source exhibit variations in properties of concrete, especially in compressive strength. This variation in the strength of cement is related to the composition of raw materials as well as variations in the manufacturing process. The cement shall be tested initially once from each source of supply and, subsequently at every two months interval.

Adequate storage undercover is necessary for production from moisture. Set cement with hard lumps is to be rejected.

- **Aggregates**

In any concrete, aggregates (fine and coarse) usually occupy 70 – 75% and between 60 – 80% of the total volume of the concrete mass (Alam et al., 2016). 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. This, suggests that the selection and proportioning of aggregates shall be given due attention as it not only affects the strength but the durability and structural performance of the concrete also. Further, the aggregate is cheaper than cement and thus it is cheaper to use as much quantity of aggregate and as little cement as possible. Aggregates provide better strength, stability and durability to the structure made out of cement concrete than cement paste alone.

Aggregate is not truly inert because its physical, thermal and chemical properties influence the performance of concrete, while selecting aggregate for a particular concrete, the economy of the mixture, the strength of the hardened mass and durability of the structure must first be considered. Grading, maximum size, shape and moisture content of the aggregate are the major source of variability. Aggregate shall be separately stockpiled in single sizes. The graded aggregate should not be allowed to segregate (Alam et al., 2016).

- **Water**

The water used for mixing concrete shall be free from silt, organic matter, alkali and suspended impurities, sulphates and chlorides in water should not exceed the permissive limits. Generally, water fit for drinking may be used for mixing concrete.

- **Equipment**

The equipment used for batching, mixing and vibration shall be of the right capacity. Weigh batches shall be frequently checked for their accuracy.

- **Workmanship**

The activities involved in the workmanship is all stages of concreting i.e. batching of materials, mixing, transportation, placing, compaction, curing and finally testing and inspection.

- **Concrete Mix Ratio**

When making concrete, it's important to use the concrete mixing ratio to produce a strong, durable mix. Mixing water with the cement, sand and stone will form a paste that will bind 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 you use to mix the concrete (very fluid) the weaker the concrete mix. The less water you use 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).

- **Batching of Concrete**

The correct measurements of the various materials used in the correct mix are called batching. Errors in batching are partly responsible for the variation in the quality of concrete can be batched in two ways as was said by (Brainkart, 2016.)

1. By Volume Batching
2. By Mass (Weight) Batching

Weight batching of materials is always preferred over volume batching. When weight-batching is not possible and the aggregates are batched by volume measures to be regularly checked for weight-volume ratio.

- **Mixing of Concrete**

This is the practical means of producing fresh concrete and placing it in the form so that it can harden into the structure referred to as "concrete". The sequence of operation is that the correct quantities of cement, aggregates and water, possible also admixtures are batched and mix in a correct mixer which produces fresh concrete. This is transported from a mixer to its final location. The fresh concrete is then placed in the forms and compacted to achieve a dense mass which is allowed and helped to harden. The objective of mixing of concrete is to coat the surface of all aggregate particles with cement paste and to blend all ingredients of concrete into uniform mass (Alam et al., 2016). Mixing of concrete is done either by hand or by machine. Mixer performances shall be checked for conformity to the requirements of the relevant standards. Concrete shall be mixed for the required time; both under mixing and over-mixing shall be avoided.

- **Transportation**

After mixing, concrete shall be transported and placed at the site as quickly as possible without segregation, drying etc., as soon as the concrete is discharged from the mixer internal and external forces starts acting to separate the dissimilar constituents. If over-weight concrete is confined in restricting forms, the coarser and heavier particles tend to settle and finer and lighter materials tend to rise. If concrete is to be transported for some distance over rough ground the runs shall be kept as short as possible since the vibration of this nature can cause segregation of the materials in the mix (Alam et al., 2016). For the same reason, concrete should not be dropped from a height of more than 1m. If this is unavoidable a chute shall be used. The green concrete shall be handled, transported and placed in such a manner that it does not get segregated.

- **Placing**

The formwork and position of reinforcement shall be checked before placing concrete to make sure that they are clean and free from detritus position. Care needs to be taken when discharging concrete from skips to avoid dislodging the reinforcement or overfilling the framework. When filling columns and walls; care shall be taken that concrete does not strike the face of the formwork, which might affect the surface finish of the hardened concrete. For deep sections, the concrete shall be placed in uniform layers, typically not more than about 500mm thick being fully compacted (Alam et al., 2016).

- **Compaction**

Compacting of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of placing and mixing concrete, the air is likely to get trapped in the concrete. If this air is not detrained out fully, the concrete losses strength considerably. Anticipated targets of strength, impermeability and durability of concrete can be achieved only by thorough and adequate compaction. Also, 1% of the air voids left in concrete due to incomplete compaction can lower the compressive strength by nearly 5% (Gambhir, 2004 as cited by Alam et al., 2016).

- **Curing**

Curing of concrete is the process of manufacturing satisfactory moisture content and a favourable temperature in concrete during the period immediately after placement of the concrete so that hydration of cement may continue till the desired properties are developed sufficiently to meet the requirements service. The reasons for curing concrete saturated or as nearly saturated as possible, until originally water-filled space in the fresh cement paste has been filled to the desired extent by the product of hydration of cement, to prevent the loss of water by evaporation and to maintain the process of hydration, to reduce shrinkage of concrete and to preserve the properties of concrete. Adequate curing is essential for the handling and development of the strength of concrete. The curing period depends upon the shape, size of member, ambient and humidity conditions, type of cement and the mix proportions. Nevertheless, the first week or ten days are the most critical, as any drying out during this young age can cause an irreparable loss in the quality of concrete. Generally, the long-term compressive strength of concrete moist cured for only 3 days or 7 days will be about 60 percent and 80 percent respectively, of the one cured for 28 days or more (Gambhir, 2004 as cited by Alam et al., 2016).

- **Formwork**

Formwork is a structure, usually temporary, used to contain poured concrete and to mould to the required dimensions and support until it can support itself. It consists primarily of the contact material and bearers that directly support the face contact material, proper removal of formwork is an important factor to achieve good quality concrete during service life (Alam et al., 2016).

- **Inspection and Testing**

Inspection and testing play a vital role in the overall quality control process. The inspection could be of two types, quality control inspection and acceptance inspection. For repeated operations early inspection is vital and once the plant has stabilized, occasional checks may be sufficient to ensure continued satisfactory results. The operations which are not repetitive would require on the other hand more constant scrutiny (Alam et al., 2016). Apart from the test on concrete materials, concrete can be tested both in the fresh and hardened states. The test on fresh concrete offers some opportunity for necessary corrective actions to be taken before it is finally placed. These include tests on workability and compressive strength respectively.

- Personnel

The basic requirements for the success of quality assurance are the availability of experienced knowledgeable and trained personnel at all levels (Alam et al., 2016). The designer and the specification writer should know construction operations as well. The site engineer shall be able to comprehend the specification stipulation. In fact, quality must be a discipline imbibed in the mind and there shall be a strong motivation to do everything right the first time (Alam et al., 2016).

2.8 Challenges to Quality Management in Concrete Production

Although quality management has been widely accepted in the manufacturing industry the construction industry is slow in its implementation even though countries faced the adoption (Harrison, 2019) even though Japan and the USA have accepted the concept. Some reasons as postulated by Tang et al (2005) with regards to the challenges faced in the adoption of quality management practice in the construction industry are the perceived threat to foreman and project manager roles, disinterest at the level, lack of understanding of what Quality Management was, particularly on-site: geographically dispersed sites, fear of job losses, inadequate training, plan not clearly defined, employee skeptics and resistance to data collection (e.g. rework costs, non-conformances, material waste). Lack of top management's support commitment and leadership are the three most important barriers in the implementation of quality management practices in Pakistan (Nawaz & Ikram, 2013). Another constant with the implementation of Quality Management practices in the construction industry is associated with the traditional way of selecting a contractor based on price and not quality. This situation does not encourage contractors to adopt Quality

Assurance practices. The construction industry in Ghana is growing in complexity and to be competitive at the global level (Asamoah, 2012), total quality assurance should be strictly adhered to to ensure client satisfaction and profitability. Many Ghanaian construction companies have comprehensive quality plans just as safety plans as opined by Dotse (1997) as cited in Asamoah (2012) argue that the quality of plan does not necessarily correlate to the company quality performance. Quality in each phase is affected by the quality in the preceding phase; therefore, customer service in each phase is important for the overall quality performance of the process (Odusami et al., 2010). Quality is, therefore an important feature of any construction company because the safety of the construction companies and the stakeholders depends on the quality of the structure (Idoro, 2010).

Haupt and Whiteman (2004) and Bubshait and Al-Atiq (1999) reiterated that Total Quality Assurance as a management system has not been as effective in the construction industry as much as it has been in other industries because of adequate 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. Contractors have failed in setting out adequate funds required for the accomplishments of improving and maintaining the requisite quality expected of construction products and services. Harrison (2019) reports that technical and sustainability challenges are facing the concrete industry and not the commercial challenges. Harrison explained that technical challenges deal with an increasing number of cement types, additions and different aggregates, the use of maximum W/C ratio and minimum cement content as the means of achieving acceptable durability becomes questionable and specifiers are seeking to specify durability performance. He further asserts that how to provide a technically sound, cost-effective system for specifying durability by performance is another challenge facing the concrete sector.

Harrison continued to say that, two technical challenges are not new nor, do they need new technical research, but they are issues that continue to blight the concrete sector. These are:

- The addition of water on site; and,
- Lack of achievement of the specified minimum cover.

On the other hand, concerning sustainability, Harrison (2019) said that sustainability challenges are split into correcting the perception of concrete as a sustainable material and improving reality.

Correcting the Perception

Sustainability has three pillars but often the focus is placed only on the environmental pillar, and then on the global warming potential (GWP). Harrison defined global warming potential (GWP) as a relative measure of how much heat a greenhouse gas traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the gas in question to the amount of heat trapped by a similar mass of carbon dioxide. It is expressed in units of $KgCO_2$ equiv.

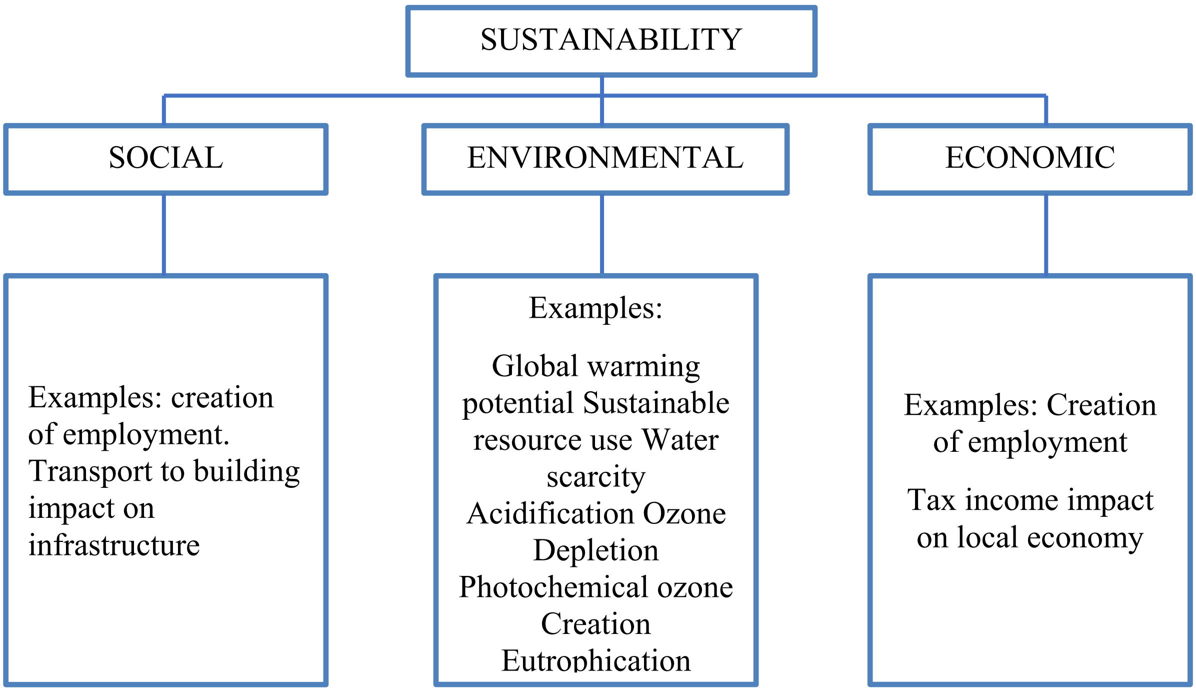

Figure 2.8: The Pillars of Sustainability

Source: (Harrison, 2019).

Eutrophication is the excessive richness of nutrients in a body of water.

Global Warming Potential (GWP) is an important aspect of sustainability, there are other equally important aspects. Sustainable resource use and the social-economic benefits of using local material are equally important factors and are often not taken into account (Harrison, 2019).

- **Improving Reality**

There is significant scope for improving the environmental impact of using concrete solutions both at the concept design stage and in the material selection. According to Willar et al. (2009) the all-encompassing management philosophy termed total quality assurance has generated a tremendous amount of interest and has emerged in the forefront as a major management movement, influencing many sectors of the economy worldwide. The subject matter has churned up some commitment on the part of the management principles aimed at achieving quality performance in all aspects, i.e. product, service, process, profit, and productivity (Idrus & Sodangi, 2010; Sodangi et al., 2010;). The fundamental difference between QA/QC (quality assurance/ quality control) approach and TQM is that the former is a "top-down" approach whereas the latter is a centralized approach which makes TQM consists of management principles aimed at achieving quality performance in all aspects i.e. product, service, process, profit, and productivity. The principles of TQM have been widely used by the manufacturing and service industries, and they have seemingly been welcomed by the construction industry as an opportunity to improve construction quality management (Sodangi et al., 2010). The success of applying TQM to the construction industry would be felt in the nearest time. Considerable research has been directed at implementing TQM in the construction industry. Most of which deal with specific building blocks of TQM (e.g. service, quality continuous improvement), with some attention focused on identifying opportunities, barriers to and procedures for implementing TQM in construction firms.

Zadry and Yusof (2007) developed the theory of constraints (TOC), this is to assist organizations to think about the problems, develop breakthrough solutions and implement those solutions successfully by using Decision Tree analysis. The (TOC) can be assimilated into Quality Assurance Practices Implementation as a mechanism to ensure the profitability and productivity of an organization. According to Panuwatwanich and Nguyen (2017), not all industries that implement Quality Assurance practices had positive satisfaction. Thus Suwandeji (2015) opined that for a public organisation, Quality Assurance practices affecting their implementation are leadership, training, organizational structure, communication, incentives, measurement and evaluation and teamwork. Incentives and evaluation and effective communication contributed to public organization success.

2.8.1 Culture of the Construction Industry

The culture of the construction industry or companies relies heavily on the company's ability to have strong program management skills, attention to detail and most importantly, the ability to monitor a wide range of tasks to keep projects on time and within budget (Riddell, 2016). Additionally, the culture involves making sure everyone is at their assigned positions, performing their designated task, at the proper time. Riddell said that the construction industry's culture promotes a high degree of efficiency and accountability, as delays become extremely costly to the overall project. The culture in the construction industry tends to have a hierarchical power structure (Riddell, 2016).

However, compared to other industries, many of the duties, aside from the owner and senior management seem to be separated by functional expertise more than anything. The centralized project has one PM overseeing operations, while a matrix structure will have multiple managers with autonomy in construction has helped the industry grow, since lower employees can still learn to work on their deadlines (Riddell, 2016). Essentially, culture is acknowledged asa set of learned moral values and meanings that are shared within a group of people (Nguyen & Watanabe, 2018). In the context of construction project organizations (CPOs) among critical success factors (CSFs), cultural factors arguably play a vital role in the success or failure of project management, cultural fare essential determinants of management practices; thus, culture has recently been examined in the study as a CSF of a construction project (Nguyen & Watanabe, 2018). To ensure the success of a CPO, management should pay significant attention to the understanding of cultural aspects and explain how culture's impact can contribute to the CPO effectiveness.

2.8.2 Knowledge Management

Knowledge management can be defined as the process of creating, sharing, using and managing the knowledge and information of an organization (Girad, 2015). According to (April, Izadi & Ahmadi, 2004) knowledge management is the systematic underpinning, observation, measurement, and optimization of the company's knowledge economics. Greene (2017) stated that we live in a knowledge economy" making knowledge one of the modern company's most important assets. Greene added that it's estimated that poor knowledge-sharing practices cost fortune 500 companies $31.5 billion annually and 74 percent of organizations estimate that effective knowledge management's disciplines increase company productivity by 10 – 40%. Given the importance of knowledge to efficiency and productivity, organizations must manage their knowledge effectively. Greene (2017) outlines 6 key benefits of knowledge management in an organization. These are as follows:

- Spend less time recreating existing knowledge

- Get the information you need sooner (and fewer headaches)
- Make fewer mistakes
- Make informed decisions
- Provide better services to employee and customers

2.8.3 Transfer of Technology

It can be defined as scientific methods of production or distribution from one enterprise, institution, or country to another, as through foreign investment, international trade, licensing of patents rights, technical assistance and training. Dictionary of International Trade (DIT, 2019). UNIDO (2004) also define technology transfer is the mechanism by which the accumulated knowledge developed by a specific entity is transferred wholly or partially to another one to allow the receiver to benefit from such knowledge. Technology transfer usually involves some source of technology, a group which possesses specialized technical skills, which transfers the technology to a target group of receptors who do not possess those specialized technical skills, and who therefore cannot create the tool themselves (Carayannis et al., 1997). The major categories of technology transfers and commercialization involve the transfer of:

- Technology is codified and embodied in tangible artifacts.
- Processes for implementing technology.
- Knowledge and skills that provide the basis for technology and process development. In another sense, technology transfer.
- Is to improve the technological capability of business enterprises in developing countries. The advantages of technology transfer could be (Bennett, 2002).
- A production process or part of a process that improves production efficiency reduces costs, improves quality control, and/or reduces environmental pollution.

- A product which is better quality, has less damaging of the environment in its use; or,
- A combination of process and product as the production of a better product often requires changes in the process.

2.8.4 Employee Training and Quality

The importance is recognized by every quality expert. Under best practices quality becomes everyone's responsibility and training must be targeted for every level of the company. There should be customized training plans for management, engineers, technicians, home and field office staff, support personnel and field labour (Smith, 1998). It can be argued that the transient construction workforce is quite different from the relatively stable manufacturing workforce. This transient nature may make it more difficult to train workers, particularly craft labour, for the construction industry (Burati et al., 1992).

However, there are many aspects such as training and awareness that are similar between the safety consciousness if construction firms that had safety forced upon them with the formation of the occupational safety and health administration have proven the cost-effectiveness of their safety programs and now use their safety records as a marketing tool. Some of the same techniques used to instill safety awareness in craft labour may be adaptable to instill similar quality awareness. It is easy to envision using a good-quality performance record as a strong marketing tool if best practices concepts become widely accepted throughout the construction (Oberlender, 1993). Industry workers switching from one company to another should require less good practice training since all workers would have received basic quality awareness in their previous employment (Burati et al., 1992). The training effort may include instruction in the basics of best practices, cause and effect analysis, team problem solving, interpersonal communication and interaction, rudimentary statistical methods and cost of quality measurements. A study of best practices in more than 200 companies found that the skills in human interaction, leadership and initiative are instrumental to the success of any quality improvement effort. The demands on these interpersonal skills increase as the complexity and sophistication of the technical systems increase. The training effort follows a specific plan, and its implementation and effectiveness are carefully tracked. It is initiated in a limited number of pilot teams. The success stories of the pilot teams are then used to fuel the training efforts.

Follow-up training is essential and is part of the overall plan and a job requirement for each individual. The training of employees in the design phase was found to be not very important, in the construction phase moderately important, and the operation phase very important by the respondent. (Gunaydin's, 1997) Findings are parallel to ISO 9001 which emphasizes the importance of training and underlines that activities demanding acquired skills should be identified and the necessary training provided (Doyle, 1994).

2.8.5 Teamwork among Professionals

Quality teams provide companies with a structured environment necessary for successfully implementing and continuously applying the best practices process. Quality training is conducted and a continuous improvement process executed through a well-planned team structure (Lukman et al, 2011). The ultimate goal of the team approach is to get everyone, including contractors, designers, vendors, sub-contractors and owners involved with the best practices process. At the industry level, extending the best practices concept to the parties mentioned above in the form of joint teams achieves higher customer satisfaction. These joint teams are responsible for establishing joint goals, plans and controls. The teams provide a mechanism for listening to and communicating with the owner and for measuring the level of customer satisfaction. Two obstacles to establishing joint teams are the state of legal independence between companies and their traditional methods of working individually (Juran, 1988). These obstacles can be overcome in the construction industry. However, if the owner is dedicated to doing so, there are several case studies of successful partnering arrangements. For example, on a large refinery project, best practice was applied on a project team basis, representative of the owner and the two major contractors on the project served on the project quality steering committee. While this is a new concept, early progress is encouraging (Burati et al., 1992).

At the company level, teams composed of department representatives are necessary to implement best practices throughout the organization. The same team approach can be used at the project level. "Extent of teamwork of parties participating in the design phase" was found to be the most important factor that affects quality in Gunaydin's study of best practices in construction projects. In the same study, construction managers and designers ranked this factor as the most important factor (Gundydin, 1997). The results show that teamwork among parties such as structural, electrical, environmental, civil engineers, architects and owners is essential to reach the quality goal for design. In the construction phase, "the extent of teamwork of parties participating in the construction process" was found to be very important and ranked 2nd by construction and 4th by construction managers (Gundydin, 1997). It appears that the importance of teamwork in the design phase was relatively more pronounced than in the construction phase.

2.8.6 Statistical Method

Statistical Method provides problem-solving tools to the Quality Assurance process. According to Periseo (1989), statistical method provides teams with the tools to identify the causes of quality problems, to communicate in a precise language that can be understood by all team members, to verify, repeat and reproduce measurements based on data to determine the past, present and to a lesser degree, the future status of the work process, and to make decisions on facts that are based on data rather than the opinions and preferences of individual or groups. The importance of statistical techniques is also underlined by ISO 9000. However contrary to Quality Assurance philosophy, the use of statistical methods was found to be in Gunaydin's survey the least important factor that affects quality in the construction process and ranked at the very bottom of the management lists in the design and construction phases by designers, constructors and construction managers (Gunaydin, 1997). It can be concluded that all professionals involved in the study agree that the use of statistical methods has relatively very little effect on the quality of the construction project. This finding supports Helland's contention that individual construction activities are typically unique and eliminate the potential for any kind of statistical process control (Helland, 1994).

2.8.7 Supplier Involvement

The ability to produce a quality product largely depends on the relationship among the parties involved in the process, the supplier, the processor, and the customer. The quality of any stage in a process is contingent upon the quality of the previous stages. The quality of the project built by the constructor is directly related to the quality of the plans and specifications prepared by the designer, the quality of the equipment and materials supplied by the vendors and the quality of work performed by the subcontractors. The close and long-term relationships with these suppliers to the construction process are required if the constructor is to achieve the best economy and quality (Oberlender, 1993). Traditionally, in the construction industry, contractors, subcontractors and vendors are all pitted against one another to compete based on low-bid contracts, yet the fourth of Deming's recommendations for reaching a high level of quality stresses those companies must end the practice of awarding business based on price tag alone. According to Peters (1987), successful projects in the future are likely to be decided based on quality life-cycle costs (not initial cost), and supplier responsiveness, which can only be achieved through partnership relationships; these relationships will involve fewer suppliers and they are expected to be based on mutual trust. This is already being proven true in certain areas of the industrial construction market. Long-term partnering agreements have been formed between several owners and contractors. Some owners are requiring their contractors are requiring their vendors to implement Quality Assurance practices if they wish to be considered for future work (Burati et al., 1992).

2.9 Summary of Literature Review

The section reviewed the relevant literature with regards to Quality Assurance practices of concrete production. It was divided into seven parts; the first part looked at the overview of construction projects; where the materials used in the construction projects were examined and also the concrete production in the construction projects specifically looking into the inside and off-site concrete production. The second part looked at the concept of quality the various definitions of off-site concrete productions. The second part looked at the concept of quality of the various definitions of quality and quality management. The third section was a review of the determinants of the quality of concrete. It examined the technical, environmental, and managerial as determinants of quality of concrete. The fourth section was a brief review of quality management practices, specifically the reactive and planned quality management. The fifth section was basically on the review on best practices in quality management. In this regard, the section examined the applicability of best practices and the process of concrete production. The sixth section was a review of the factors affecting the adoption of best practices in concrete production. The final section examined the challenges to quality management in concrete production.

CHAPTER THREE

METHODOLOGY

3.1. Introduction

This chapter highlights the procedures and strategies that were used in collecting and analysing the data. The main sections discussed in this chapter include research design, target population, sampling techniques and sample size, data collection instruments, data collection techniques, and data analysis.

3.2 Research Philosophy

In conducting research, it is important to consider the philosophical assumptions or paradigm that underpin the study. A paradigm may be considered as a "set of beliefs, values and techniques which is shared by members of a scientific community, and which acts as a guide or map, dictating the kinds of problems scientists should address and the types of explanations that are acceptable to them" (Kuhn, 1970). The positivists believe in empiricism, the idea that observation and measurement are at the core of the scientific endeavour. Thus the positivists assume an objective reality which is single and concrete. Positivist researchers are independent from what is being researched. This is because of distance or objective separateness between the researcher and object of study and therefore knowledge is discovered and verified through direct observations or measurements of reality. The positivists believe that the only way to conduct research is through a quantitative means and this is equated with truth.

In the present study, the researcher's stance is positivism because it is usually supported by investigating or studying an observable social reality and the final product could be law-like generalization similar to those produced by a physical and natural scientist (Saunders et al., 2009).

3.3 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.

3.4 Research Strategy

. The study adopted a quantitative research strategy based on the nature of information required to find insightful answers to the pertinent research questions as shown in Section 1.4 of chapter one.

3.5 Research Design

The study employed a descriptive survey design. Given the time frame of the research, a longitudinal survey was impossible. Therefore a cross-sectional survey approach was adopted. 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.

3.6. Population

This study seeks to examine how quality assurance of concrete product is maintained at its production stage at the various construction worksites as well as already mixed concrete companies in the Greater Accra Region, Ghana. The target population of the study comprised construction professionals employed by D1K1 construction companies within the Greater Accra Region. Thus the project managers, quality officers, project engineers, site engineers/managers, Works superintendents and site supervisors. Greater Accra region was chosen as a study area because the highest concentration of D1K1 companies is located 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 2019 were 52. Out of this, 19 of them are currently operating in the Greater Accra region representing 36.5%. A sampling frame was compiled for the construction professionals working in the 19 D1K1 operating in the Greater Accra Region in 2019.

3.7 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 a census approach in the first stage in which the population of D1K1 contractors operating in the Greater Accra was determinedin the second stage systematic random sampling was adopted to select the construction professionals covered in the survey 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 147 in the region, 95 of them representing 65% was chosen as a sample size.

3.7.1 Sample Size Estimation

Cochran's formula for estimating sample size was used to determine the required representative samples for this study.

$$n = \left(\frac{\pi}{\left(1 + \frac{\pi}{N}\right)} \right) \quad Where \quad N = population\ size$$

$$\pi = \left(\frac{\left(z_{\alpha/2}\right)^2 p(1-p)}{\alpha} \right)$$ Where; p is the proportion of individuals selected to study $z_{\frac{\alpha}{2}}$ Is the confidence level α Is the error term

where; $Z_{\alpha/2} = 1.96,\ \alpha = 0.05,\ p = 0.50$

$$\pi = \left(\frac{(1.96)^2\ 0.5(1-0.5)}{0.05^2} \right) = 384.16$$

Substitution into the Cochran's formulae

- **The sample size for the study**

$$n=\left[\frac{384.16}{1+(\frac{384.16}{147})}\right]$$

n=95 construction project team professionals

This large sample size was considered to enable the study to involve a reasonable number of respondents in the study to authenticate the results to be obtained.

A simple random sampling technique was utilized. This technique allows every member of the target population an equal chance to be selected (Gay, 1992). It has the advantage of reducing bias associated with non-random selection.

3.8 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.

3.8.1 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.

3.8.2 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).

3.7 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. Moreover, it employed crosstabulation, 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 project managers at the site and the site manager at the office.

Table 3.1 details of data analysis

S/N	Research Question	Variables	Method of Analysis	Outcome
1	What are the effective quality assurance practices of concrete production by construction companies in Ghana?	All relevant variables of the study (variables related to quality assurance practices)	Quantitative data Descriptive statistics; pie chart, mean and standard deviation. Rankings Compare means; ANOVA	Objective 1 achieved. Quality assurance practices in concrete production
2	What are the contractors' knowledge of elements of quality assurance in concrete works in Ghana?	All relevant variables of the study (variables related to the elements of knowledge of quality assurance practices)	Quantitative data Descriptive statistics; mean and standard deviation cross tabulation. Rankings Compare means; ANOVA	Objective 2 achieved. Element of knowledge of concrete production.

3	What are the challenges of quality assurance practices facing the construction companies in the production of quality concrete in Ghana?	Underlying challenges in the industry toward the implementation of quality assurance practices.	Quantitative data Descriptive statistics; mean and standard deviation. Ranking. Non-parametric; chi-square	Objective 3 achieved. Critical challenges found.
4	What type of material measure put in place by construction companies in Ghana to achieve quality concrete?	All relevant variables of the study	Quantitative data. Descriptive statistics; mean and standard deviation. Ranking. Non-parametric; chi-square	Objective 4 achieved. Proposed measures were found.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF RESULTS

4.0 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 Greater Accra Region, Ghana. Data were gathered from 73 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.

4.1 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. 95 questionnaires were distributed and 73 completed questionnaires were returned representing a response rate of 76.84%.

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 $RS = \frac{73}{95} \times 100 = 76.84\ \%$)

4.2 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.

4.2.1 Level of Education of Respondents

The level of education was analyzed with the following details in Figure 4.1 below. From Figure 4.1, it was observed that 30.1% 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.

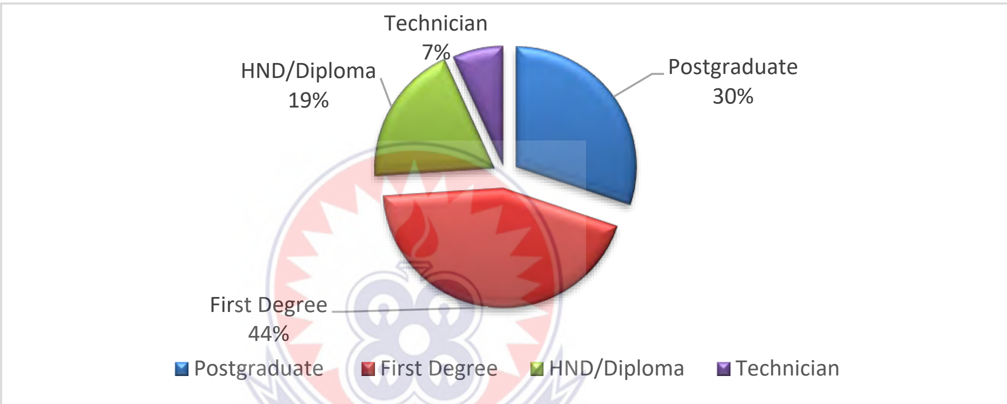

Figure 4.1 Level of Education of Respondents

4.2.2 Job Title/Position of the Respondent

It was observed from Fig 4.2 that the majority of the respondents representing 32.9% were project managers, 13.7% were also quality officers, 20.5% were project engineers whiles 4.1% and 5.5% were site supervisors and Work Superintendent respectively. Thus, the majority of the respondents are well experienced in their area of specialty which gives certainty in the data collected.

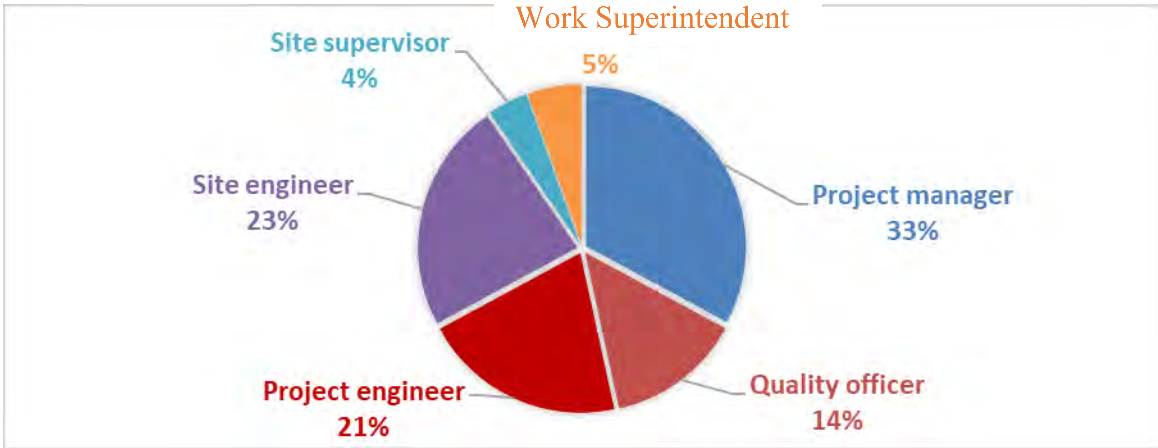

Figure 4.2 Job Title / Position of Respondents

4.2.3 Years of Experience in the Industry

The researcher enquires from the respondents the number of years they have spent in the construction industry concerning their experience as far as quality production of concrete is concerned. It 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 Fig.4.3 below.

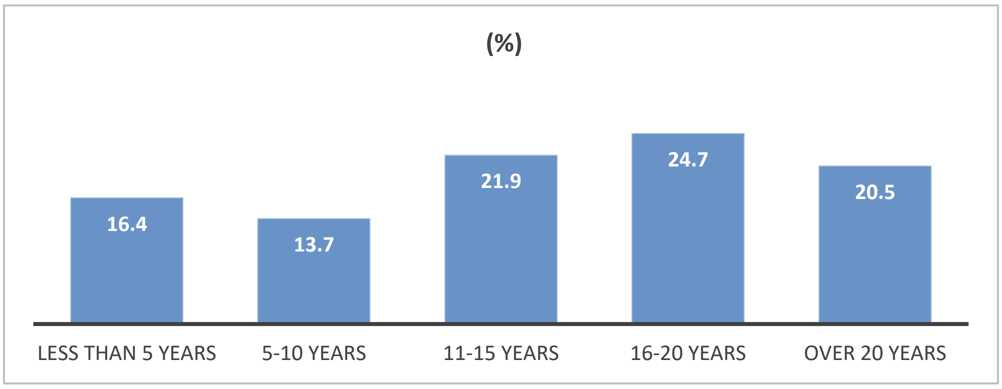

Fig. 4.3 Years of Experience in the Industry Source

4.3.4 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.

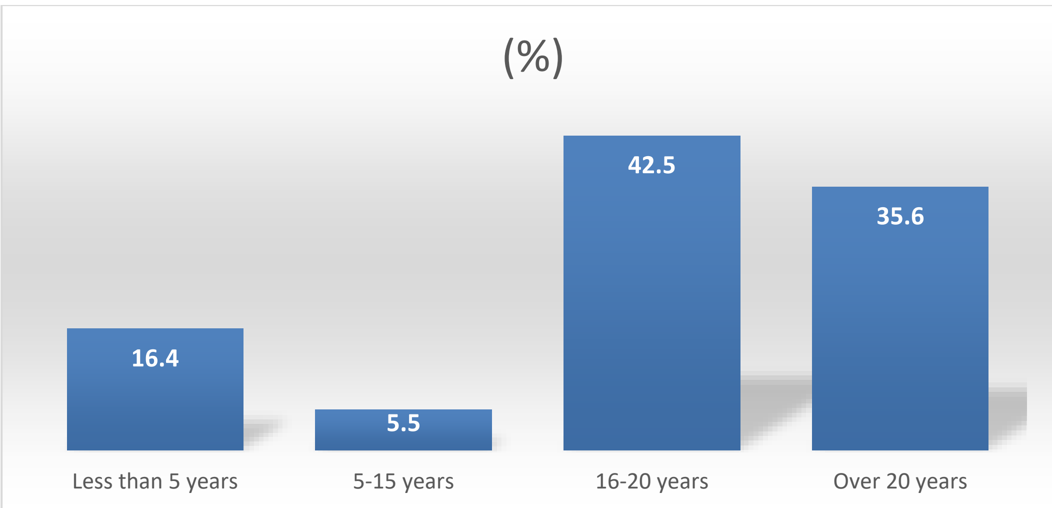

Fig. 4.4 Existence of companies

4.2.5 The Stage Respondent Joined their Current Project

From Figure 4.5, 19.2% of respondents joined their current project at the pre-tender stage, 24.7% joined the project at the post-tender stage whiles majority thus 56.2% joined their present company at the start of the project. This indicates that the majority of respondents were not present during the planning stages of the project.

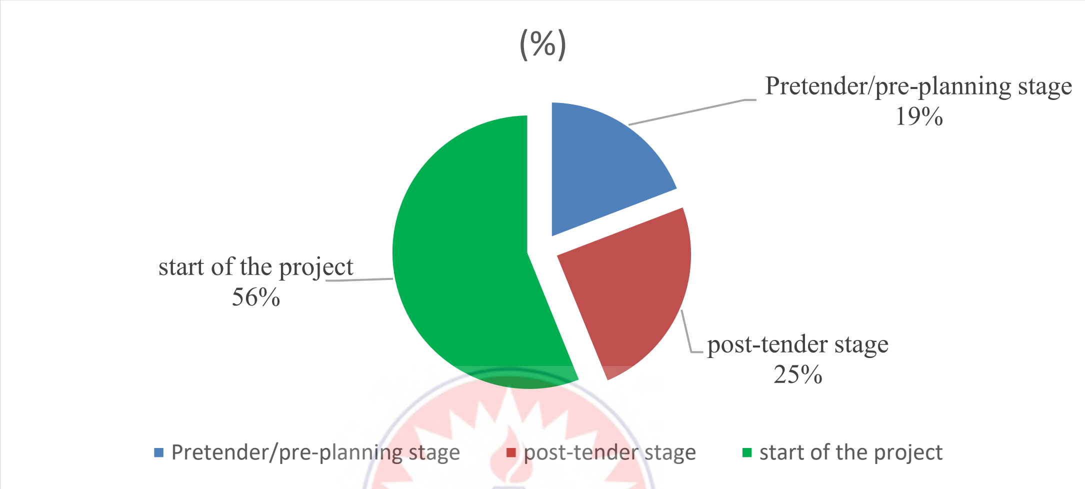

Fig. 4.5 Stage Respondent Joined their Current Project.

4.3 Quality Assurance Practices in Concrete Production on Construction Projects

To explain the results obtained from Tables 4.1 to 4.4, the following range is used using descriptive statistics; thus 1.00-2.40 = strongly disagree, 2.50-2.90 = disagree, 3.00-3.50 = Neutral = 3.60- 4.00 = agree and above 4.01 and above = strongly agree to indicate the extent to which companies ensures quality assurance practices in concrete production on construction projects.

Using the mean score to rank the analysed data in Table 4.4.1 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 from the Table. 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 from the Table 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 on the Table.

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 on the Table.

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 from Table 4.1.

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 4.1 Quality Assurance Practices in Concrete Production on Construction Projects

Item	**Responses**			
	N	**Mean**	**St.Dev**	**Rank**
In my company, all concrete products are designed to suit fitness for use	73	4.60	.493	1
All concrete products are produced in conformity to specifications and standards	73	4.38	.637	2
My company rely on experienced supervisors to conduct supervision during concrete production	73	4.34	.628	3
The degree of excellence is considered in my company whenever a concrete product is to be produced	73	4.08	.493	4

Specified required proportion of each components identified in the drawing specification are strictly adhered to	73	4.03	.164	5
Performance requirement of concrete is checked at its design stage to ensure safety	73	4.00	.624	6
Successive inspection of works during concrete operation is considered in my company	73	3.96	.889	7
Durability and reliability considerations are observed during concrete production stage	73	3.88	.666	8
Raw materials to be used for concrete product are well checked against standards and specifications	73	3.86	.822	9
Site engineers at the site sometimes reduce some quantity of materials to be used	73	2.96	.920	10
The use of substandard materials for concrete production is compromised in my company	73	2.36	.903	11

4.3.1 Testing of hypothesis on quality assurance practices

The researcher further used analysis of variance (ANOVA) test to determine the differences in responses hence, the hypothesis;

Null Hypothesis: There is no significant difference among the project teams concerning their responses on quality assurance practices in concrete production.

To test the above hypothesis, ANOVA was done using F test. The four categories of the project team (position) considered in this study included project manager, quality officer, project engineer, site engineer, work superintendent, and site supervisor. The mean scores were found out along with the standard deviation. Based on this, the F value was computed. The results are summarized in Table 4.2

Since P-Value is less than 0.05, the null hypothesis is rejected at 5 percent level of significance concerning; rely on experienced supervisors to conduct supervision (p=0.003), degree of excellence is considered (p=0.004), concrete products are produced in conformity to specifications and standards (p=0.010), employee participation in non-work related activities (p=0.004), Concrete product are produced in conformity to specifications and standards (p=0.010), and Concrete products are designed to suit fitness for use (p=0.000). Hence it is concluded that there is no significant difference concerning the responses among the project team members used in the study.

Table 4.2 ANOVA for significant difference among project team concerning their responses on quality assurance practices in concrete production.

Variable	Position	Mean	SD	F Value	P Value
Rely on experienced supervisors to conduct supervision	Project Manager	4.21	0.721	4.071	.003
	Quality Officer	4.13	0.352		
	Project Engineer	4.10	0.738		
	Site Engineer	4.82	0.393		
	Work Superintendent	4.00	0.000		
	site supervisor	4.75	0.500		
Degree of excellence is considered	Project Manager	4.00	0.590	.356	0.004
	Quality Officer	4.07	0.258		
	Project Engineer	4.10	0.738		
	Site Engineer	4.18	0.393		
	Work Superintendent	4.00	0.000		
	site supervisor	4.25	0.500		
Concrete product are produced in conformity to specifications and standards	Project Manager	4.42	0.776	.498	0.010
	Quality Officer	4.33	0.488		
	Project Engineer	4.30	0.823		
	Site Engineer	4.29	0.470		

	Work Superintendent	4.67	0.577		
	site supervisor	4.75	0.500		
Concrete products are designed to suit fitness for use	Project Manager	4.58	0.504	2.009	0.000
	Quality Officer	4.87	0.352		
	Project Engineer	4.70	0.483		
	Site Engineer	4.41	0.507		
	Work Superintendent	4.67	0.577		
	site supervisor	4.25	0.500		

The mean difference is significant at the 0.05 level

4.4 Knowledge of Element of Quality assurance in 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 concrete production. 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 as follows in Table 4.5.

From the Table, most respondents strongly agree with the mean value 4.40 that they regard durability and reliability as key dimensions for achieving quality concrete which ranked first on the Table. It was further observed from the Table 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 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 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 on the Table.

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

i. *I carefully weigh the 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 concrete to be produced*
iii. *In my company, strict measures are adopted to deal with suppliers of materials used in concrete production*

That notwithstanding, respondents remain neutral with mean values 3.26, 3.14 and 3.03 in that order on the statements below and ranked 8th to 10th on the Table.

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 Concrete Production

Item	Responses			
	N	Mean	St. Dev	Rank
I regard durability and reliability as a key dimensions for achieving quality concrete	73	4.40	.493	1
My company ensures that drawings and specifications are concise, clear and void of information	73	4.11	.657	2
I design the correct mix ratio of each category of concrete prescribed for the work under each contract	73	4.11	.621	3
Achieving excellence through the high quality concrete product is the main objective of my contractor	73	4.10	.988	4
I carefully weigh the concrete production process against the serviceability of concrete elements	73	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	73	3.78	.975	6
In my company, strict measures are adopted to deal with suppliers of materials used in concrete production	73	3.73	.449	7
The contractor understands the implications of compromising the specified specifications in the drawings	73	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	73	3.14	.962	9
Every employee in my company feels the contractor provides full support to process and project quality improvement	73	3.03	.552	10
The contractor makes the adequate provision of standard and required material resources for the production of concrete	73	2.77	1.264	11

4.4.1 Analysis of Variance on Knowledge on Element of Quality assurance in Concrete Production

The researcher 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 4.5. 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 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 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		

4.5 Challenges to the Implementation of Quality Assurance Practices in Concrete Production

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

It revealed from the Table that respondents strongly agree to the statement 'difficult to keep permanently employed key site operatives for 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 Practices 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	73	4.25	.434	1
Inappropriate use of construction materials in their right proportions is resorted to in the face of challenges	73	3.89	.614	2
It is sometimes difficult to get certain skill personnel for a specific task	73	3.84	.373	3
Inadequate material and financial resources constraints	73	3.63	1.184	4
Adverse weather conditions sometimes make it difficult for concrete to achieve its required strength	73	3.26	1.131	5

Sometimes, financial constraints make it difficult for some contractors to buy from the right source	73	3.26	1.000	6
Effective access to obtain the reviewed construction detailed drawings and specifications are sometimes difficult	73	3.23	.979	7
Lack of proper planning of site operations often resulting in issues many of which border on quality	73	3.01	1.112	8
Procurement officers purchase materials and components from suppliers who do not put in place quality assurance measures	73	2.99	.993	9
Test that ought to be done to ascertain the required needed strength of concrete is ignored	73	2.79	1.213	10

4.6.1 Chi-Square on Challenges

It is clearly shown from Table 4.7 that on average, 12.2 responses were observed in each category of respondents. From Table 4.7 the calculated x^2 statistic was 18.753. The significance level (p=0.00) is less than the threshold value of 0.05 therefore, H_1 (the responses from the various respondents are not the same) is rejected in favor of H_0 (the responses from the various respondents are the same).

Table 4.6 Crosstab on job title responses

Category	It is difficult to keep permanently employed key site operatives for concrete operations due to financial constraints		
	Observed N	Expected N	Residual
Project Manager	24	12.2	11.8
Quality Officer	15	12.2	2.8
Project Engineer	10	12.2	-2.2
Site Engineer	17	12.2	4.8
Work Superintendent	3	12.2	-9.2
site supervisor	4	12.2	-8.2
Total	**73**		

Table 4.7 Chi-Square Test

Category	It is difficult to keep permanently employed key site operatives for concrete operations due to financial constraints				
	Observed N	Expected N	Residual	x^2	Sig.
Agree	55	36.5	18.5	18.753	0.00
Strongly Agree	18	36.5	-18.5		
Total	73				

4.5.1 ANOVA analysis on Challenges

Difficulty in getting certain skill personnel for a specific task, inappropriate use of construction materials in their right proportions, as well as difficult to keep permanently employed key site operatives due to financial constraints, as variables observe inconsistent responses in the descriptive statistics. It was imperative to determine how different the responses were hence; ANOVA test was employed using the usual threshold p value of 0.05 as shown is table 4.8.

Since P Value is less than 0.05, the null hypothesis is rejected at 5 percent level of significance with respect to difficult to keep permanently employed key site operatives (F= 3.237, p=0.011) and inappropriate use of construction materials in their right proportions (F=4.053, P=0.003) it suggest that, there is a significant difference concerning the responses among the project team used in the study on the above variables.

However, the following variables; 'Difficult to get certain skill personnel for a specific task (F= 0.615, P= 0.689) and inadequate material and financial resources constraints (F=2.312, P= 0.55) had p values greater than the usual threshold level of 0.05 indicating the significant difference in these responses. It, therefore, suggests that there were significant differences in responses though they represent agree or strongly agree.

Table 4.8 ANOVA analysis on Challenges

Variable	Position	Mean	SD	F Value	P-Value
Difficult to keep permanently employed key site operatives	Project Manager	4.21	.415	3.237	.011
	Quality Officer	4.60	.507		
	Project Engineer	4.20	.422		
	Site Engineer	4.12	.332		
	Work Superintendent	4.00	.000		
	site supervisor	4.00	.000		
Difficult to get certain skill personnel for a specific task	Project Manager	3.83	.381	.615	.689
	Quality Officer	3.93	.258		
	Project Engineer	3.70	.483		
	Site Engineer	3.82	.393		
	Work Superintendent	4.00	.000		
	site supervisor	3.75	.500		
Inappropriate use of construction materials in their right proportions	Project Manager	3.92	.654	4.053	0.003 .
	Quality Officer	3.87	.352		
	Project Engineer	4.10	.568		
	Site Engineer	4.06	.429		
	Work Superintendent	3.67	.577		
	site supervisor	2.75	.957		

Inadequate material and financial resources constraints	Project Manager	3.79	1.351		
	Quality Officer	4.07	.704		
	Project Engineer	3.10	1.197	2.312	
	Site Engineer	3.06	1.029		
	Work Superintendent	4.33	.577		0.055
	site supervisor	4.25	1.500		

4.6 Measures put in Place to Achieve Higher Quality Concrete

The results on measures put in place to achieve higher quality assurance in producing 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 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 4.9 shows measures put in place to achieve higher quality concrete.

Table 4.9 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	73	4.68	.468	1
Well graded aggregates are used for concrete mix	73	4.30	.462	2
Water cement ratio proportions are correctly checked and controlled	73	4.11	.657	3
All records of testing are well kept for future references	73	3.73	.932	4
Mixing of concrete is strictly done on-site using a concrete mixer	73	3.59	1.188	5
Frequent checking of material quality is always done	73	3.56	.957	6
Batching of materials are sometimes varied using either batching by volume or by weight	73	3.55	.972	7
Full production test is usually done to ascertain the quality desired	73	3.55	.501	8
Baseline studies are conducted to ascertain practical limits to the strength of the concrete depending on the quality specifications	73	3.23	.717	9
Pre-testing of material strength is frequently done to achieve the desired quality	73	3.22	1.627	10
Frequent monitoring of concrete processing using Shewhart control chart	73	2.82	1.378	11
Employees sometimes receive training related to their duty prior to the commencement of the project	73	2.60	1.152	12
Depending upon the type of work, ready mixed concrete are transported onto the site	73	2.55	1.248	13

4.7.1 x^2 Analysis of Materials used in the mix

The researcher further analyzed the individual responses from the various professionals within the industry who were sampled on the materials used in the mix in an attempt to produce a quality concrete product. Still pegging the p-value at 0.05 at 95% confidence interval, it was hypothesized that;

H_0: There is no significant difference in the responses from the professionals used in the study.

H_1: There is a significance difference in the responses from the professionals used in the study.

From the output in Table 4.11, the calculated x^2 statistic for 1 degree of freedom is 9.986. Additionally, it indicates that the significance value (0.002 is less than the usual threshold value of 0.05. This suggests that the null hypothesis H_0 (There is no significant difference in the responses from the professionals used in the study) is rejected in favor of the alternate hypothesis, H_1 (There is a significant difference in the responses from the professionals used in the study).

Table 4.10 Descriptive Statistics on Materials used in the mix

Descriptive Statistics					
Variable	N	Mean	Std. Deviation	Min.	Max.
Materials used in the concrete mix are free from impurities	73	4.68	.468	4	5

Table 4.11 Chi-Square Analysis on Materials used in the mix

	Observed N	Expected N	Residual	Chi-Square	df	Sig.
Agree	23	36.5	-13.5	9.986[a]	1	.002
Strongly Agree	50	36.5	13.5			
Total	**73**					

CHAPTER FIVE

DISCUSSION OF RESULTS

5.0 Introduction

This chapter presents the detailed discussions of the findings obtained from the field data gathered on the topic of evaluating quality assurance practices of concrete production by construction firms in Ghana. The main study objectives included; determine effective quality assurance practices in concrete production on a construction project in Ghana, assessing the level of application of knowledge of element of quality assurance on concrete production, identifying the challenges to the implementation of quality assurance practices in concrete production and the measures companies put in place to achieve the higher quality concrete product. With this, inferences would be made where appropriate to reaffirm the results.

5.1. Quality assurance practices in Concrete Production on Construction Projects

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. The meaning of this definition is not far from the results obtained in Table 4.4 in the previous chapter. Most respondents in the study strongly agree that in their companies, all concrete products are designed to suit fitness for use. This result is an indication of the fact that companies have plans and systematic procedures necessary to ensure that concrete products being produced are of good quality which meet all the needed requirements. This result has a very close relationship with the definition made by Wick and Veilleux (2003) which said quality control is a set of specific procedures including planning, coordinating, developing, checking, reviewing, and scheduling the work. Not only that, it revealed in most responses that most companies ensure that all concrete products are produced in conformity to specifications and standards. This is in line with the CIOB (2019).According to CIOB (2019), technical specifications define the type of controls that must be carried out to ensure the construction works are carried out correctly. They include not only the products and materials but also the execution and completion of the works. One way of controlling quality is to inspect or verify a finished product (CIOB, 2019).

The result further revealed that most companies rely on experienced supervisors to conduct supervision during concrete production. The reliance of experienced supervisors in most companies has to do with the monitoring of the processes to pursue the elimination of sources that lead to unsatisfactory quality performance of the product as expressed by (CIOB, 2019).

Also, it was found that most companies strictly adhered to the specified required proportions of each component as identified in the drawing specification. This is to ensure that the quality to be achieved is not compromised said (Artidi & Gungydin, 1997). The results further skewed that most companies check the performance requirements of concrete at its design stage to ensure safety. This has affirmed that establishing the project requirements for quality begins at project inception as opined by Artidi and Gungydin (1997). Regarding durability and reliability considerations during the 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 the literature. It was further revealed that raw materials to be used for concrete products are well checked against standards and specifications. This implies that companies consideration to quality assurance is not compromised in any way. The project quality management plan (QMP) guidance document provides information about concrete material related quality assurance (QA) and quality control (QC) practices for the Bureau of Reclamation Construction projects with significant concrete features (Fay, 2015). Concrete manufacturing uses raw materials such as sand and rocks which are in their quality state and constitute approximately 65% to 75% of the concrete's total volume (Becker 2013; Sabay et al., 2015). The result in furtherance showed that most companies consider some degree of excellence in their respective companies whenever a concrete product is to be produced.

However, respondents showed their disagreement to the following statements 'Site engineers at the site sometimes reduce some quantity of materials to be used and The use of substandard materials for concrete production is compromised in my company as reverse items in ascertaining their response reliability. It is important to note that these reverse responses reaffirm that companies are very particular with quality assurance practices especially concrete production on construction projects. Again, it is an indication of the fact that there was a significant level of consistency in responses towards achieving concrete product quality.

Quality Management practices according to Ferguson and Clayton (1998) is a practice covering activities necessary to provide quality in the work to meet the project related policies procedures requirements. In relation, quality assurance involves establishing project-related policies, procedures, standards, and systems necessary to produce a quality product. Tan and Rahman (1989) expressed similar sentiment saying that, enhancing quality assurance management practices in the construction industry mean improving, maintaining and ensuring that, the required standards are obtained so as to meet the customer satisfaction that will later bring about sustained competitiveness and financial survival

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

5.2 Knowledge of Element of Quality assurance in Concrete Production

From Table 4.2, the results indicate that most respondents strongly agree that they regard durability and reliability as key dimensions for achieving quality concrete production. This implies that each respondent is aware of the various quality assurance practices in the industry. It is important to note that all the respondents in the study occupy various managerial positions in their respective companies are educated. Therefore, there is a need to have the requisite knowledge for quality assurance practices in the industry for survival. Results further revealed that the majority of the respondents were of the view that, their companies ensure that drawings and specifications are concise, clear, and void of other information. This means that both graphical and other written documentation contained in the contract document are clearer for understanding. Significantly, the implications are that interpretations in the drawings pose no challenge, especially quality requirement considerations.

That notwithstanding, respondents expressed that their companies design correct mix ratios of each category of concrete project prescribed for the work under each contract. This means that specified mix ratios are being followed to attain the strong, durable, and desired quality required. With this, Alam et al. (2016) were of the view that accurate concrete mixing ratios can be achieved by measuring the dry materials using buckets or concrete mixer throughout the project, hence, rational proportioning of the ingredients of concrete are the essence of the mix design. In a related development, the results further revealed that achieving excellence through high-quality concrete product is crucial.

Concrete is generally produced in batches at the site with the locally available materials of variable characteristics. It is therefore likely to be variable from one batch to another yet, quality maintained (Alam et al., 2016). 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.

Notwithstanding, every employee almost every company feels the contractor provides full support to process and project quality improvement. Conversely, respondents denied though inconsistency that the contractor makes the adequate provision of standards and required material resources for the production of concrete. It is worthy to note that probably some contractors will however neglect and ignore some factors as minor which will eventually compromise the desired quality to attained. It is therefore up to the industry players to ensure that standards are fully followed in an attempt to produce the quality concrete product desired.

5.3 Challenges to the Implementation of Quality Assurance Practices in Concrete Production

On the challenges that militate against the implementation of quality assurance practices in concrete production, there were varied opinions. It revealed that some companies find it difficult to keep permanently employed key site operatives due to financial constraints.

Here, it is worthy to note that some contractors have failed in setting out adequate funds required for the accomplishments of improving and maintaining the requisite quality expected of construction products and services. Haupt and Whiteman (2004) and Bubshait and Al-Atiq (1999) reiterated 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) that the basic requirements for the success of quality assurance are the availability of experienced knowledgeable and trained personnel at all levels.

As it is, Tang et al. (2005) postulated that lack of understanding of what quality management is particularly on-site, inadequate training, plans not clearly defined and employee skeptics and resistance to data collection are some of the major challenges faced regarding the adoption of quality management practices in the construction industry.

That notwithstanding, the fact maintains that many Ghanaian construction companies have comprehensive quality plans just as safety plans as opined by Dotse (1997) cited in Alam et al. (2016) but the quality of plans does not necessarily correlate to the company quality performance. Therefore, quality in each phase is affected by the quality in the preceding phase; hence, customer service in each phase is important for the overall quality performance of the process (Odusami et al., 2010). Quality is, therefore an important feature of any construction firm because the safety of the construction companies and the stakeholders depends on the quality of the structure (Idoro, 2010). It is therefore imperative for the industry players and other interested stakeholders to commonly address the challenge for quality sustenance.

5.4 Measures for Achieving Higher Quality Concrete

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).

Also, companies frequently check the material quality and keep records of all testing documents for future references. With these, Obrien (1989) was of the view that presently, testing and inspection requirements are part of the contract specifications. He further stressed that to develop a firm plan, the testing and inspection requirements can be combined into a new division of the specifications. This would emphasize quality control and provide an organized location in which all quality control issues are identified to bidders.

Mixing of concrete according to the responses, is supposed to be strictly done on-site using a concrete mixer. This will enable the machine operators to maintain the homogeneity obtained at the time of mixing and also prevent circumstances of reaching on-site late when transporting from elsewhere. Results further revealed that batching of materials is sometimes varied either by weight or volume. Weight batching of materials is always preferred over volume batching. When weight-batching is not possible and the aggregates are batched by volume measures have to be in place to regularly checked for weight-volume ratio (Alam et al., 2016). It is very important to be consistent with a particular type of batching. Switching from one type to another on a particular type of project will probably compromise the quality desired (Brainkart, 2018).

Similarly, results revealed that companies usually engage in full production tests to ascertain the desired quality. This includes pre-testing of material strength to achieve the desired quality of concrete product to be produced. As asserted by Alam et al. (2016), inspection and testing play a vital role in the overall quality control process. Apart from the test on concrete materials, concrete can be tested both in the fresh and hardened states. The test on fresh concrete offers a certain opportunity for necessary corrective actions to be taken before it is finally placed. These include tests on workability and compressive strength respectively.

However, conducting baseline studies to ascertain the practical limit to the strength of the concrete depending on the specifications is necessary. Though companies do conduct pre-testing and inspection, frequent monitoring of concrete processing is somehow low in some companies. One of the most important aspects to consider during a construction projects is the strength and maturity of concrete at any given time according to Pepin (2017). It prevailed that almost all the companies do produce their concrete mix on site. It is important to note that, on-site mix concrete has a low risk of delay before casting maintains homogeneity during pouring.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.0 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 practices in the production of concrete by construction firms in Ghana and develop strategies for effective quality assurance practices in concrete production. Relevant related literature was reviewed to find out the existing practices and principles of quality assurance especially in concrete production in the construction industry. In other to achieve the aim of the study, the researcher 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.

To explain the results obtained from various Tables, the researcher used the following range using descriptive statistics; thus 1.00-2.40 = strongly disagree, 2.50-2.90 = disagree, 3.00-3.50 = Neutral = 3.60- 4.00 = agree and above 4.01 and above = strongly agree to indicate the extent to which companies ensures quality assurance practices in concrete production on construction projects. Other statistical tools such as Chi-Square, Analysis of Variance (ANOVA) were further employed to determine the significant differences among the various responses. With these tools, the usual threshold value of 0.05 (p-value) was used as a deciding factor to indicate whether there are differences in responses obtained.

6.1 Summary of the Quality Assurance Practices

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

i. All concrete products are designed to suit fitness for use
ii. All concrete products are produced in conformity to specifications and standards
iii. Companies rely on experienced supervisors to conduct supervision during concrete production
iv. The degree of excellence is considered whenever a 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 concrete is checked at its design stage to ensure safety.

6.2 Summary to the Knowledge of the Element of the Quality Assurance Practices

The study revealed that most project team members know the elements of quality assurance practices 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

6.3 Summary of the Challenges to the Implementation of the Quality Assurance Practices

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

6.4 Summary of the Practical Measures for the Implementation of Quality Assurance Practices

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

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

6.5 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.

6.6 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.

6.6 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 COMPANY MANAGERS AND QUALITY OFFICERS

This questionnaire is designed for a Master of Philosophy research titled "Improving Quality Assurance Practices of Concrete Construction Production by Construction Firms in 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 concrete production. The respondent's information provided will be treated as confidentially as possible since this research in 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 CONCRETE PRODUCTION

Please indicate the extent to which you agree or disagree to the following statement on quality assurances practices in 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 concrete production on construction projects	**1**	**2**	**3**	**4**	**5**
The degree of excellence is considered in my company whenever a concrete product is to be produced					
Successive inspection of works during concrete operation is considered in my company					
In my company, all concrete product are designed to suit fitness for use					
All concrete product are produced in conformity to specifications and standards					
Performance requirement of concrete is checked at its design stage to ensure safety					
Durability and reliability considerations are observed during concrete production stage					
Specified required proportion of each components identified in the drawing specification are strictly adhered to					
My company rely on experienced supervisors to conduct supervision during concrete production					
Raw materials to be used for concrete product are well checked against standards and specifications					
The use of substandard materials for 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					
The contractor defines the responsibility of personnel who manage,					
The contractor makes adequate provision of standard and required material					
Every employee in my company feels contractor provides full support to					
There is existence of a communication system notifying all staff about the					
I regard durability and reliability as key dimensions for achieving					
I design the correct mix ratio for each category of concrete prescribed for					
In my company, strict measures are adopted to deal with supplies of					
I carefully weigh the concrete production process against serviceability					
Achieving excellence through high quality concrete products is the main					
My company ensures that drawings and specifications are concise, clear					

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	1	2	3	4	5
Inadequate material and financial resources constraints					
Effective access to obtain the reviewed construction detailed drawings					
It is sometimes difficult to get certain skill personnel for a specific task					
It is difficult to keep permanently employed key site operatives for					
Sometimes, financial constraints make it difficult for some contractors					
Procurement officers purchase materials and components from suppliers					
Inappropriate use of construction materials in their right proportions is					
Adverse weather conditions sometimes make it difficult for concrete to					
Tests that ought to be done to ascertain the required needed strength					
Lack of proper planning of site operations often resulting in					

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					
Pre-testing of material strength is frequently done to achieve the					
Employees sometimes receive training related to their duty prior to the					
Full production test are usually done to ascertain the quality desired					
Frequent checking of material quality is always done					
Frequent monitoring of concreting processes using Shewhart control					
All records of testing are well kept for future references					
Baseline studies are conducted to ascertain practical limits to the					