ANALYSIS OF CHEMICAL ADMIXTURE USE ON THE QUALITY OF CONCRETE IN NAIROBI COUNTY, KENYA

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Analysis of Chemical Admixture use on the Quality of Concrete in Nairobi County, Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

This thesis is dedicated to my wife Francisca, children Karen, Serene and Reinard, parents and friends, who have been of great support. And to the Almighty God, for his guidance and grace throughout the entire study.

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LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BS	British Standard
$CaCl_2$	Calcium Chloride
Ca/g	Calorie per gram
C_3A	Tricalcium Aluminate
C_3S	Tricalcium Silicate
Ec	Modulus of Elasticity
Fc	Compressive Strength
HPC	High Performance Concrete
HRWR	High Range Water Reducing Chemical Admixtures
HSC	High Strength Concrete
NCA	National Construction Authority
MLS	Modified Lignosulphonate
MPA	Mega Pascal
MT	Metric Tonne
PCE	Polycarboxylates
SNF	Sulphonated Naphthalene Formaldehyde Condensate

SMF	Sulphonated Melamine Formaldehyde Condensate
SP	Super Plasticizer
SPSS	Statistical Package for Social Sciences
w/c	Water Cement Ratio
WRA	Water Reducing Admixture
QC	Quality Control

ABSTRACT

Quality of concrete has been the focus of key stakeholders in the construction industry of Kenya for quite a while now. The main question has been, 'what exactly leads to concrete failure' and has inspired inquiry into the (i) quality of the materials used; (ii) design mix adopted; (iii) methods of batching the materials; (iv) methods of handling and placing concrete; and (v) use of additives to add value. This study set out to establish whether chemical admixtures are being used in the construction industry of Kenya and whether they actually enhance the quality of concrete in the industry. The study adopted a mixed research strategy - incorporating qualitative and quantitative research approaches – and used a cross-sectional research design. A sample of 62 contractors from Nairobi County - registered under Category 1 of the NCA (National Construction Authority of Kenya) - were used for data collection in this research, which was done using a questionnaire. Both qualitative and quantitative data were collected. Descriptive analysis of the data was done on the quantitative data - using the Statistical Package for Social Sciences (SPSS for Windows) - while thematic analysis done on the qualitative data. The study established the use of accelerating, retarding, viscosity improving, air entrainment and waterproofing admixtures in Nairobi County. The study came to the conclusions that chemical admixtures are currently used in the construction industry of Kenya to improve the quality of concrete, and that use of the admixtures enhances construction project management in the industry. The study recommends formulation of legislation to guide use of the admixtures. This legislation should address the current challenge of counterfeit chemical admixtures and improve training of contractors in the application of the admixtures.

CHAPTER ONE

INTRODUCTION TO THE STUDY

1.1 Background to the Problem

This chapter presents the research problem and its setting. It begins by introducing the background to the problem that sets the stage for the explaining and laying out of the real problem under study. Later the chapter brings out the problem of the study through statement of the problem. The objectives of the study both general and specific are discussed followed by the research questions. The chapter also captures the scope of the study, limitations and justification of the study. Finally terms used in the study are discussed at the end.

The construction industry the world over depends on concrete as one of the major material to deliver huge and very important projects. The Kenya's vision 2030 seeks to address the rising needs of its population through infrastructure development. Reinforced concrete being the most commonly used construction material forms an integral part of this development strategy (Okumu et al., 2017). About 90-95 percent of the construction materials market for both structural and non-structural applications is made of concrete compared with other materials used for similar functions (Alsadey, 2015). Concrete as a material has evolved over the years from the conventional product that it was during its invention to counter its many weaknesses. More than 50 years ago (before the 1960s'), the concretes produced were mostly 1:2:4 and 1:1:2 nominal mixes with cube strengths of 15 to 25 MPa (Kwan et al., 2010). The water content was not specified, albeit the water/cement ratio was known to be the major factor governing the strength.

This Conventional Ordinary Portland Cement Concrete which was designed on the basis of compressive strength did not meet many functional requirements as it is found deficit in aggressive environments, time of construction, energy absorption capacity, repair and retrofit- ting jobs etc (Patel & Shah, 2013). This weakness led to poor concrete structures some of which fail and collapse and in most cases a lack of proper skill to utilise concrete in a more optimised and efficient way.

To counter this problem many work of research needed to be undertaken to come up with a solution. In the 1960s', plasticizers produced in the form of lignosulphonic acids emerged (Kwan et al., 2010). Later, in the 1970s', melamine- and naphthalene-based plasticizers were developed and most recently polycarboxylate-based SPs made of synthetic molecules. These superplasticizers acted by deflocculating the concrete mix and thoroughly dispersing the cement lumps which form during mixing thus freeing up any extra water in the mix. This in effect reduced the amount of water required to make the mix workable.

Some of the studies conducted across the globe and locally in Kenya to try and understand the effects of chemical admixtures in improving the quality of concrete are mentioned below. Alsadey (2015) in his study on the *Effect of Superplasticizer on Fresh and Hardened Properties of Concrete* and (Tamrakar & Mishra, 2013) on *Experimental Studies on Property of Concrete due to Different Ingredient based Super Plasticizer* concluded that the use of superplasticizer improves the compressive strength of concrete, increases workability and reduce slump loss. However, very high dosages of superplasticizer tend to impair the cohesiveness of concrete.

In Kenya (Cheruiyot et al., 2014) in the study of *Use of Stone Dust in the design of high performance concrete* concluded that the manufacture of High strength concrete (HPC) using locally available stone dust and two types of superplasticizer is possible with strengths of over 80 Kn/mm2.That it significantly reduces structural members (columns sizes, beam depths) which are limited to modulus of elasticity. There is also significant reduction in the total weight of reinforcement steel when high strength concrete is used. Also benefits accrued from letting extra space created from the smaller column sizes are significant for clients who have smaller development space and want to maximize it or for structure that have bigger floor spans.

1.2 Statement of the Problem

The use of chemical admixtures provides a shift in the production of high performance concrete that present enormous benefits to concrete users. The Construction Industry in Kenya seems to be rooted in the past in terms of the use of chemical admixtures to enhance the quality of concrete. Traditional concrete practices have been shown to be inefficient in material, labor and equipment usage, slow in project delivery, and the structures produced are of low strength and durability, resulting in high maintenance or early replacement costs (Koteng, 2013). Additional costs are incurred in interruptions to other services during lengthy construction. Traditional concrete practices therefore result in a slow pace of development and inefficient use of development funds.

There is no formal record on the current use of admixture in the industry. There is no policy for the use of admixtures in the industry despite the evidence of existence of these chemicals in the Country.

1.3 General Objective

To investigate the use of chemical admixtures to enhance quality of concrete in Nairobi, Kenya.

1.3.1 Specific Objectives

The specific objectives of the study are: -

1. To establish the type of chemical admixtures being used in concrete.
2. To establish the contribution of chemical admixtures in enhancing the efficiency of construction project management by impacting on quality.
3. To find out contractors' opinions and suggestions on the use and enhancement of admixture use in the construction industry of Kenya.

1.4 Research Questions

1. What are the types of chemical admixtures being used in concrete?
2. What are the contributions of chemical admixtures in enhancing the efficiency of construction project management?
3. What are the contractors' opinions and suggestions on improving usage of the admixture in the construction industry of Kenya?

1.5 Scope of the Research

The research area is Nairobi County in the republic of Kenya a country in sub-Saharan. Kenya is governed under two level of government the central which is the overall in charge of all resources and security and 47 counties for devolvement of resources to the grass root regions. This research will be conducted in Nairobi County. The study will focus on contractors registered under category one of National Construction Authority.

This study will cover the interview of Contractors registered under category one by the National Construction Authority. This group of contractors offers the highest service to the industry due to their experience and capacity (technical, financial and human resource). The study will focus on establishing the effect of chemical admixtures on quality of concrete. Other effects of chemical admixtures on cost and time will not be part of this study. Purposive sampling will be used to identify contractors within NCA 1 and interview them through questionnaires with both closed and opened questions. The theoretical scope for this study will cover concrete quality and admixtures and related studies across the world by other researchers.

1.6 Limitations

A few limitations constrained this study in one way or another. These limitations are as follows;

I. Selection of contractors was done using purposive sampling. This limits the findings of the study from being generalized for the entire population of contractors across the country.

II. Lack of prior research study on the topic. This limited the research design of the study and in effect hindered a thorough analysis of the results. This pave way for further research on this topic area to specifically target other groups such as ready mix concrete suppliers who might provide more data than the general population of contractors. Even though applications of admixtures have been greatly used in Japan, Europe and United States of America, little has been done here in Kenya (Cheruiyot et al., 2014).

1.7 Justification of the Study

The study has chosen to look keenly into concrete and admixtures because of the new demand for concrete necessitated by the volume of concrete poured and complexity in mixing, placing and pouring the same. These are explained below.

Challenges experienced in the construction of buildings and infrastructural projects is the logistical nightmare of working in the central business district and high build areas like Upperhill and Westlands. These are areas where a contactor cannot store sand, ballast and cement and be able to concrete on site due to lack of space, noise generated in mixing and the pollution to adjacent occupied buildings. Such negligence by law is an offence under tort and the contractor and the client might be sued. This brings about the mixing of concrete offsite and transportation of the same either during the day or at night. In some cases where the contractor does not have the capacity, the purchase of concrete from ready mix concrete suppliers.

The same build up areas lead to the adoption of advance techniques like pumping of concrete to the highest levels of tall buildings which is now the order of the day. This reduces the number of workers needed in any given work site and complement well with concrete delivery from far locations. The same can be delivered by a crane which can also be costly and space restricted. Thus all concrete which requires pumping must be dosed with admixtures to achieve a very high slump with good viscosity.

Further to this discourse, the ever increasing scope of work in any given development has increased the volume of concrete in any given day pour to unprecedented amount.

The daily concrete production goal for a medium-sized contractor in East Africa is to pour between twenty and fifty cubic meters of concrete, using portable 125-liter mixers. The resulting 160 to 400 mix loads are hauled in wheelbarrows and poured into moulds (Figueroa, 2014). A standard mix used in Kenya, yielding concrete with f_c of 25 megapascals [MPa], requires 400 kilograms of cement. Therefore, on a typical construction site, builders use between 160 and 400 bags of cement per day, each of which weighs 50kg. It is challenging to ensure quality when the process is so cumbersome and physically taxing (Figure 1.0). This suggests that any pour more than 25 cubic metre and with a strict quality control process might require a different approach. This may call for purchase of concrete or mixing offsite or both to beat the volume challenge, quality and management of the project.

Figure 1.1: Mixing Structural Concrete in Nairobi (Figueroa, 2014).

The study has been undertaken in Nairobi due to its large concentration of contractors. Indeed from the list of NCA 1 contractors, we find 86% of these contractors belonging to Nairobi.

1.8 Significance of the Study

In view of the challenges facing concrete buildings in Kenya, it is important to identify the role of chemical admixtures in improving concrete quality in Kenya. This will alleviate the many losses of lives and wastage of public and private resources that go down the drain once the buildings come down.

This study is important to the field of social sciences as it will identify the gap in Literature that needs to be filled. More importantly will be the basis for future studies that will investigate chemical admixtures and quality of concrete in a different perspective but guided by the outcome of this study.

The beneficiary of this study will be the consultants involved in the design and specification of materials in construction industry, the contractors and the government of Kenya through the National construction Authority and the County Council of Nairobi.

1.9 Definition of Terms

Additive*:* a substance added to another in relatively small amounts to impart or improve desirable properties or suppress undesirable properties (ACI, 2013).

Admixture: a material other than water, aggregates, cementitious materials, and fiber reinforcement, used as an ingredient of a cementitious mixture to modify its freshly mixed, setting, or hardened properties and that is added to the batch before or during its mixing (ACI, 2013).

Chemical admixture*:* Admixtures are materials other than cement, aggregate and water that are added to concrete either before or during its mixing to alter its properties, such as workability, curing temperature range, set time or colour (Jorjani& Hojjati, 2013).

Concrete: mixture of hydraulic cement, aggregates, and water, with or without admixtures, fibres, or other cementitious materials (ACI, 2013)

Construction: A process that consists of the clearing, dredging, excavating, and grading of land and other activity associated with buildings, structures, or other types of real property such as bridges, dams, roads(G.O.K., 2011).

Concrete Mix design: the proportions of ingredients that make the most economical use of available materials to produce mortar or concrete of the required properties (ACI, 2013).

Substandard construction: construction deviating from or falling short of a standard or norm.

Poor workmanship: The work and skill of a workman that is poor.

Workability: that property of freshly mixed concrete or mortar that determines the ease with which it can be mixed, placed, consolidated, and finished to a homogenous condition (ACI, 2013).

1.10 Outline of the Study

Chapter one is the introduction to the research problem. The chapter discusses briefly the background to the problem that which is the concrete and chemical admixtures in the world and in Kenya. What is the problem of the study and the aim and objectives to be met? Research questions have been formulated that will be answered by the study at the end. The scope of the study in terms of geographical location and the methodological scope have been explained. The limitations of the study and justification have been covered. This is followed by the significance of the study and finally definition of keys terms that appears in the study.

Chapter two explores the literature related to the study by other authors. It describes the history of concrete and the emergence of high strength and high performance concrete. To bring concrete into perspective, the study discusses the cement and its various types and where and when they can be used. It also discusses the properties of fresh concrete that influence its quality and performance. The mixing, handling, placing and compacting of concrete is discussed. Chemical admixtures which form the basis of this study are explored with six admixtures being explained; accelerating, retarding, water reducing, viscosity improving, waterproofing and air-entrainment. The mechanism of chemical admixture action of water reducing has been explained which affects most of the fresh properties of concrete like workability, segregation and bleeding. The theoretical and conceptual frameworks. The gap in the literature is identified at the end of the review.

Chapter three lays down the methodology used in the study. The research design, population, data collection, pilot study, data analysis and presentation are also discussed in this chapter.

Chapter four is on data presentation, analysis and discussions. It present analysis of the data collected and the results observed from the analysed data. Discussion of the results is also presented.

Chapter five gives the findings of the study, conclusions and recommendations. The contribution to knowledge by this study is also highlighted and the research gap identified.

CHAPTER TWO

LITERATUREREVIEW

2.1 Introduction

In chapter one the problem and its setting were presented. In this chapter 2, the review of the literature related to concrete and its chemical admixtures is presented. The chapter is organised into five major section mainly; the nature of concrete; laying of concrete; chemical admixture; influence of concrete quality on construction project management. Finally the theoretical and conceptual frameworks in the study are highlighted.

2.2 History of concrete

Building structures in Kenya are mainly made of two important materials; Cement and Steel of which Concrete is used more than any other man made material on this planet. Concrete has been defined as a composite material that consists essentially of a binding medium within which are embedded particles or fragments of aggregate, usually a combination of fine aggregate and coarse aggregate (ACI as cited in Koteng, 2013). Each of these components contribute to the strength that concrete possesses (Gambhir, 2004). Even though the Romans used concrete extensively and various lime-based binders were developed in the 18th century, culminating in the first patent for Portland cement in 1824, it was the work of Abrams in the 1920s that set down some basic principles of the technology of concrete, in the sense of an appropriately proportioned mixture of cement, sand, gravel or crushed rock, and water (Banfill, 2006). He established the eponymous rule that the strength of hardened concrete is inversely proportional to the water/cement ratio, thus showing that the higher water contents needed to give more easily workable concrete had a negative effect on strength. This is a result of the pore space left behind by the consumption of water during hydration of the cement: the higher the water content the higher the porosity and the lower the strength.

2.3 High Strength Concrete

Concrete in the broadest sense, is any product or mass made by the use of a cementing medium. Concrete is a mixture of hydraulic cement, aggregates, and water, with or without admixtures, fibres, or other cementitious materials (ACI, 2013). It is made with several types of cement and also containing pozzolana, fly ash, blast-furnace slag, micro-silica, additives, recycled concrete aggregate, admixtures, polymers, fibres, and so on.

There exist many types of concrete which have been developed for special purposes. In general, the cement-based matrix is modified in some way so as to improve particular properties (Neville and Brooks, 2010). Some of these type of concrete are very recent additions to the concrete scene.When the compressive strength of concrete is higher than 50 mega pascal (MPa), it is usually defined as High Strength Concrete (HSC) (Xiao & Jianzhuang, 2004). At the very beginning, reducing the water-cement ratio was the easiest way to reach high compressive strength. Therefore, in HSC, the fifth ingredient, a water reducing agent or super plasticizer, is inevitable. However, sometimes the compressive strength is not considered as important and necessary as some other properties, such as low permeability, durability and excellent workability. Thus, high performance concrete (HPC) was proposed and widely studied at the end of the last century.

The use of High-Strength Concrete (HSC) has become more commonplace in the building and transportation industry in the United States (US) because of its beneficial economical and material properties (Myers & Carrasquillo, 1998). HSC is advantageous since it reduces material requirements in axial or flexural members, permits longer member spans and allows for increased member spacing; thereby reducing material and total project costs.

2.4 High Performance Concrete

Concrete mix design is normally carried out to meet the compressive strength of concrete required based on the structural design. This concrete usually focuses on the compressive strength as the key requirement. Concrete which is designed on the basis of compressive strength does not meet many functional requirements as it is found deficit in aggressive environments, time of construction, energy absorption capacity, repair and retrofitting jobs etc. (Patel & Shah, 2013). So, there is a need to design High Performance Concrete which is far superior to conventional concrete as the Ingredients of High Performance Concrete contribute most efficiently to the various properties required. The strategic Highway Research Programme (SHRP) has defined a High Performance Concrete (HPC) as concrete meeting one of the following requirements (Patel & Shah, 2013):

1) 4 hours compressive strength ≥17.5 N/mm2;

2) 24 hours compressive strength ≥35 N/mm2;

3) 28 days compressive strength ≥70 N/mm2;

4) Water cement ratio ≤0.35;

5) Durability factor >80 after 300 cycles of freezing and thawing.

The definition of HPC has changed significantly over the years, and a consensus has not yet been reached as to its definition. According to Zia, Leming & Ahmad, (1991) HPC can be defined as any concrete that satisfies the criteria proposed to overcome limitations of conventional concretes. In many cases, the enhanced property of an HPC is strength, although this may not always be the case. In some situations the enhanced property may be elastic modulus, flexural strength, tensile strength, durability (permeability, freeze-thaw resistance, abrasion resistance, or scaling deicing resistance) constructability, or economics.

2.4 Other Properties of Fresh Concrete

Fresh concrete is a transient material with continuously changing properties. It is, however, essential that these are such that the concrete can be handled, transported, placed, compacted and finished to form a homogenous, usually void-free, solid mass that realizes the full potential hardened properties (Domone, 2003).

2.4.1 Workability

Most projects desire a concrete that is easy to handle and place. This might be through hand placing by wheelbarrows, using a bucket lifted by a crane or pumped to the structure directly. This brings about a most important desire of concrete by all builders known as workability. Workability is that property of freshly mixed concrete or mortar which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished (ACI, 1990). Neville, (2010) define workability as the amount of useful internal work necessary to produce full compaction. This property of concrete determines the volume that can be handle and the method of mixing, transportation and placing.

Figueroa, (2014) showed in figure 2.1 that the strength of concrete increases with the increase in density. Increase in density arises due to a good workable concrete that leads to a reduced amount of voids. Voids appear in concrete as bubbles of entrapped air spaces left after excess water has been expelled. The volume of this water is determined by the amount of water used as a consequence of the prescribed water cement ratio for the project. Voids also arise due to the grading of fine particles in the mix and by the fact that the bubbles are more easily expelled from a wetter mix than a dry one. To conclude, Neville (2010) says that for any given method of compaction which is affected by workability there may be an optimum water content of the mix at which the sum of volumes of air bubbles and of water space will be a minimum, and density will be a maximum.

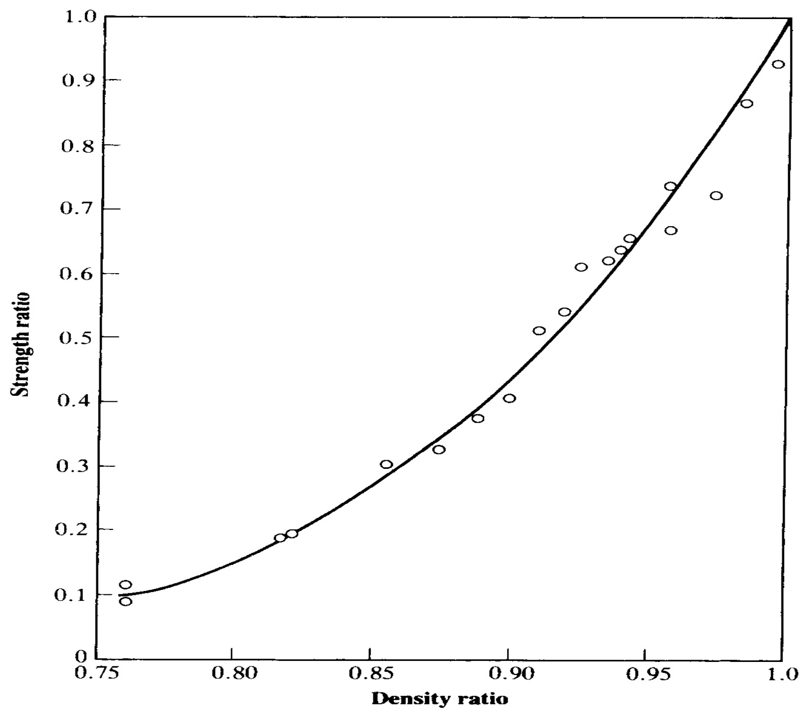


Figure 2.1: Relationship between strength ratio and density ratio. Source: Figueroa, 2014.

2.4.2 Segregation

In view of the above discussion, we note that compaction of concrete which leads to a dense mass of concrete results into high strength. In order for concrete to be well compacted, there must be cohesiveness of the material used without which the material separate or segregate. Segregation can be defined as a separation of the constituents of a heterogeneous mixture so that their distribution is no longer uniform (Neville, 2010). Segregation mainly occurs due largely because of how concrete is constituted, mixed and placed. In the fresh state, a judicious combination of portland cement (PC) and siliceous mineral admixtures, together with appropriate chemical admixtures, can enhance flowability, and pumping qualities, and reduce segregation, bleeding and the tendency for autogenous and plastic shrinkage (Swamy, 2008). On the other hand dropping concrete from a considerable height, passing along a chute particularly with changes of direction and discharging against an obstacle, all encourage segregation so that under such circumstance a particularly cohesive mix should be used. Many sites in Kenya employ the method of lifting concrete to higher floor levels by throwing them from one platform to the next until it reached the top (Figure 2.2). With the demand of high rise building and other projects such as dams, it becomes important for concrete to achieve a good cohesiveness that can allow for easy placement.

Figure 2.2: Platform prepared for placing concrete in the first floor of a building in Kenya Source: Field work, 2016.

2.4.3 Bleeding

Bleed water is the clear water that can gradually accumulate at the surface of freshly placed concrete, mortar, grout, or paste. Bleed water is caused by sedimentation or settlement of solid particles (cement and any aggregate) and the simultaneous upward migration of water. This upward migration of water and its accumulation at the surface is called bleeding, also referred to as water gain, weeping, and sweating in some countries (Kosmatka, 1999). A small amount of bleeding is normal and expected on freshly placed concrete. It does not necessarily have an adverse effect on the quality of the plastic or hardened concrete. However, excessive bleeding can lead to some performance problems with plastic or hardened concrete. With proper mix proportioning, mixture ingredients, placing equipment, and proper construction practices, bleeding can be controlled to a desirable level. Ramachandra (1984) states that water reducers and retarders affect the rate and capacity of fresh concrete to bleed and settle under the influence of gravity. He states that lignosulphate and particularly glucose reduce the rate and capacity of bleeding. Conversely Sodium gluconate increases the capacity for bleeding even though the mixing water is reduced.

2.5 Mixing, Handling, Placing and Compaction of Concrete

2.5.1 Mixing and Mix Design

Every development has a particular concrete strength requirement for the size of the structure, the anticipated load from use be it a school, a residential apartment or a car park and lastly the desired size of structural components. The required properties of hardened concrete are specified by the designer of the structure and the properties of fresh concrete are governed by the type of construction and by the techniques of placing and transportation (Neville & Brooks, 2010). Other types of concrete require protection from adverse environmental contaminants such as underground water with salts of chloride or sulphates. Economic reasons also determine the type of concrete to be used. All these factors will ensure that concrete has to be designed for every other structure to meets its particular requirement.

Mix design can therefore be defined as the process of selecting suitable ingredients of concrete and determine their relative quantities with the purpose of producing an economical concrete which has certain minimum properties, notably workability, strength and durability (Neville & Brooks, 2010). Poorly constituted concrete will therefore lead to quality challenges such as segregation, bleeding, lack of enough strength, poor finishes and might lead to collapse of the structure.

2.5.2 Handling

Concrete are very dynamic properties and must be handled carefully from design to final compaction in order to achieve the planned quality. This means that even a good concrete mix that is poorly handled can lead to quality failure.Neville and Brooks (2010) notes several methods of handling concrete which depends on economical consideration and quantity of concrete to be transported. There are several possibilities ranging from wheelbarrows, buckets, skips and belt conveyors to special trucks and pumping.

2.5.3 Placing and Compaction

This is a very important part of concrete work since it can lead to serious challenges if it is done poorly. The methods chosen for placing and compacting the concrete will depend on the type of construction, the total volume to be placed, the required rate of placing and the preferences and expertise of the construction companies involved (Newman & Choo, 2003).There are several rules that have been suggested in handling concrete.

1. Hand shoveling and moving concrete by immersion or poker vibrators should be avoided.
2. Concrete should be placed in uniform layers not in large heaps or sloping layers.
3. Thickness of the layer should be compatible with the method of vibration so that entrapped air can be removed from the bottom of each layer.
4. The rate of placing and compaction should be equal.
5. Concrete to be filled to formwork at a rate of 2m per hour to avoid formation of cold joints.
6. Each layer to be fully compacted before placing the next one and subsequently layer should be placed whilst the underlying layer is still plastic so that monolithic construction is achieved.
7. Collision between concrete and formwork should be avoided. For deep section, a long down pipe or tremie ensures accuracy of location of concrete and minimum segregation.
8. Concrete should be placed in a vertical plane.

2.6 Portland Cement

2.6.1 Ordinary Portland Cement (Type I)

Type I Portland cement is general purpose cement suitable for all uses where the special properties of other types of cements are not required (AST C150, 2007). It is used where cement or concrete is not subject to specific exposures, such as sulfate attack from soil or water, or to an objectionable temperature rise due to heat generated by hydration. Its uses include pavements and sidewalks, reinforced concrete buildings, bridges, railway structures, tanks, reservoirs, culverts, sewers, water pipes and masonry units. Savanah Cement 42.5R, Rhino RX4 and RX5 conform to this category and Kenyan Standard KS EAS.18-1 (Savanah Cement, 2017; Athi River Mining Cement, 2017).

2.6.2 Type II Portland Cement

Type II portland cement is used where precaution against moderate sulfate attack is important, as in drainage structures where sulfate concentrations in ground water are higher than normal but not unusually severe (Table 1). Type II cement will usually generate less heat at a slower rate than Type I (Taylor, 1997). With this moderate heat of hydration (an optional requirement), Type II cement can be used in structures of considerable mass, such as large piers, heavy abutments, and heavy retaining walls. Its use will reduce temperature rise especially important when the concrete is placed in warm weather. In Kenya, Mombasa Portland Pozzolanic Cement (Nyumba) corresponds to ASTM Type CEM II cement and meets the requirements of East African Standard KS EAS.18-1 and ISO 9001: 2000 Quality Management System (Mombasa Cement, 2017). Rhino cement RX3, RX4 and RXS all belong to this category (ARM, 2017). These types of cement commonly used in the Kenyan market are compatible to chemical admixtures. In was concluded in *The Effect of Retarding Chemical Superplasticizers on the Setting Time of Cement Pastes in Kenya: A Case Study of Ready Mix Concrete in Nairobi* that Mombasa PPC a type II cement is compatible with Master Rheobuild RMC 80 and sika viscrocrete 10 all superplasticizers (Katimi, 2016).

2.6.3 Type III Rapid Hardening Cement

Type III is a high-early strength portland cement that provides high strengths at an early period, usually a week or less. It is used when forms are to be removed as soon as possible, or when the structure must be put into service quickly. In cold weather, its use permits a reduction in the controlled curing period. It is chemically and physically similar to Type I cement, except that the cement particles in Type III have been ground finer than in Type I and additional calcium sulfate is usually added to control setting time (Tonyan, 2010). The sole reason for using this type of cement is when formwork needs to be removed earlier for re-use or when early strength gain will be required for immediate continuity of construction. The cost of type III cement is marginally higher than that of Type I.

2.6.4 Type IV Low Heat Portland Cement

Type IV is a low heat of hydration cement for use where the rate and amount of heat generated must be minimized. It develops strength at a slower rate than Type I cement. Type IV portland cement is intended for use in massive concrete structures, such as large gravity dams, where the temperature rise resulting from heat generated during curing is a critical factor. This cement was developed in the USA purposely to construct dams where mass pour is required thus the need to control the heat of hydration during setting. According to Neville, (2010) both ASTM C 150-05 and BS 1370:1979 limit the heat of hydration to 250 J/g (60cal/g) at the age of 7 days and 290 J/g (70 cal/g) at 28 days. Bamburi Portland Pozzolanic Cement (Nguvu) and Blue Triangle Portland Pozzolanic cement falls intothis category and meets the physical and chemical requirements of East African Standard KS EAS.18-1 (Lafarge Kenya, as cited in Katimi, 2016). Lastly Katimi (2016) confirmed in *The Effect of Retarding Chemical Superplasticizers on the Setting Time of Cement Pastes in Kenya: A Case Study of Ready Mix Concrete in Nairobi* that Bamburi and Blue Triangle PPC all type IV cement are compatible with Master Rheobuild RMC 80 and sika viscrocrete 10 all superplasticizers (Katimi, 2016).

2.6.5 Type V Cement

Cement is also used in areas of extreme conditions such as sulfate concentration. This has a potential to chemically react with cement to break it down. Type V is a sulfate-resisting cement used only in concrete exposed to severe sulfate action principally where soils or ground waters have a high sulfate content (Taylor, 1997). Table 2.1 describes sulfate concentrations requiring the use of Type V portland cement. Low Tricalcium Aluminate (C_3A) content, generally 5% or less, is required when high sulfate resistance is needed.

Table 2.1: Type of cement use against various sulfate concentration (Taylor, 1997).

Relative Degree of Sulfate Attack	Percentage Water-Soluble Sulfate (as SO4) in Soil Samples	Sulfate (as SO4) in Water Samples, Ppm	Cement Type
Negligible	0.00 to 0.10	0 to 150	I
Positive	0.10 to 0.20	150 to 1,500	II
Severe	0.20 to 2.00	1,500 to 10,000	V*
Very Severe	2.00 or more	10,000 or more	V plus pozzolan**

* Or approved portland-pozzolan cement providing comparable sulfate resistance when used in concrete.

** Should be approved pozzolan that has been determined by tests to improve sulfate resistance when used in concrete with Type V cement.

2.7 Chemical Admixture

An admixture is defined in ASTM C125 as a material other than water, aggregates, hydraulic cement and fiber reinforcement that is used as an ingredient of concrete or mortar and is added to the batch immediately before or during its mixing. Admixtures interact chemically with the ingredients of the concrete and affect its performance in the fresh and hardened state (Collepardi, 2005). They confer special beneficial effects to concrete. They can enhance workability of the fresh mixture, and strength or durability of the hardened concrete. Depending on the enhanced property, chemical admixtures can be classified as water reducers, superplasticizers, accelerators, retarders, air-entraining agents, corrosion inhibitors, alkali-aggregate expansion inhibitors, shrinkage reducing admixtures, etc. This study will discuss a few due based on their availability in the market which acts as a pointer to their current requirement by the industry.

2.7.1 Classification of Chemical Admixtures

2.7.1. 1 Accelerating Admixtures

These are the kind of admixtures that are used to fast track the setting of cement paste in concrete to bring about certain desired effects required by a specific project. Accelerators primarily comprise of inorganic materials and can be subdivided into two general categories based on their desired application. Hardening accelerators which are used to achieve a higher initial strength will usually achieve strength greater than 120 percent at 24 hours compared to an equivalent concrete without the accelerator added (UK Cement Admixtures Association, 2006). The second type of accelerators is set accelerating admixtures. These set accelerating admixtures reduce the time for the mix to transform from the plastic to the hardened state. Generally an admixture will fulfil only one of the two primary categories. These admixtures are used for concrete repair mix designs and in prestressed or precast applications, where time delays cost customers or precasters significant amounts of money and inconvenience.

Calcium chloride – due to its many advantages in increasing the basic strength rate and reducing the setting time – has been of significance as the most commonly used setting accelerators (Chan et al, 1999). In recent years, due to the recognition of the effect of the presence of chloride ions in reinforced concrete on the corrosion of re-bars, other non-chloride accelerators (with calcium formate, calcium nitrite, calcium nitrate, sodium or calcium thiocianate or tri-ethanol amine basis) which did not create corrosion problems became widely used. However, acceleration without the risk of corrosion can be achieved by the use of very rapid hardening cement or of chloride free admixtures. Most of the latter are based on calcium formate, which although being slightly acidic accelerates the hydration of cement. Calcium formate sometimes combines with some materials like sodium nitrite so as to enhance the development of basic strength (Chan et al., 1999). He further states that the performance of this additive significantly depends on the type of cement used (due to the effect of SO3 existing in cement for the material's performance). Studies show that C3A to SO3 ratio must be larger than 4 so that calcium formate acts as an effective accelerator.

The effects of accelerators on hardened concrete are as important as they are for the fresh mix. Benefits of their use include accelerated strength development in both compression and in flexural modes, although less so in the latter. Modulus of elasticity, too, increases at a faster rate. Abrasion resistance and erosion resistance are improved with the use of accelerating admixtures, as is pore structure, due to reduced porosity. Frost resistance in concrete is better at early ages when calcium chloride accelerators are used, but performance declines with time, and resistance is actually worse at later ages.

2.7.1.2 Retarding Admixtures

Retarding admixtures are used to slow down the initial set of concrete by the users so as to allow for the concrete to be transported or placed either by pumping or cranes a process which might take time. This eliminates the risk of the concrete setting prematurely on the concrete truck, mixer, buckets or pump line. The slow setting of concrete also becomes important in high temperatures by avoiding thermal cracking due to heat of hydration when setting rapidly. Retarders are specified in ASTM C 494 as Type B admixtures and are used in varying proportions, often in combination with other admixtures, so that, as working temperatures increase, higher doses of the admixture may be used to obtain a uniform setting time (ACI 305R, 1999).

Simple retarders typically consist of one of four relatively inexpensive materials: lignin, borax, sugars, or tartaric acids or salts. Retarders serve best to compensate for unwanted accelerations of working times due to changes in temperature or cement or due to other admixture side effects. They also are used to extend the working time required for complicated or high-volume placements and for retarding the set of concrete at a surface where an exposed aggregate finish is desired. Retarding admixtures interfere with the critical chemical reactions of the fastest hydrating cement reactant groups, (Tricalcium aluminate) C_3A and (Tricalcium silicate) C_3S (Collepardi, 1984). These reactants normally initiate the hydration process in the early stages. Retarders create a thin film over cement particles (by reacting with C3A and C3S compounds existing in cement) and so prevent from or reduce their reaction with water (Jorjani & Hojjati, 2013). The thickness of the thin film determines to which extent the hydration rate is reduced. After a while, the film is removed and hydration begins. Eventually, the hydration process accelerates due to another initially slower reaction group, and the heat of reaction allows the hydration to continue at a normal rate until completion.

2.7.1.3 Air-Entrainment Admixture

These are a class of admixtures used to safe guard concrete from the effect of freezing and thawing. These chemicals produce small bubbles in the range of 0.05mm to 1.25mm in diameter (Chan et al., 1999). Because air-entraining agents provide extremely small and well-dispersed air bubbles in the paste, they act as localized stress reducers in the cured matrix (Whitney, 2008). These bubbles fill the capillary pores of concrete and discontinue the moving action of water into the pores. This in effect reduces the amount of water that can lead to destruction during freezing and thawing conditions.

2.7.1.4 Waterproofing Admixtures

Many buildings incorporate basement floors for parking which are mostly below ground with high water table. Other structures are also constructed under water such as bridges, ports and jetties. All these structures require concrete that is either insulated from water ingress or highly impermeable to water. Concrete absorbs water because surface tension in capillary pores in the hydrated cement paste absorbs water by capillary suction. Waterproofing admixtures aim at preventing this penetration of water into concrete (Neville & Brooks, 2010). One action of waterproofing admixtures is through reaction with the calcium hydroxide in hydrated cement paste; examples of products used are stearic acid and some vegetable and animal fats. The effect is to make the concrete hydrophobic. Another action of waterproofing admixtures is through coalescence on contact with the hydrated cement paste which, because of its alkalinity, breaks down the 'waterproofing' emulsion; an example is an emulsion of very finely divided wax. The effect here, too, is to make the concrete hydrophobic. The third type of waterproofing admixture is in the form of very fine material containing calcium stearate or some hydrocarbon resins or coal tar pitches which produce hydrophobic surfaces. While imparting hydrophobic properties to concrete is valuable, in practice, complete coating of all surfaces of capillary pores is difficult to attain, with the consequence that full waterproofing is unlikely to be achieved. Some waterproofing admixtures, in addition to their hydrophobic action, also effect pore blocking through a coalescent component.

An experimental research was done in Singapore, Hong Kong and China which achieved the following results on the beneficial properties of waterproofing admixture; (1) Significant reduction in water permeability and water absorption at the same water-to-cementitious ratio as the control; (2) Significant reduction in drying shrinkage that corresponds to improved resistance to cracking under drying conditions; (3) Reductions in water absorption, shrinkage, and water permeability were observed with typical OPC, fly ash or GGBFS concretes. (4) No adverse effect to concrete's air content and setting time; (5) Highly dosage-effective and show good compressive strength development. (Zhang et al, 2008). The waterproofing admixture used was (Adprufe® 100 and Adprufe AP1 and AP3 – produced by Grace Waterproofing Company) based upon a glycol ether shrinkage reducing admixture (SRA) and additional hydrophobic elements providing enhanced hydrophobic action.

2.7.1.5 Viscosity Improving Admixture

Pumping of concrete and placing in very congested areas of steel reinforcement has necessitated the need to provide concrete with special ability. Viscosity-modifying admixtures (VMAs) also called anti-washout admixtures (AWAs) are often used in mix-design of highly fluid cementitious materials, including self-compacting concretes (SCCs), pumpable concretes, etc. to avoid solid-liquid separation and to improve the robustness of the formulation (Bouras, Chaouche & Kaci, 2008). Viscosity modifying admixtures are sometimes used to produce self-leveling concrete or self-consolidating concrete (SCC), which is used wherever extreme congestion due to reinforcement configurations or unusual geometry of the forms requires a very fluid, cohesive concrete that resists bleeding and segregation (Khayat, 1996). That is the primary objective when using these admixtures. However, one can expect some influence on the rheological behaviour since addition of VMA will change the rheology of the aqueous phase and the interactions between the solid particles

Like any other product, this admixture has a negative side effect to concrete which needs to be noted. Disadvantages of anti-washout or viscosity-enhancing admixtures include the typical reductions in strength and modulus of elasticity (Whitney, 2008). Set time, cure time, shrinkage, and creep are not significantly affected by the presence of AWAs themselves but may be influenced by the addition of higher levels of High range water reducing admixtures (HRWR) associated with the use of AWAs. In most cases most admixtures will be combined with others in order to bring out their full potential.

2.7.1.6 Water Reducing Admixtures

There are many types of water reducing admixtures which are according to ASTM C494 are classified into categories based on their function in concrete in line with water reducing ability (Sun, 2008). These are; regular water reducing admixture that reduce water up to 5 to 10%; midrange water reducing admixture and superplasticizers (SPs) that reduces water between 15 to 30%. Refer table 2.2 below.

(a) Regular Water Reducing Admixtures (WRA)

Water reducing admixtures are made of different materials based on their evolution. The main compounds used in the manufacture of water reducing admixtures can be divided into four groups, namely, lignosulphonate, hydroxyl carboxylic acids and their salts, carbohydrates and other compounds (Ramachandran, 1995). These compounds have different water reducing effects on concrete.

Table2.2: Types of water reducing admixtures (ASTM C494)

Classification	Common Name	Typical Dosage	Increase In slump, mm	Water reduction		ASTM Specification
				%	w/c	
Low-Range	Regular	0.1	50~80	5-10	-0.05	C494
Mid-Range	Mid-range	0.5	50~100	10-15	-0.10	
High-Range	Superplasticizer	0.1	>100	15-30	-0.15	C494, C1017
Active ingredient by weight of cement i.e. solid weight by cement (swbc)						

Since 1930s, water reducing admixtures (plasticizers) and their properties were discovered in concrete and before the spread of these materials, it was possible to change concrete efficiency only by changing the amount of water and the ratio of water to cement (Jorjani& Hojjati, 2013).

(b) High Range water reducing admixture/Superplasticizers

High-range water reducers (HRWRs) are also known as superplasticizers, super fluidizers, and super water reducers due to their higher efficiency than conventional WRAs in improving workability and flow of concrete mixes. Superplasticizers are a water-reducing admixture that causes a significant increase in flowability with little effect on viscosity (Khayat & Assaad, 1999). In late 1960s, products based on naphthalene sulfonates were developed in Japan, and concurrently the melamine sulfonate products were introduced in West Germany (Mehta, 1999).

The continual use of water reducing admixtures led to the desire for better performance of concrete. This means more solutions were tried with different results. Thus in the early 1960's, high-range water reducers or superplasticizers were developed and introduced into the concrete technology market (Tamrakar and Mishra, 2013). There are several types of superplasticizers in the market notably First generation consisting of Modified Lignosulphonate (MLS), Second generation consisting of Sulphonated Melamine/ Napthalene formaldehyde Condensates and third generation consisting of Polycarboxylate based (PCE).In Kenya, Master Rheobuild RMC 80 (Formerly Rheobuild LD 80) which is a new product in the Kenyan market is a high range, high performance and water reducing agent based on high molecular weight polymers and refined lignosulphonates and produced by Master Builders. On the other hand, Sika Viscocrete10 which has been used in Kenya for over a decade is a third generation high performance superplasticizer based on modified polycarboxylate polymer and all conforms to the requirements of EN 934-2, and ASTM C-494 (Katimi, 2016).

(c) Benefits

In the fresh state, utilization of superplasticizer will normally reduce tendency to bleeding due to the reduction in water/ cement ratio or water content of concrete. However, if water/ cement ratio is maintained, there is tendency that superplasticizer will prolong the time of set of concrete as more water is available after deflocculation. Since addition of SP will provide more water for concrete mixing, not only the hydration process will not be disturbed, but, it is accelerated by the additional water from deflocculation of cement particles (Alsadey, 2012).

2.8 Mechanism of Water Reduction

When cement in the concrete mix react with water, it tends to flocculate and thus requiring more water to make the mix workable (Figure 2.3a). This result in the need for more water for the mix which evaporates later and leave behind pores. This kind of concrete becomes less durable, susceptible to water ingress and of less strength.

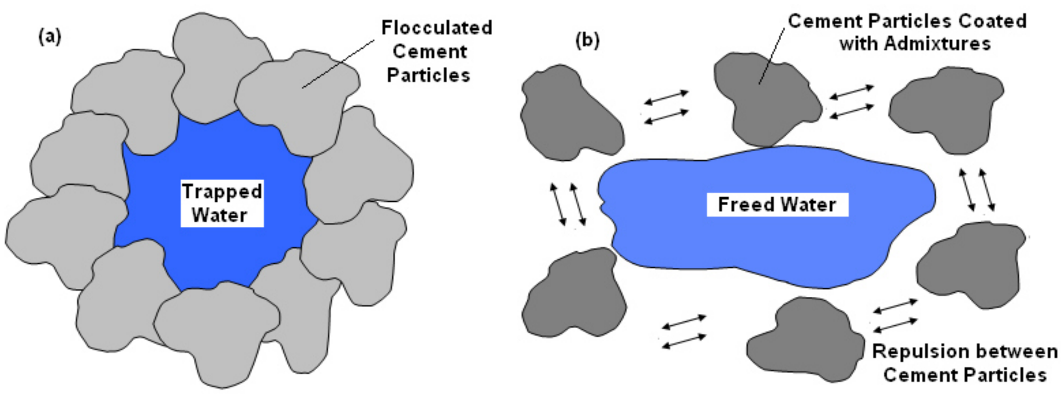


Figure 2.3: (a) Flocculation of cement particles resulting in trapped water (b) Deflocculation of cement particles upon adsorption of water reducing admixtures. Source: Law, 2004.

a). Electrostatics Repulsion

In normal concrete, cement in the mix agglomerate and forms lumps. The electrostatic attractive forces, existing among cement particles and causing agglomeration, would be neutralized by the adsorption of anionic polymers negatively charged, such as Sulphonated Naphthalene Formaldehyde Condensate (SNF) or Sulphonated Melamine Formaldehyde Condensate SMF, for the presence of SO_3 - groups on the surface of cement particles (Collepardi, 2005). The dispersion of cement particles would be related with the electrical repulsion produced by the negatively charged groups (SO_3 -) on the other side of the main polymer chain (Figure 2.3 b).

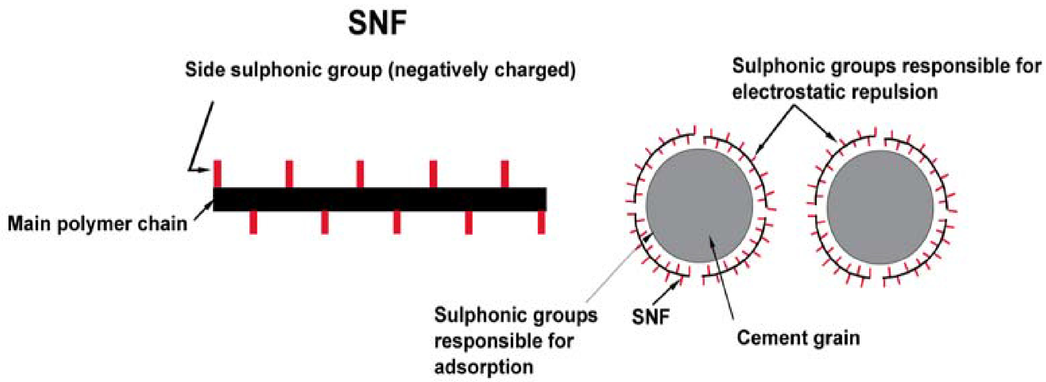


Figure 2.4: Schematic picture of sulfonated polymer (SNF) and its electrostatic repulsion effect on the dispersion of cement particles. Source: Collepardi, 2005.

(b) Steric Hindrance

Another proposition on the mechanism of dispersion of cement paste by admixtures involves the long chain negative charges carried by carboxyl group of the admixture molecule. The dispersion mechanism performed by the Poly Carboxly-based superplasticizers could be related more to a steric hindrance effect (produced by the presence of neutral side long graft chains) rather than to the presence of negatively charged anionic groups (COO-) which are responsible for the adsorption of the polymers on the surface of cement particles (Collepardi, 2005). Refer to figure 2.4.and 2.5. This explains the thorough dispersion of cement paste thus freeing trapped water and enhances the flowability of concrete due to increase cement particle interaction with aggregates and water.

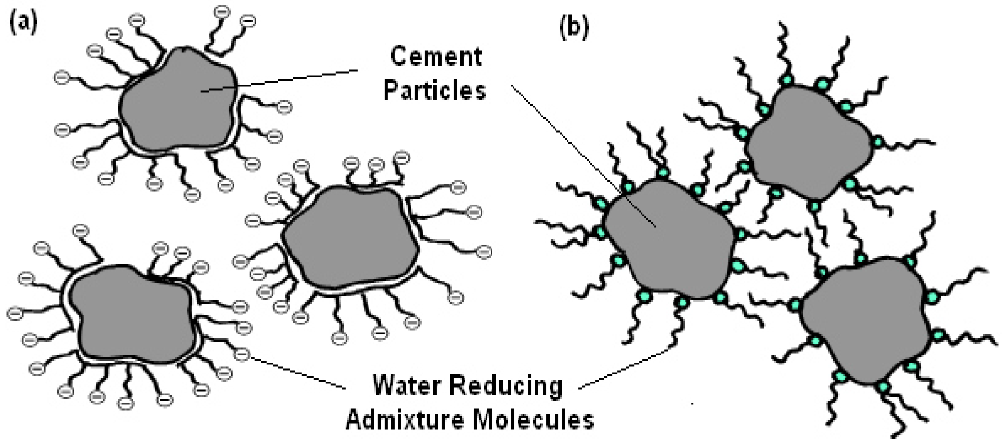


Figure 2.5: Repulsion of cement particles by (a) electrostatic repulsion (b) steric hindrance. Source: Ramachandran, 1998.

2.9 Admixtures found in Kenya Construction Industry

2.9.1 Superplasticizers

A few chemical admixtures have been identified in the course of the study. Master Rheobuild RMC 80 (Formerly Rheobuild LD 80). This is a high range, high performance and water reducing agent based on high molecular weight polymers and refined lignosulphonates and produced by Master Builders Inc (Katimi, 2016). It meets the requirements of EN 934-2, Master Rheobuild RMC 80 is a new product in the Kenyan market. Sika Viscocrete10.This is a third generation high performance superplasticizer based on modified polycarboxylate polymer and produced by Sika. It conforms to the requirements of ASTM C-494, Standard Specification for Chemical Admixtures for Concrete, Types A, B, D, F and G. Sika Viscocrete 10 has been used in Kenya for over a decade. Cheruiyot et al. (2014) used Sika admixture Sika® ViscoCrete®-HE, a water reducer and super plasticizer obtained from the local dealers were used in the design for concrete manufacture.

2.10 Project Management and Quality of Concrete

The utilisation of concrete to produce a structure can only be undertaken under a project - a temporary endeavour undertaken to create a unique product or service. It is temporary in nature because it has a definite ending point, and unique because the product or service differs in some distinguishing way from all similar products or services (Project Management Body of Knowledge, 1996).Once a project is conceived it must be managed in order to produce the expected results. Project management is defined as an application of knowledge, skills, tools and techniques to project activities to meet project requirements (Project Management Body of Knowledge, 2004). This is accomplished through the application and integration of the project management processes of initiation, planning, executing, monitoring and controlling. Quality assurance and control, particularly in materials, are major concerns of construction project management.

Managing the quality of concrete will ensure that the project is delivered on time, cost and quality thus having a positive impact on the performance of project management. Jorjani and Hojjati (2013) point out that the main purpose of these admixtures is to produce high performance concrete by reducing the cost of production and improving its workability. Adoption of admixtures facilitates efficient use concrete in almost all environmental conditions such as marine construction, hot weather concreting, cold-weather concreting, etc.

The managerial benefits of increased use of admixtures in concrete cannot be overemphasized. It enhances so many properties of concrete such as strength, freeze-thaw resistance, permeability, workability, etc. There are a few disadvantages as well with admixtures but they can be controlled. In Asia, specifiers of concrete are now recognizing that the use of this new admixture technology in concrete has many technical, environmental and overall cost benefits in civil engineering, building and underground construction requiring the most impermeable and watertight concrete with the lowest shrinkage (King, 2002). This improvement of concrete quality and handling goes along way in enhancing construction project management and leads to increased efficiency in the handling of large and complex development projects.

2.11 Significance research findings on performance of concrete with admixtures

The use of admixtures in the world is widespread with the admixture undergoing several innovations. In India, Tamrakar and Mishra (2013) carried out experimental study on Property of concrete due to different ingredients based. The paper was conducted to study the effect of superplasticizer on properties of concrete with characteristic strength of 20 and 40 N/mm^2. One of the admixtures used was Glenium 140. They concluded that workability of concrete can be increased by addition of superplasticizer. However, very high dosages of SP tend to impair the cohesiveness of concrete. Slump loss can be reduced by using the chemical admixtures

In Libya, Alsadey (2015) carried out a laboratory experiment to study the Effect of Superplasticizer on Fresh and Hardened Properties of Concrete. He studied the fresh and hardened properties of concrete for M35 grade and the results compared with normal concrete. The tests considered for study were, slump test and compressive strength test. The results showed that the increase of superplasticizer dose in concrete led to improved slump and slightly increase in the compressive strength than that of normal concrete.

In Kenya, Cheruiyot, Abuodha and Kabubo in 2014 on the study on Use of Stone Dust in the Design of High Performance Concrete used a laboratory experiment to understand the performance of admixtures in concrete. Stone dust was collected from Athi River crushing plant for testing after stock pile sampling. Ordinary Portland cement (CEM 42.5) and admixture Sika® ViscoCrete®-HE, a water reducer and super plasticizer obtained from the local dealers were used in the design for concrete manufacture (Cheruiyot et al., 2014).They concluded that the Manufacture High strength concrete (HPC) using locally available stone dust is possible with strengths of over 80 kN/mm2 with a Modulus of Elasticity of 49.4 Gpa achieved using stone dust obtained from Mlolongo Quarries. That the use of High strength concrete significantly reduces structural members (columns sizes, beam depths). The sizes are however limited by modulus of elasticity particularly for slender columns and shear reinforcement for heavily loaded columns and foundation pads. There is also significant reduction in the total weight of reinforcement steel when high strength concrete is used. The benefits accrued from letting extra space created from the smaller column sizes are significant and present a business case when life cycle costs of the structure are considered. This is important for clients who have smaller development space and want to maximize it or for structure that have bigger floor spans. The findings were significant for understanding the impact of the use of admixture in the local industry in Kenya. The benefits are commercial in nature and give more incentives to study further the effects of these admixtures.

2.12 Theoretical framework.

2.12.1 Rheology of fresh concrete.

Rheology is the science of the deformation and flow of matter, and hence it is concerned with the relationships between stress, strain, rate of strain and time. We are concerned with flow and movement, and so we are interested in the relationship between stress and rate of strain (Domone, 2003). Fluids flow by the action of shear stress causing a sliding movement between successive adjacent layers, as illustrated for laminar (non-turbulent) flow in Figure 1.10. The relationship between shear stress (τ) and rate of shear strain (γ) is called the flow curve, and can take a variety of forms, as shown in Figure 1.11. The simplest form is a straight line passing

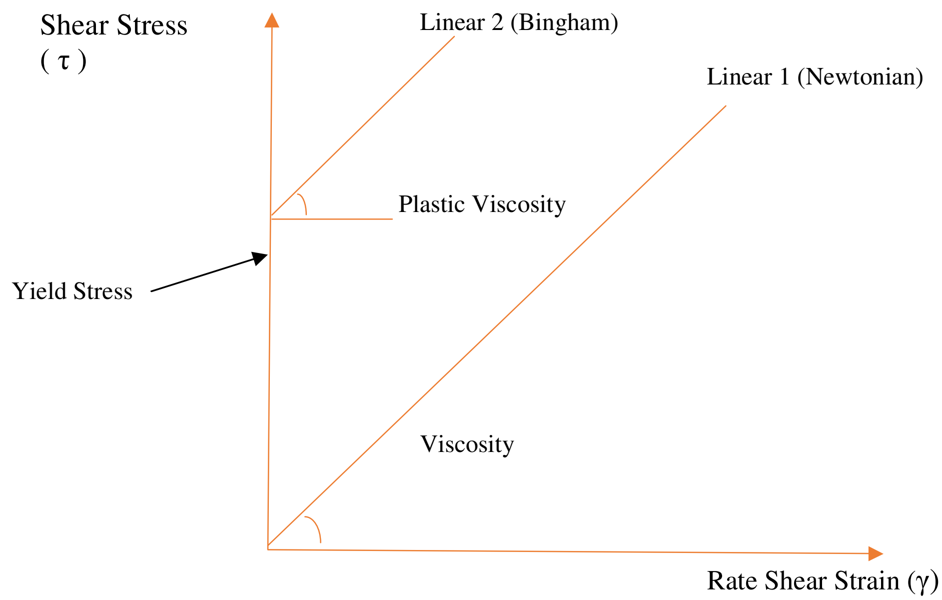


Figure 2.6: Types of flow curves. Source: Domone, 2003**.**

The straight linear (line 1) passing at the zero point of intersection between shear stress and shear strain represent Newtonian fluids. These are fluid whose yield stress is zero thus allowing the liquids to flow easily example being water, petrol, oil, etc.

The equation of the line is

$$\tau = \mu \gamma$$

and the single constant μ (called the coefficient of viscosity) is sufficient to fully describe the flow behaviour.

Other liquids flow with a bit or resistance and are represented by curve 2 (Bingham). Flow will only commence when the shear stress exceeds this threshold value, which is often called the yield stress (Domone, 2003). Concrete is considered by most researchers in most circumstances to behave like a Bingham fluid. A Bingham fluid flow is characterized by two entities: the yield stress and the plastic viscosity. The yield stress is the stress needed to start moving the concrete, while the plastic viscosity is a characterization of the flow of the concrete once the stress is higher than the yield stress the equation for this is represented below;

$$\tau = \tau o + \mu \gamma$$

In order for concrete to flow easily, it must attain the behaviour of Newtonian fluids which have zero yield stress. This can be made possible by the addition of more water and cement paste but with detrimental effect on final strength and durability due to pores created by the excess water as they evaporate. This can then be made possible by the use of chemical admixture. Yield stress and, to a lesser extent, plastic viscosity decrease with increasing superplasticiser concentration and above a critical concentration the flow is essentially Newtonian where the interparticle attraction is overwhelmed by the presence of the admixture (Banfill, 2006). Lastly, Larrard (as cited in Domone, 2003) , who concluded that knowledge of the rheological behaviour of fresh concrete allows the user to perform rapid, successful placement of high-quality concrete, saving time and money, and producing structures of long service life (Domone, 2003).

2.13 Conceptual Framework

In this study, a visual representation of the relationships amongst the variables conceptualized is as shown in Figure 2.7 below.

Independent Variables.

Chemical Admixtures.

The study has establishes several admixtures that are currently used in concrete across the world. These admixtures aid in altering the behaviour of concrete its fresh and dry state to the desire of the user. Some of these properties of admixture that helps change the concrete state in its fresh state includes; set acceleration and retardation; viscosity improvement; water reduction of the mix and air-entrainment. The attributes that affect the dry concrete state includes; waterproofing, and durability.

Quality of Concrete

This is another independent variable in the study. It entails all the attributes that define what an acceptable and proper concrete is. These qualities are durability of concrete and strength.

Dependent Variable

Concrete

The dependent Variable of the study is concrete. This is the constituent material that is used in the building of structures.

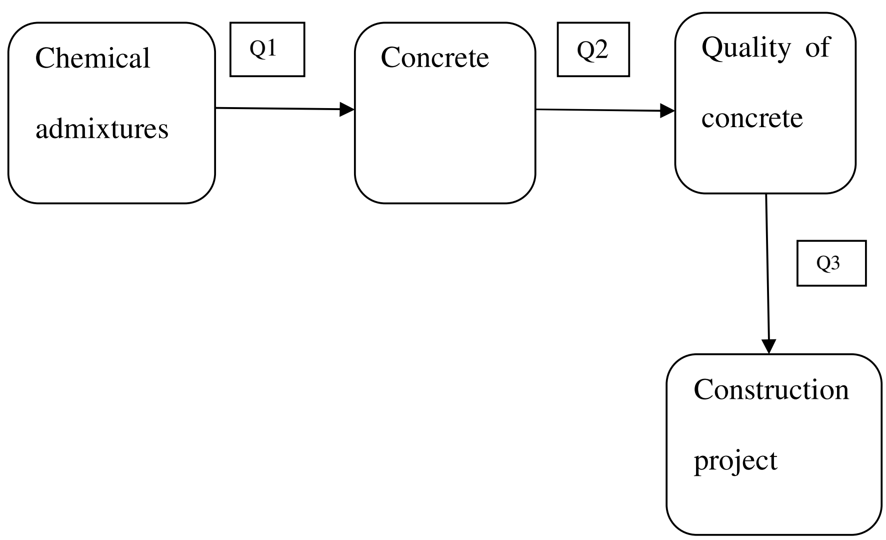


Figure 2.7: Conceptual framework.

2.14 Research Gap.

There exists considerable research work on the use of high performance concrete that which utilised chemical admixture in the rest of the world. Little has been done here in Kenya on the same (Cheruiyot et al., 2014). He carried out a laboratory test by using two types of superplasticizer to achieve a concrete strength of 92.7 KN/mm2. Kitimi (2016) researched on the impact of superplasticizers on different cement paste based on pozzolanic Portland cement (PPC) available in Kenya. This involved a laboratory test to get the results. There exist a gap in literature on the use of chemical admixture in the construction industry in Kenya and their specific effects on concrete quality and impact on project management.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

In chapter two, the literature reviewed for this study has been presented. In chapter three the methodology used in the study is outlined. The chapter presents the research design, sampling and collection methods of data and data analysis methods adopted.

3.2 Research Design

This study utilised cross-sectional research design. This was in line with the concern of the current status of the use of chemical admixtures in resolving the quality of concrete in Kenya. Accordingly, the 'where', 'who' and 'what' questions asked by this research were answered by employing survey design methods: questionnaires. Additional questions including the 'hows' and 'whys' were answered by employing thematic network analysis. Review of the related literature informed the research and aided in the design of both the conceptual framework and questionnaires.

3.3 Research Method

This research adopted both quantitative and qualitative method. This is a quantitative study since it is concerned with the numbers and frequencies with which contractors use admixtures.

3.4 Pilot Study

The study conducted a pilot study to test the questionnaire that was prepared to handle the research questions. Find attached the questionnaire in Appendix B. National Construction Authority (NCA) was contacted for a list of registered construction firms in Kenya under category 1. This group comprised both local and international contractors who are highly experienced and thus their information can be relied on when it comes to the actual usage and impact of admixtures in the industry. NCA has categorized building contractors into various classes depending on experience and capacity. These classifications are detailed in Appendix H. The study established that 86 contractors are registered under this category of which 74 operate and have offices in Nairobi. The other twelve operate from Mombasa, Mandera, Embu, Kiambu and Uasin Gishu.

A random sample of contractors was extracted using Microsoft excel software from the list of 74 and the questionnaire administered. Out of the 10 issued questionnaires prepared for this exercise, only four were returned with one fully filled. The study encountered the following challenges that were instrumental in the formulation of the final study;

- the contractors out rightly refused their buildings to be measured for strength using the Schmidt hammer test (Sound test). The use of admixture was to be compared with the strength of concrete and what was specified.
- Locating some of the contractors was difficult as we could not find their physical location as all their number as per NCA register were not working.

The pilot study finally advised the study on the use of purposive sampling to be able to target the NCA 1 contractors that are available in their offices or the ones found on sites within Nairobi. The questionnaire was adjusted to questionnaire that are not sensitive or biased but one which is able to collect the requisite data without suspicion or resistance from the contractors.

3.5 Population Sample and Sampling

3.5.1 Population

Polit and Hungler (1999) refer to the population as an aggregate or totality of all the objects, subjects or members that conform to a set of specifications. In this study, National construction Authority (NCA) was contacted for a list of registered construction firms in Kenya under category 1. This group comprised both local and international contractors who are highly experienced and thus their information can be relied on when it comes to the actual usage and impact of admixtures in the industry. NCA has categorized building contractors into various classes depending on experience and capacity. These classifications are detailed in Appendix H. The study established that 86 contractors are registered under this category of which 74 operate and have offices in Nairobi. The other twelve operate from Mombasa, Mandera, Embu, Kiambu and Uasin Gishu.

3.6 Sampling procedure and Technique

Sampling procedures informs on how the segment of the population involved in data collection was selected and how the data was finally collected. It is in fact a definite plan for obtaining a sample from a given population (Kothari, 2004). This refers to the technique or the procedure the researcher would adopt in selecting items for the sample.

The selection of the sample may either be probabilistic or non-probabilistic. Probabilistic sampling is based on the concept of random selection whereas non-probabilistic sampling is 'non-random' sampling (Kothari, 2004). For purpose of this study, companies who formed the sampling units were purposefully selected. This was necessitated by the findings of the pilot study. The pilot study discovered that a majority of NCA 1 contractors are international contractors from other countries and may not be having permanent physical location. The address they provided during registration may have changed in the course of time or they might have relocated to another town or left the country at the time of carrying out the study. This study adopted the purposive sampling in the final issue of questionnaire to have a high chance of netting contractors who have physical location in Nairobi and listed as NCA 1. The high number of contractors is required due to the descriptive design adopted for this study.

The minimum statistically acceptable sample size was determined by employing the Yamane (1967:886) formula to justify the responsive sample of the survey.

This states that;

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

Where;

n = the sample size

N= the population size

e = the level of precision

$$n = \frac{74}{1 + 74(0.05)^2} = 62.4$$

We take n to be 62.

3.7 Data Collection

Data collection was done using questionnaires. This was owing to the large number of contractors sampled for the survey, large amounts of information was to be collected within a short period of time and in a relatively cost effective way (Creswell, 2013). The results of the questionnaires can be quickly and easily quantified by the researcher using the SPSS software package since the responses from the questionnaire are highly structured and easily coded as opposed to the use of an interview schedule.

The questionnaires used comprised of Likert Scale (did not use –extremely used) questions for the body and an open ended question for the conclusion. The Likert Scale is a psychometric response scale primarily used in questionnaires to obtain participant's preferences or degree of agreement with a statement or set of statements (Garson, 2013). According to Garson, the advantage of the Likert Scale is that it is the most universal method for survey collection, therefore it is easily understood. The responses are easily quantifiable and subject to computation of mathematical analysis. Since Likert Scale questions do not require the participant to provide a simple and concrete yes or no answer, it does not force the participant to take a stand on a particular topic, but allows them to respond in a degree of agreement; this makes question answering easier on the respondent. Also, the responses presented accommodate neutral or undecided feelings of participants.

The minimum statistically acceptable sample size was determined by employing the Yamane (1967:886) formula to justify the responsive sample of the survey which yielded 62. These contractors were purposively picked from the list of 74 and contacted physically in their offices after booking appointments on the telephone. Others requested the questionnaire to be sent through email while a few were found on site. Out of this 41 questionnaires were received back representing 66% of the sample frame.

3.7.1 Source of Data

Two types of data were collected in this study namely primary and secondary. The primary data were collected through questions drafted and presented to respondents identified by this study. These are original data collected for the first time. Secondary data were also utilised from past data collected in academic journals, internet and government publications and books.

3.7.2 Questionnaire

A researcher needs to develop instruments which will aid in collecting data necessary for the study. A questionnaire is a formalised set of questions for obtaining information from respondents. It includes instruction for its completion, response alternatives where appropriate and specific means for recording responses (Frazer & Lawley, 2000). Each item in the questionnaire is developed to address a specific objective, research question or hypothesis of the study. The researcher must also know how the information obtained from each questionnaire item will be analysed (Mugenda & Mugenda, 2003).

3.8 Data Analysis

This section describes the processing of and analysis of both qualitative and quantitative data collected.

3.8.1 Processing and Analysing Qualitative Data

This study adopted Thematic Network Analysis of qualitative data. Thematic analysis is a method for identifying, analysing, and reporting patterns (themes) within data (Braun & Clarke, 2006). This method involved several steps geared towards moving the researcher from a broader understanding of the data into discovering salient and common patterns that leads to themes.

Step 1. Code Material

The study identified 71 codes based on the theoretical interest regarding the opinion of contractors on the use of chemical admixtures in the construction industry in Kenya.

Step 2. Identification of themes

The 71 codes were arranged into 8 major clusters that relate to each other on a topical issue. Out of these 8 major clusters, 23 basic themes were abstracted from the coded text segments. This involved going through the coded words over and over again while trying to pick out the common themes in the created codes. Lastly the themes were rechecked and refined. These themes was worked on to accommodate new text segments, as well as old ones; also to be specific enough to pertain to one idea, but broad enough to find incarnations in various different text segments (Attride & Jennifer, 2001).

Step 3. Construct Thematic Networks

The next step involved the identification of basic themes from a number of codes that conformed to the same topical issues. This led again to refinement of the basic themes into organising themes. This becomes a broader theme that explains several basic themes into one by capturing the common underlying issue. Finally the organising themes are gathered and interpreted under a global theme. This resulted into one sentence or few words that describe the theme holistically on a higher level of understanding. In light of the Basic Themes, summarize the main qualitative claim, proposition, argument, assertion or assumption that the Organizing Themes are about (Attride and Jennifer, 2001).

Step 4. Describe and Explore Thematic Networks

(a) Describe the network

(b) Explore the network

Step 5. Summarize Thematic Networks

Step 6. Interpret Patterns

3.8.2 Processing and Analysing Quantitative Data

The quantitative data for this study were analysed using Statitistical package of social

Descriptive analysis of the data was done on the quantitative data - using the Statistical Package for Social Sciences (SPSS for Windows). Frequencies and percentage for the use of admixtures were noted to generate an understanding of whether the admixtures are used and in what proportion.

3.9 Data Presentation

Presentation of the data collected from the quantitative analyses was done using univariate techniques were presented using simple graphs by the use of Microsoft Excel Tables. However, in cases where the analysis generated a lot of tables, a summary table, derived from the individual tables, was provided in the text using Microsoft word. Qualitative data was presented using thematic network analysis.

3.10 Ethical Considerations

According to Burton (2000), there are a number of elements among the data collection methods or instruments used to gather the information that can give rise to ethical concerns. In order to ensure that all the procedures were ethical in nature and that appropriate ethical approaches were taken at all times, the researcher took great efforts.

3.10.1 Subject matter

The research was undertaken under a subject that was neither sensitive, controversial, embarrassing, contentious nor upsetting.

3.10.2 Participants

The researcher took careful consideration in this study in the selection of the participants.

- That the participants were not part of my class mates.
- The participants were not coerced to participate in this study.
- The participants are not an over-researched group,
- The participants were actual practioner and among the selected by the study.

3.10.3 Matters around researcher

There was no conflict of interest by myself in this study. The study is undertaken purely for academic purpose.

3.10.4 Recruitment of Participants

- Participation in the study was voluntary.
- Participants were able to withdraw at whatever time they felt not willing to proceed.
- No deception of any kind was involved to get participants or information from them.

3.10.5 Risk or hazard to participants

Despite the study of chemicals, there was no physical or mental risk to participants due to the nature of collection of information.

3.10.6 Confidentiality issues

The introduction letter confirmed and guarantees the confidentiality of the data presented to the study. This data was to be used only for purpose of academic work and will not be disclosed to third party for other use.

CHAPTER FOUR

DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

This chapter presents analysis, findings and discussion of the study in line with objectives. The main purpose of this study was to investigate the influence of chemical admixture on the quality of concrete in the construction industry in Kenya.

The study raised three specific objectives; to investigate current practices and beliefs on the use of chemical admixtures in concrete in Kenya; to investigate the current advancement, use and benefits of chemical admixtures in the world today through literature review; to identify the gap that exist in terms of practices and benefits between the world today and Kenya. The researcher presents the data collected in form of figures and graphs. The thematic areas of focus for this study were the opinion of the contractors on the influence of chemical admixture on construction project management. Themes were derived from the responses and outlined in detailed.

4.2 Background of Respondents

4.2.1 Response Rate

A total of 62 questionnaires were issued out to contractors around Nairobi County. 41 questionnaires were returned and analysed. The response rate was 66%.The response rate was deemed sufficient to be used to make conclusions about the research problem. If descriptive statistics are to be used, e.g., mean, frequencies, then nearly any sample size will suffice (Israel, 1992). According to Gay (as cited in Mugenda & Mugenda, 2003) he suggests that for descriptive studies, ten percent of the accessible population is enough.

4.2.2 Classification of Contractors by NCA

All contractors accessed by this study were registered under category one which is the highest classification (Appendix F). They are the most qualified of all cadres of contractors in the country and their experience and opinion was highly valuable and dependable for this study. According to NCA this group consisted of 86 construction firms country wide. Important to note is the fact that NCA updates its list of contracts annually based on payment of annual subscription fee. As such there could be other contractors who have been omitted from this list by the authority. This list of 86 comprises of 10 companies that are outside Nairobi and 2 that were not accessible either through the internet or physically.

4.2.3 Distribution of Respondents

The distribution of the respondent suggests a variety of professionals handle projects in various construction firms (Figure 4.1). The majority of them were engineers at 34% who answered most of the questionnaire. This adds to the reliability of their information which this study considers first hand. Construction managers at 17% were involved in answering the questionnaires clearly indicating their level of understanding or engagement with the project. Another class of respondents was labelled others which comprised of clerk of works, foremen and quality officers as indicated in the questionnaires.

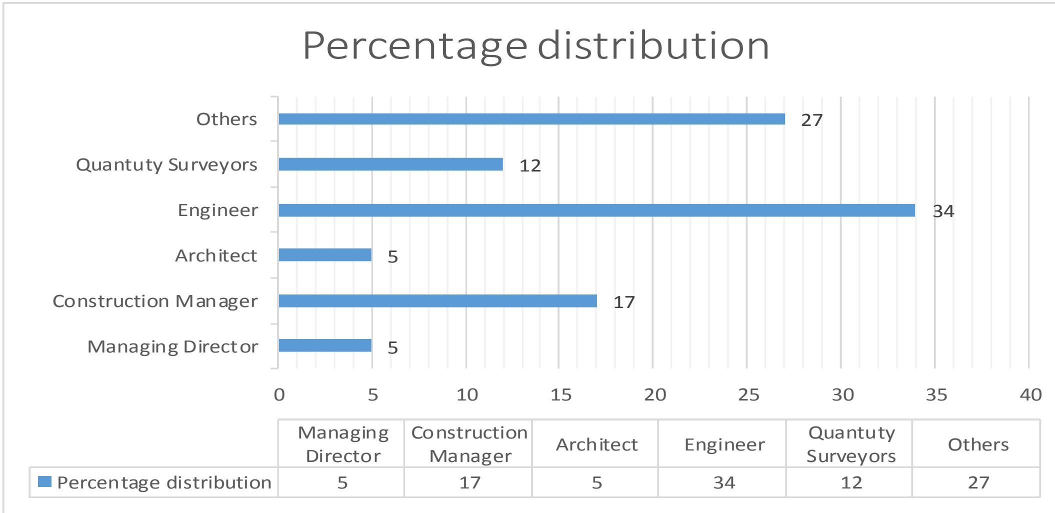
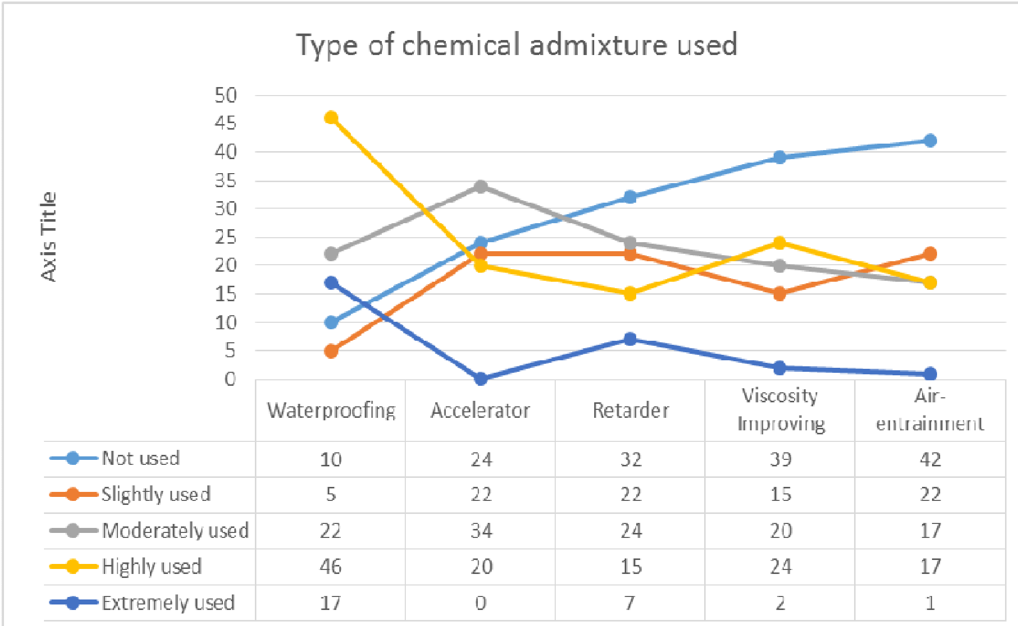


Figure 4.1: Distribution of respondents.

4.3 To establish the type of chemical admixtures being used in concrete

The contractors were requested to give their factual information on the types of chemical admixtures that they have used in their projects in Kenya using the questionnaires provided. The response for the questions was rated in Likert Scale of 5 where 1 = Not used, 2= Slightly used, 3= Moderately used, 4= Highly used, and 5= Extremely used. The percentage for each response and their respective Likert Mean was computed and the results presented using line graph. The results of the analysis of data from the questionnaires presented to the contractors with respect to chemical admixture used by contractors are shown in figure 4.2.



	Waterproofing	Accelerator	Retarder	Viscosity Improving	Air-entrainment
Not used	10	24	32	39	42
Slightly used	5	22	22	15	22
Moderately used	22	34	24	20	17
Highly used	46	20	15	24	17
Extremely used	17	0	7	2	1

Figure 4.2: Types of chemical admixture used.

The study revealed that waterproofing admixture is the most used in the industry with 17% using it extremely and 46% highly. This truly reflect the fact that most building waterproof their basement floors and also water retaining structures such as water, septic and fuel tanks. Only 5% of the contractors do not use this type of admixture which leads to the conclusion that it is a very essential product in the industry. The interviewed contractors claimed that Nairobi is rocky and contain underground water which affects the substructure.

On the use of set accelerating admixture, none of the contractors depend on it as we recorded 0% for the extremely used part. However, 20% highly uses this type of admixture, 34% moderately and 22% slightly.

Seven percent of contractors indicated that they highly depend on retarding admixtures and 15% depend on it highly. Further 24% moderately use it making a total of 46%. This represented a huge number indicating the growing demand for retarding admixture.

On the use of viscosity improving admixture, 2% of the contractors used it entirely for all their operations 24% depend on it highly and 20% moderately. This is a fairly used admixture based on these percentages which represent 46%. However of interest to note is the huge number of contractors, 39% who do not use it.

Lastly, we had the air-entrainment admixture with a majority of the contractors 58% having used it somehow. However, 42 % have not used it at all indicating the huge gap of knowledge in the same class of contractors.

Table 4.1: Results for the percentage of concrete which uses admixtures.

Descriptive Statistics		
Percentage of concrete that used admixture	Mean	Standard Deviation
Percentage of concrete that used admixture	49.37	28.95

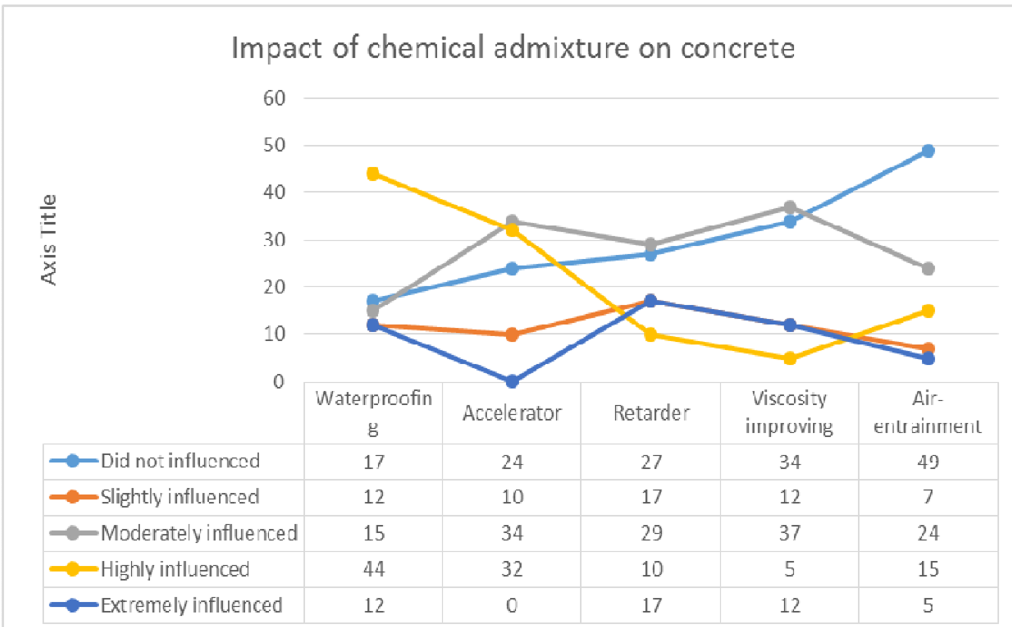
The mean result from the above table 4.1 indicates 49.37. This show that an average of 49.37% of concrete produced by NCA 1 contractors utilizes chemical admixture. This finding is very important and eliminates the notion that these admixtures are not used at all. In fact from the literature, chemical admixture is a wide spread material that is used extensively in particular for major infrastructural projects.

4.4 To establish the contribution of chemical admixtures in enhancing the efficiency of construction project management by impacting on quality

4.4.1 Impact of Chemical Admixture in handling Concrete in construction

The study set out to identify the impact of chemical admixture on concrete which will reflect on its quality (figure 4.3). The respondents viewed waterproofing as having a great influence on the handling of concrete at 44% and 12% thinking that it extremely influenced concrete handling.

Three quarters in total of the contractors polled that set accelerating admixture has a big influence on the handling of concrete the highest being 32% of whom highly believed so. 24% of them felt otherwise may be due to their lack of experience with these admixtures. This is corroborated with the actual percentage of contractors who have never used admixtures at 24%.



	Waterproofing	Accelerator	Retarder	Viscosity improving	Air-entrainment
Did not influenced	17	24	27	34	49
Slightly influenced	12	10	17	12	7
Moderately influenced	15	34	29	37	24
Highly influenced	44	32	10	5	15
Extremely influenced	12	0	17	12	5

Figure 4.3: Impact of chemical admixture on concrete.

A majority of the contractors agreed with the question concerning the effect of retarding admixture on the handling of concrete. Indeed 73% in general agreed with 17% and 10% agreeing extremely and highly. This can partly be explained by 32% of the respondent in above figure who have not used admixture before.

Thirty Four percent of the contractors have never used viscosity improving admixtures but at least 66% of them have used either once or always.

Air-entrainment admixture is the least used with 49% believing that it has no influence on the handling of concrete. About 20% strongly reported their position which suggests great influence on the handling of concrete.

4.4.2 The extent to which Chemical Admixture influence the quality of concrete.

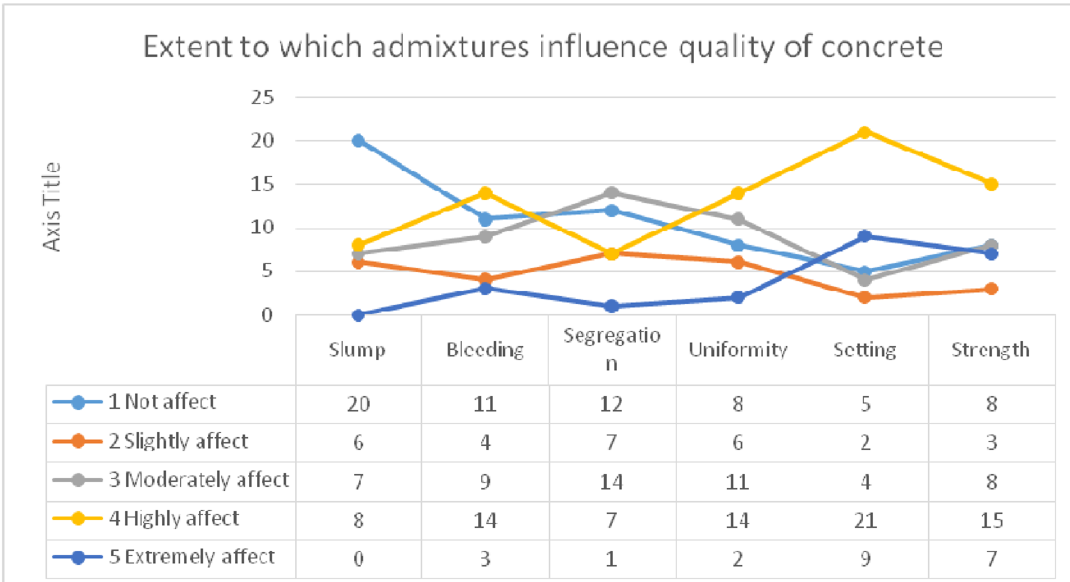


Figure 4.4: Extent to which admixtures influence quality of concrete.

The study set out to identify the impact of chemical admixture on concrete which will reflect on its quality (figure 4.4). A majority of respondents at 63% felt that chemical admixtures will not have an effect on the slump of concrete. On the effect of admixture on bleeding, 34% acknowledged highly the influence of admixture to quality and 7% extremely high. This indicates the general consensus that bleeding will be managed well when admixture is used. The segregation of concrete will also be managed well with 34% saying it will moderately affect and 19% in total highly and extremely influence. The study points out that admixtures will affect uniformity in a positive way with 39% highly and extremely agreeing and 27% believing it will moderately influence. The last two properties of concrete that is setting of concrete and strength were highly polled for agreement at 73% and 53% respectively. This indicated how well the respondents are familiar with the two properties of concrete and probably having experienced in their course of work.

4.5 Contractors' opinions and suggestions on the use and enhancement of admixture use in the construction industry of Kenya

4.5.1 The Opinions of Contractors on the influence of Chemical Admixtures

The findings of thematic network analysis has brought out very interesting themes that were carefully brought out from the 41 questionnaires successfully returned from the field work (Appendix I). These opinions and suggestions have brought out salient features on the study that are now presented for documentation. According to Mugenda and Mugenda (2003), qualitative studies obtain detailed information about the phenomenon being studied and then try to establish patterns, trends and relationships from the information gathered.

a. Improves quality of concrete

Most of the contractors strongly believed that chemical admixture assist in project management by helping in delivering quality concrete which reduces re-works and thus save cost of repairs. The codes representing improvement of quality were numerous highlighting the strong opinion. The comments from contractors were as follows;

'Admixtures help us to achieve the recommended water cement ratio from the design mix, greatly improves workability, save time and improves workmanship on site' **(Q-26)**

'Improve the strength of concrete and quality of building structures. Makes concrete workable and provide good slump' **(Q-24)**

'The use of these chemical admixtures should be encouraged and embraced in the construction industry since they increase the strength and improve the properties of concrete and enhances and increase the life span of structures' **(Q-07)**

The contractors note that most plain mix design requires less water to cement content in order to achieve a dense concrete that will allow the achievement of the desired class of concrete. Unfortunately this same concrete cannot be pumped due to its thick mix consistency or low slump around 50mm. Thus they reckon that the use of admixture allows them to achieve a highly fluid mix with high slump about 150 to 200mm that enable them to pump without adding more water and consequently achieve the desired strength in line with the mix design.

b. Solves logistical challenges of concreting in cities

With the use of retarder admixtures, concrete is transported through the heavy traffic currently in almost all roads in Nairobi. This assist in project management especially of buildings in the central business district, Upperhill and Westland where space is really constraint. Client comments on the same found below;

'Since construction industry is moving away from the small mixes to large batching mixes, admixtures should be emphasized. This is also important to counter traffic and lack of space to stockpile aggregates' (**Q-09).**

'Use of admixtures makes transport of concrete (ready mix) easier' **(Q-24)**

c. Deliver projects on time

It reduces large concrete pour to one day and even hours due to premixed concrete which is done offsite. On the other hand it enable precast units of a project to be prepared well in advance of the task and finally takes just a few hours to install thus save a lot of time in particular for roads concrete work.

*'Admixtures use reduces the number of days required by concrete to achieve sufficient strength to allow for construction work to continue with formwork still erected'***(Q-15)**

'Admixtures speeds-up project i.e strength gain and setting' **(Q-33)**

4.5.2 Suggestions for enhancing the use of Chemical Admixtures

The study has established that chemical admixtures are being used in the construction industry. The various contractors interviewed had different suggestion

s on the way forward in terms of this admixtures. These are;

a. Further study on cost implication

The findings on cost implication on the use of chemical admixtures were diverse. Some of the participants intimidated that admixtures reduce input of concrete which in effect reduce cost whereas others say it reduces cement and lastly it reduces the cost of repair. On the other hand enough of the participants said that admixtures are expensive and that the cost should come down. This study concludes that further studies require to be undertaken to ascertain the true position.

b. Policy framework on usage of chemical admixtures

Some contractors felt that proper procedures in ways of legislation should be formed to guide the use of the admixtures. They feel this will maximize on the benefit of these admixtures and at the same time eliminate abuse of the same due to trial and error method that is currently the norm. The contractors would also wish to have the use of admixtures incorporated in the bill of quantities and technical specifications of projects.

Contractors noted three major challenges of technical, marketing and regulation on the use of admixtures in the industry. On technical matters, the contractors noted the need for high supervision in order to use the chemical admixtures successfully. This coupled with experts on admixture/concrete will guarantee success.

On marketing, most contractors felt the marketing of these products have been below per. A lot of awareness needs to be put across for players to know the availability of admixtures and where to purchase them.

Lastly the regulation of chemical admixtures in Kenya is lacking and as such the contractors, suppliers and manufacturers are using admixtures on an ad-hoc basis. With the rise of use of these chemicals by ready mix concrete producers, many counterfeit products have entered the market threatening to reverse whatever gain that can be derived from their use.

c. Recommended for large and complex projects

Due to the technical nature and perceived benefits in managing concrete set time, the participants suggested the following; that chemical admixtures should not be used in small projects; should be used only for special projects; should be used only with ordinary Portland cement (OPC); good for large ready mix concrete for large projects. Thus the finding here suggest the use of admixtures only for ready mix concrete and large and complex projects.

d. Sensitization in their use

There is very little information available to the industry players. Most participants cried out for training by the manufacturers, suppliers and the National Construction Authority. This should be followed by marketing to bring out awareness of availability of the products.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents a summary of the research work and the conclusions and recommendations. The overall recommendation is that there is need to establish a policy and legal framework for the use of concrete chemical admixtures in the construction industry of Kenya. Finally the proposed areas for further studies are highlighted.

5.2 Summary of the research work

5.2.1 Purpose of the study

The use of chemical admixtures provides a shift in the production of high performance concrete that present enormous benefits to concrete users. The Construction Industry in Kenya seems to be rooted in the past in terms of the use of chemical admixtures to enhance the quality of concrete. Traditional concrete practices have been shown to be inefficient in material, labor and equipment usage, slow in project delivery, and the structures produced are of low strength and durability, resulting in high maintenance or early replacement costs (Koteng, 2013). Additional costs are incurred in interruptions to other services during lengthy construction. Traditional concrete practices therefore result in a slow pace of development and inefficient use of development funds. There is no formal record on the current use of admixture in the industry. There is no policy for the use of admixtures in the industry despite the evidence of existence of these chemicals in the Country.

The study aimed to establish the role played by chemical admixture in aiding the quality of concrete in the construction industry in Kenya. In line with this aim, three objectives were raised by the study. To establish the type of chemical admixtures being used in concrete; to establish the effect of chemical admixture on concrete quality and contribution of chemical admixture in construction project management and lastly to find out the opinions and suggestion of contractors' on how to further the use of chemical admixture in the industry.

5.2.2 Literature Reviewed

History of concrete was reviewed to give an understanding of its origin and to provide a snapshot of its evolution over time. Types of concrete that have emerged like High strength and High performance concrete. The properties of concrete which defines its ability and weaknesses were highlighted. This was important to understand the likely failures of concrete our industry. This was followed by a look at the type of cement used in construction. Of the five classes of cement only three were predominant in Kenya; type I, II and IV. All being used for general purpose work and in a few instance specialised function like the ordinary Portland cement type I. The types of chemical admixtures were discussed with a view to understanding better what is available in the world and what they do. This being one of the major variables in the study allowed for an in depth focus on the problem. Other studies carried out on concrete and admixtures were reviewed to find out their outcome and conclusion. Lastly how management of quality affects project management was looked into.

5.2.3 Methodology Used

In this study, National construction Authority (NCA) was contacted for a list of registered construction firms in Kenya under category 1, which formed the sampling frame. The minimum statistically acceptable sample size was determined by employing the Yamane (1967:886) formula to justify the responsive sample of the survey which yielded 62. This contractors were purposively picked form the list of 74 and contacted physically in their offices after booking appointments on the telephone. Others requested the questionnaire to be sent through email while a few were found on site. Out of this 41 questionnaires were received back representing 66% of the sample frame. Quantitative data were analysed using Statistical Package of Social Sciences (SPSS) software and data presented in tables and figures. Qualitative data were analysed using thematic network method and data presented in a thematic network and summarized in form of key themes.

5.2.4 Findings of the study

a. *Objective 1: To establish the type of chemical admixtures being used in concrete*

The study revealed that admixtures are being used in projects by the category one contractors in Nairobi. Waterproofing is the most widely used followed by set accelerator which mainly is used for precast concrete products. Retarders are also used mainly to transport concrete to congested city centre and other locations with high traffic. Viscosity improving admixture and air-entrainment were the least used in that order.

b. *Objective 2: To establish the contribution of chemical admixtures in enhancing the efficiency of construction project management by impacting on quality.*

Impact of chemical admixture in the handling of concrete. Most of the contractors felt that waterproofing admixtures affect concrete the most. In general all the other admixtures impact positively on the handling of concrete starting from set accelerator, retarder, viscosity improving and air-entrainment.

On the percentage of concrete that uses admixture by this group of contractors, the study establishes 49.37%. This is almost half of the concrete that is used by the contractors.

c. *Objective 3: To find out contractors' opinions and suggestions on the use and enhancement of admixture use in the construction industry of Kenya.*

Lastly the study set out to find the opinion of the contractors on the impact of chemical in construction project management and further usage. The contractors strongly felt that admixtures will improve the quality of concrete. In their opinion admixtures help in the transportation of concrete and to deliver projects on time. They too think that the use of admixtures give them a head start over the other contractors who do not use them.

They further suggested that training need to be undertaken to help them understand better these admixtures and should lead to enactment of laws to regulate their use while at the same time the building code to be amended. They also complained that in as much as the admixtures are beneficial, the cost is not friendly coupled with counterfeit chemicals which bring losses and no positive result on the concrete. They point out the lack of interest from regulatory bodies in the construction industry like National Construction Authority, County Council of Nairobi, Board of registration of architects and quantity surveyors and Engineers registration board in promoting the use of admixtures.

5.3 Conclusions

5.3.1 Conclusions about the research question

I. ***What are the types of chemical admixtures being used in concrete?***

The literature review points out to the use of high range water reducing admixture also known as superplasticizers (Kitimi, 2016). Master Rheobuild RMC 80 (Formerly Rheobuild LD 80) and Sika Viscocrete10. Cheruiyot et al. (2014) also utilized Sika® ViscoCrete®-HE, a water reducer and superplasticizer. These are the pointer from the literature of the admixtures available and used in the country.

The findings of this research give a broader insight into the types of admixtures used since the method used to collect data involved a huge number of contractors. These are waterproofing, set acceleration, retarders, and viscosity improving and air-entrainment admixtures. The study did not inquire of particular brands used to avoid alienating the participants from giving information.

II. ***What are the contributions of chemical admixtures in enhancing the efficiency of construction project management?***

Koteng (2013) noted that traditional concrete practices have been shown to be inefficient in material, labour and equipment usage, slow in project delivery, and the structures produced are of low strength and durability, resulting in high maintenance or early replacement costs. Cheruiyot et al. (2014) concluded that design of structures using high strength concrete reduces significantly the structural member sizes, steel reinforcement and increase the available usable space in the structure. He further states that there is also significant reduction in the total weight of reinforcement steel when high strength concrete is used.

The study found admixtures to improve the quality of concrete positively by altering the set time of concrete according the desire of the user, improves uniformity of concrete, increase strength and resolve bleeding challenges. Further the study note that the admixtures have less influence on segregation of concrete and loss of slum.

III. What are the contractors' opinions and suggestions on improving usage of the admixture in the construction industry of Kenya?

Cheruiyot et al. (2014) made several recommendations based on his findings on the study on the *Use of Stone Dust in the Design of High Performance Concrete*. These include the construction industry to consider use of high strength concrete (HPC) in the current market as it will greatly improve the construction standards; the existence of enough justification for its use in high storey structures especially in rapidly congested areas of the cities where land has reduced; its use will help architects improve their designs particularly where they require big spaces or minimum columns at the centre of the structure. Further Koteng (2013) on his study of *Concrete use for sustainable development* suggested the following; The changeover from traditional methods of concrete use will require retraining of operators in the construction industry, improving research and teaching institutions. Early high investment costs will be recovered through great savings in maintenance and early replacement costs.

The findings for this study agree to a larger extend with the above studies undertaken in Kenya. This study has concluded that chemical admixtures help to improve the quality of concrete for projects, it helps to solve logistical challenges of concrete work in cities and lastly to deliver projects on time. The contractors suggested several ideas that might be useful in enhancing the use of admixtures. They suggest that further study need to be undertaken to understand the cost implication of using admixtures in projects. This will it clear if it is add or reduce cost of projects. Policy framework for the use of admixtures to be enacted to guide the correct usage and protect from counterfeit products in the market. They also recommended its use in large and complex projects. To further use these admixtures, they also suggested sensitization to be carried out through training and marketing.

5.3.2 Implication for theory

The theory advanced by this study is that of Rheology of Concrete. This theory discusses the behaviour of flow of normal fluid called Newtonian fluids that flow under the influence of gravity with no force (stress) to restrain them. The other Bingham fluids under which concrete falls have difficulties in flowing under gravity due to the yield stress inherent in the mix that needs to be overcome in order to achieve flow. This resistance to flow has been the source of the current practice of water cement ratio and the source of major challenge in the quality of concrete. As noted by the study, traditional method of preparing concrete is still widely used in Nairobi, Kenya.

This study has successfully explored through literature and research and establishes facts about the benefits of chemical admixture in enhancing the quality of concrete. The three researchers that have delved into the subject of chemical admixture include; Koteng (2013) on his study of *Concrete use for sustainable development;* Cheruiyot et al. (2014 study on the *Use of Stone Dust in the Design of High Performance Concrete;* Katimi (2016) study on *The Effect of Retarding Chemical Superplasticizers on the Setting Time of Cement Pastes in Kenya: A Case Study of Ready Mix Concrete in Nairobi.*

This study contributes to the existing theory of literature with its findings and conclusions on the admixtures use in Nairobi Kenya. These are the evidence on the use of chemical admixture in Nairobi; benefits of chemical admixtures in project delivery and opinions on the benefits of chemical admixtures

5.3.3 Implication to further research

The outcome of this study enlightens the topical area of chemical admixture in Kenya. A need for further studies on chemical needs to be done in regards to policy framework on its use. In regards to methodology, this research leads the next door to a thorough research and analysis on the categories of users in the market that deals with chemical admixtures; ready mix concrete suppliers; testing laboratories; suppliers and manufacturers and all contractors in the country.

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APPENDICES

Appendix A: Research Questionnaire

Title: Investigating the effect of chemical admixtures on the quality of concrete in the construction industry in Kenya.

PART A: INFORMATION

1. Which class of contractors are you registered by National Construction Authority? ______________________
2. Which role do you play in the company? *(Tick one).*
   i. Managing Director ______
   ii. Construction Manager ______
   iii. Architect _____
   iv. Engineer ______
   v. Quantity Surveyor ______
   vi. Others (*Kindly state*)____

PART B: CHEMICAL ADMIXTURE IN CONCRETE

1. Which type of admixtures have you used in your projects before? ***(Tick one appropriate box for each item).***

NO.	DESCRIPTION	Not Used	Slightly Used	Moderately Used	Highly Used	Extremely Used
a.	Waterproofing					
b.	Set acceleration					
c.	Retarder					
d.	Viscosity improving					
e.	Air Entrainment					

2. How did the use of chemical admixture impacted on the handling of concrete in your projects? ***(Tick one appropriate box for each item).***

NO.	DESCRIPTION	Did not influenced	Slightly Influenced	Moderately Influenced	Highly Influenced	Extremely Influenced
a.	Waterproofing					
b.	Set acceleration					
c.	Retarder					
d.	Viscosity improving					
e.	Air Entrainment					

3. To what extend did chemical admixtures help solve the following challenges in your project(s) in terms of the following quality factors? ***(Tick one appropriate box for each item.)***

NO.	DESCRIPTION	Not at all	Slightly	Moderately	Highly	Extremely
a.	Segregation					
b.	Loss of slump					
c.	Bleeding					
d.	Uniformity					
e.	Setting					
f.	Strength gain					

4. What percentage of concrete did you use chemical admixture?

____________%

5. What is your opinion on the use of chemical admixtures in construction project management in Kenya?

____

____

____

____

6. What is your suggestion to further improve the use of chemical admixtures?

____

____

____

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____

____

Appendix B: Pilot Study Questionnaire.

PART A: INFORMATION

1. Which class of contractors are you registered by National Construction Authority? ______________________

2. Which role do you play in the company? *(Tick one).*

vii. Managing Director ______
viii. Construction Manager ______
ix. Architect _____
x. Engineer ______
xi. Quantity Surveyor ______
xii. Others (*Kindly state*)____

3. What is the size (Contractual amount) of the largest project you have undertaken in the last three years that has used chemical admixtures?

____

PART B: QUALITY OF CONCRETE.

1. To what extend did chemical admixtures help solve the following challenges in your project(s) in terms of the following factors? *(Tick one appropriate box for each item)*

NO.	DESCRIPTION	Not at all	Slightly	Moderately	Highly	Extremely
a.	Segregation					
b.	Loss of slump					
c.	Bleeding					
d.	Uniformity					
e.	Setting					
f.	Strength fain					

2. What was the strength of concrete achieved for the following component in the above named structure? Sound hammer, (Schmidt hammer)shall be used for this purpose.

	COMPONENT	Column 1	Column 2	Column 3	Average Strength	Specified Strength
		(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)	(N/mm^2)
a	Columns					
b	Beams					
c	Slab					

3. Did you use any admixture in the tested components? *(Tick one appropriate box for each item)*

	COMPONENT	Yes	No
a	Columns		
b	Beams		
c	Slab		

4. Which type of admixture(s) did you use in this project? *(Tick one appropriate box for each item)*

NO.	DESCRIPTION	Tick
a.	Set acceleration	
b.	Retarder	
c.	Viscosity improving	
d.	Air Entrainment	

5. What percentage of concrete did you use chemical admixture?

____________%

6. What is your opinion on the use of chemical admixtures in construction project management in Kenya?

7. What is your suggestion to further improve the use of chemical admixtures?

Appendix C: Research Introduction Letter

JOMO KENYATTA UNIVERSITY OF AGRICULTURE AND TECHNOLOGY

Setting Trends in Higher Education, Research and Innovation

School of Architecture & Building Sciences
Department of Construction Management

Date: 8th February 2016

Dear ____________________________________

Invitation to Participate in a Research Project.

My name is Cosmas Legeto, a student undertaking a research study in construction as part of a Masters degree in Construction Project Management. You are invited to participate in this research project. I am undertaking this research study under the supervision of Dr Titus Kivaa and Dr. Ahmed Alkizim of Jomo Kenyatta University of Agriculture & Technology.

This research aims to investigate the strength of concrete in construction industry in Kenya. The data for the study is obtained from interviews of the industry participants and observations of concrete components in building and study of the project documents.

Kindly fill in the attached questionnaire. The researcher and the University guarantee that the information given will be treated with strict confidentiality and will be used for purposes of the research study only.

Yours Faithfully,

Mr. Cosmas Legeto
Student, Master of Construction Project Management
clegeto@gmail.com
0722274110

Dr. Titus Kivaa, PhD
Supervisor
tkivaap@yahoo.com
0705072906

Dr. Ahmed Alkizim, PhD
Supervisor
0716000748

Appendix D: Research Permit.

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone: +254-20-2213471, 2241349, 310571, 2219420
Fax: +254-20-318245, 318249
Email: secretary@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No.
NACOSTI/P/16/82036/9379

Date:
29th February, 2016

Cosmas Kirui Legeto
Jomo Kenyatta University of Agriculture
And Technology
P.O. Box 62000-00200
NAIROBI.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Investigating the effect of chemical admixtures on the quality of concrete in the construction industry in Kenya"*** I am pleased to inform you that you have been authorized to undertake research in **Nairobi County** for a period ending **26th February, 2017.**

You are advised to report **the County Commissioner and the County Director of Education, Nairobi County** before embarking on the research project.

On completion of the research, you are expected to submit **two hard copies and one soft copy in pdf** of the research report/thesis to our office.

DR. S. K. LANGAT, OGW
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nairobi County.

The County Director of Education
Nairobi County.

JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY
DEPARTMENT OF CONSTRUCTION MANAGEMENT

P.O. BOX 62000-00200, NAIROBI, KENYA. TEL: (020)-8008485
Fax: (067)-5352711 EXT 2475 Thika. Email: conmgmt@sabs.jkuat.ac.ke

National Commission for Science, Technology & Innovation

P.O. Box 30623 – 00100

NAIROBI

28th October, 2015

Dear Sir/Madam

Ref: LEGETO COSMAS KIRUI AB3453-1189/2011

The above named is a bonifide student of Jomo Kenyatta University of Agriculture and Technology pursuing a master's degree in Construction Project Management.

He is currently undertaking a research thesis titled **"Investigating the effect of chemical admixture on the quality of concrete in the construction industry in Kenya"**.

Any assistance accorded to him will be highly appreciated.

Yours faithfully.

DEPARTMENT OF CONSTRUCTION MANAGEMENT
CHAIRMAN
OF
DEPARTMENT
JKUAT- SABS

Dr. A. Alkizim
COD, CONSTRUCTION MANAGEMENT

JKUAT is ISO 9001:2008 & ISO 14001:2004 Certified
Setting trends in higher Education, Research and Innovation

Appendix E: Table Of Codes.

QUESTION NUMBERING.

Code	Position	Code	Position
Q-01	Engineer	Q-22	Engineer
Q-02	Engineer	Q-23	Construction Manager
Q-03	Construction Manager	Q-24	Quantity Surveyor
Q-04	Engineer	Q-25	Quantity Surveyor
Q-05	Site Agent	Q-26	Quality Officer
Q-06	Construction Manager	Q-27	Supervisor
Q-07	Quantity Surveyor	Q-28	Architect
Q-08	Clerk of Works	Q-29	Construction Manager
Q-09	Construction Manager	Q-30	Engineer
Q-10	Clerk of Works	Q-31	Clerk of Works
Q-11	Construction Manager	Q-32	Project Advisor
Q-12	Site supervisor	Q-33	Quantity Surveyor
Q-13	Site supervisor	Q-34	Construction Manager
Q-14	Engineer	Q-35	Engineer
Q-15	Architect	Q-36	Quality Officer
Q-16	Engineer	Q-37	Managing Director
Q-17	Engineer	Q-38	Engineer
Q-18	Foreman	Q-39	Construction Manager
Q-19	Managing Director	Q-40	Engineer
Q-20	Quality Officer	Q-41	Foreman
Q-21	Engineer		

Appendix F: National Construction Authority (NCA) Categories of Registration of Contractors According to Capability

Annex 1.11

National Construction Authority P.O. BOX 21046-00100; website: www.nca.go.ke ; Email:info@nca.go.ke, Cell phone no: 0700021222; Direct lines: 020712096, 020712098, 020712099.

Categories of Registration according to capability

1	Contractors (Buildings)		
		Category	Value Limit (Kshs)
	1.	NCA1	Unlimited
	2.	NCA2	Upto 500,000,000.00
	3.	NCA3	Upto 300,000,000.00
	4.	NCA4	Upto 200,000,000.00
	5.	NCA5	Upto 100,000,000.00
	6.	NCA6	Upto 50,000,000.00
	7.	NCA7	Upto 20,000,000.00
2	Specialist Contractors		
		Category	Value Limit (Kshs)
	1.	NCA1	Unlimited
	2.	NCA2	Upto 250,000,000.00
	3.	NCA3	Upto 150,000,000.00
	4.	NCA4	Upto 100,000,000.00
	5.	NCA5	Upto 50,000,000.00
	6.	NCA6	Upto 20,000,000.00
	7.	NCA7	Upto 10,000,000.00
3	Roads and other Civil Works		
		Category	Value Limit (Kshs)
	1.	NCA1	Unlimited
	2.	NCA2	Upto 750,000,000.00
	3.	NCA3	Upto 500,000,000.00
	4.	NCA4	Upto 300,000,000.00
	5.	NCA5	Upto 200,000,000.00
	6.	NCA6	Upto 100,000,000.00
	7.	NCA7	Upto 50,000,000.00

Appendix G: Correspondence with NCA.

Gmail — COSMAS LEGETO <clegeto@gmail.com>

Fwd: BUILDING WORKS CONTRACTORS NCA1
3 messages

Stephen N. Nyakondo <s.nyakondo@nca.go.ke> — 1 March 2016 at 10:12
To: clegeto@gmail.com

Dear Cosmas,

I trust you are doing fine.

Please find attached the information earlier requested for your Master project.

As earlier informed through our legal department this information is **NOT** for commercial use.

Thanks,

Stephen Nyakondo.

---------- Forwarded message ----------
From: **Caroline Kaaka** <c.kaaka@nca.go.ke>
Date: Tue, Mar 1, 2016 at 9:49 AM
Subject: BUILDING WORKS CONTRACTORS NCA1
To: "Stephen N. Nyakondo" <s.nyakondo@nca.go.ke>

Morning,

Please find attached.

Regards

Caroline

Note: All emails sent from National Construction Authority (NCA) are subject to NCA's Email Policy. Please click here to read the policy.

"Visit our Website, Facebook Page and Twitter Account".

Note: All emails sent from National Construction Authority (NCA) are subject to NCA's Email Policy. Please click here to read the policy.

"Visit our Website, Facebook Page and Twitter Account".

NCA 1 BUILDING WORKS CONTRACTOR.xlsx
22K

COSMAS LEGETO <clegeto@gmail.com> — 2 March 2016 at 06:22
To: "Stephen N. Nyakondo" <s.nyakondo@nca.go.ke>

Dear Mr. Stephen,

I would wish to thank the Authority once more for their assistance with the requested information.

The list will only be used for academic purpose and a copy of the research submitted to your research department.

Thanking you once more,

Cosmas Legeto
0722 274 110
[Quoted text hidden]

COSMAS LEGETO <clegeto@gmail.com> 29 April 2016 at 04:32
To: Tkivaap@yahoo.com, "clegeto@gridline.co.ke" <clegeto@gridline.co.ke>

Dear Dr. Kivaa,

Attached find the list of contractors from NCA as forwarded to me.

With Thanks,
[Quoted text hidden]

NCA 1 BUILDING WORKS CONTRACTOR.xlsx
22K

Appendix H: List of NCA 1 Contractors.

	NAME	POSTAL ADDRESS	COUNTY	CELL PHONE
1	Afcons Africa Ltd	486-00606	NAIROBI	722411204
2	Aggregate Construction	558-00606	NAIROBI	722432974
3	China Aerospace Construction Group Company Limited	BOX 83-100071 BEIGING CHINA		
4	China Far East Construction Company Limited	21957-00505, NAIROBI		
5	China Gezhouba Group Company Limited	BOX 100000 WUHAN,HUBEI CHINA		
6	CHINA JIANGSU INTERNATIONAL LIMITED	60546-00200	0	020-2589424
7	China National Aero-Technology International Engineering	561-00521	NAIROBI	731055688
8	China Qingjian International Group (Kenya) Limited	25683-00100 NAIROBI	NAIROBI	714325738
9	China Railway 21St Bureau Group (Kenya) Company Limited	52666-00100, NAIROBI		
10	China Young Tai Eng Co Ltd			
11	Chong Qing International Construction Company Limited	40112-00623, NAIROBI		
12	Clasico Builders	38637-00623	NAIROBI	722791314
13	CRJE (EAST AFRICA) LTD	58049 -00100 NAIROBI.	NAIROBI	734917584
14	D.M Enterprises Ltd	22841-00400	NAIROBI	0737797979/0 722512023
15	Dhanjal Brothers Limited	82909-80100, MOMBASA		
16	Dinesh Construction Co. Ltd	P.O Box 49057-00100	NAIROBI	722511714
17	Don Woods Co. Ltd	73667-00200	NAIROBI	712466228
18	EggenJoinex Limited	47374-00100 NAIROBI	NAIROBI	733603128
19	Ellipse Projects Kenya Limited	BOX 211046-00100 NAIROBI	NAIROBI	733600000
20	EPCO BUILDERS LTD	55628-00200	NAIROBI	734000064
21	Fenke agencies limited	16675-00200	0	722518106
22	Fourway Construction Company Limited	2258-00200, NAIROBI		
23	Giant-Build Construction (PTY) Limited	10277-00200 NAIROBI	0	723985921
24	Golden Relief Resources Kenya Ltd	20515-00200	0	716864291
25	Hajar Services Ltd	11429-00100	NAIROBI	722792127
26	HAPPY TIME CONSTRUCTION COMPANY LIMITED	52918-80100	0	722884829
27	Hebei Water Conservancy & Hydropower (Kenya) Company Limited	21061-00100, NAIROBI		

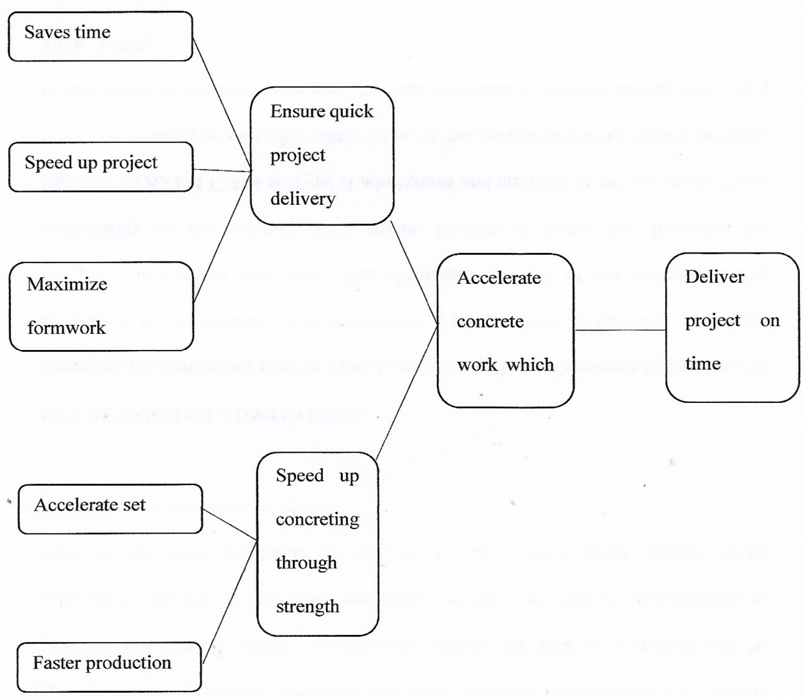
28	Hong Yuan Construction Limited	BOX 10627-00100 NAIROBI	NAIROBI	788996666
29	Intex Construction Ltd	788996666	NAIROBI	722206161
30	Jiangxi Jing Tai Water Conservancy And Electric Power Construction Kenya Limited	BOX 16848-00620 NAIROBI	NAIROBI	715881813
31	Kenyatta University	43844-00100 Nairobi	NAIROBI	721296051
32	Kings Pride Constructors Ltd	26357-00504	NAIROBI.	712531166
33	Kolin Construction Eastern Africa Limited	46817-00100, NAIROBI		
34	LaljiBhimjiSanghani	10286-00400	NAIROBI	722359080
35	laljiMeghji Patel & Co. Ltd	48514-00100	NAIROBI	722359080
36	Lee Construction Ltd	28969-00200	NAIROBI	735555503
37	Liushi Construction (K) Limited	41374-00100 NAIROBI	NAIROBI	722295637
38	Magic Gen Contractors Ltd	28548-00200	NAIROBI	20554057
39	MAKIBER (K) LIMITED	60533-00200	0	715956523
40	Mandeep Singh Construction (K) Ltd	P.O Box 18608-00500	NAIROBI	724715746
41	Mark Properties Ltd	12850 - 00400	NAIROBI	727535414
42	M-Craft Builders Limited	BOX 82247-80100 MOMBASA	MOMBA SA	
43	Mistry Javda Parbat & Co. Ltd	90643-80100	MOMBA SA	734623000
44	Mutahi Engineering Services Ltd	2547-60100	EMBU	722774761
45	NANTIE HOMES CONSTRUCTION LIMITED	52612	0	733600000
46	NGM Company Ltd	68144-00200	NAIROBI	733600671
47	Nightigale Enterprises Limited	163772-00610 NAIROBI	NAIROBI	712325051
48	Nilkanth Builders Limited	5130 - 00506 NAIROBI	NAIROBI	722999850
49	Nipsan Construction Co. Ltd	12850-00400	NAIROBI	727535414
50	NJUCA CONSOLIDATED COMPANY LTD	55-01020 THIKA	KIAMBU	722822045
51	Nyarutarama property developers (NPD) limited	50049-00200 NAIROBI	0	788308744
52	Oriental Construction Co. Ltd	48364-100	NAIROBI	722611678
53	Parbat Siyani Construction Ltd	10478-00100	NAIROBI	020-554706
54	Pivotech Company Limited	BOX 60225- DAR ES SALAAM		25442226178 22
55	Qingjian international (SEY) Group Devco limited	55950-00200 NAIROBI	0	722722682
56	Quest Civil Engineers Limited	78772-00507, NAIIROBI		
57	Sanken Overseas (K) Limited	92987-80102, MOMBASA	MOMBA SA	0720 643655
58	Scanjet Construction Limited	43492-80100, MOMBASA		

59	Seokang Limited	58810-00200 NAIROBI.	0	708418490
60	Seyani Brothers & Co. (K) Ltd	60070-00200	NAIROBI	702135460
61	Shiloah Investments Ltd	2510-40100, NAIROBI		
62	Shiv Construction Co. Ltd	4322-00506,	UASIN GISHU	721911791
63	Shree ShubhLabh Limited	1127-00606, NAIROBI		
64	Soon &Seel Building & Civil Construction	BOX 5672-00506 NAIROBI	NAIROBI	724548179
65	SOUTH SHORE INTERNATIONAL LTD	34140-80100	MOMBA SA	722848508
66	Stellar Builders	38214 - 00623	NAIROBI	725040638
67	Sultan Investment Ltd	11731 - 00400	NAIROBI	722995222
68	Team Construction Limited	4821-00200, NAIROBI		
69	Terra Firma (K) Ltd	2043-00502 NAIROBI	NAIROBI	717372844
70	Terra Firma Construction Limited	BOX 24576-00100 NAIROBI	NAIROBI	722965297
71	Terrain Services Limited	2903, KAMPALA UGANDA		
72	Thymaj Construction Co. Ltd	410-70300	MANDER A	720778484
73	Tosha Holdings Limited	28433-00100, NAIROBI		
74	Trio-Ten Ventures Limited	3728-00506 NAIROBI	NAIROBI	710548077
75	Trio-Ten Ventures Limited	3728-00506 NRB	0	710548077
76	Trio-Ten Ventures Limited	3728-00506 NRB	0	710548077
77	Tulsi Construction Co	47430-00100,	NAIROBI	722841947
78	Tunasco Insaat Taahhut Turizm Ticaret Anonim Sirketi	4000-00506 NAIROBI	NAIROBI	722513367
79	Tunasco Insaat Taahhut Turizm Ticaret Anonim Sirketi	4000-00506 NAIROBI	0	722513367
80	Unik Civil Engineering Limited	59445-00200 NAIROBI	0	722896917
81	Vee Vee Enterprises Ltd	3283-00506	NAIROBI	7126652679
82	Warren Enterprises Ltd	8251-00300	NAIROBI	724256552
83	Weihai Construction Group Co. Ltd	209-20048	NAIROBI	707963008
84	Weihai International Economic & Technical Cooperative Co	27542-0100	NAIROBI	707963008
85	Zenith Steel	18314-00500	NAIROBI	722205902
86	Zhengwei Technique kenya Ltd	27542-00100	NAIROBI	70796008

Appendix I: Thematic Network Analysis Result.

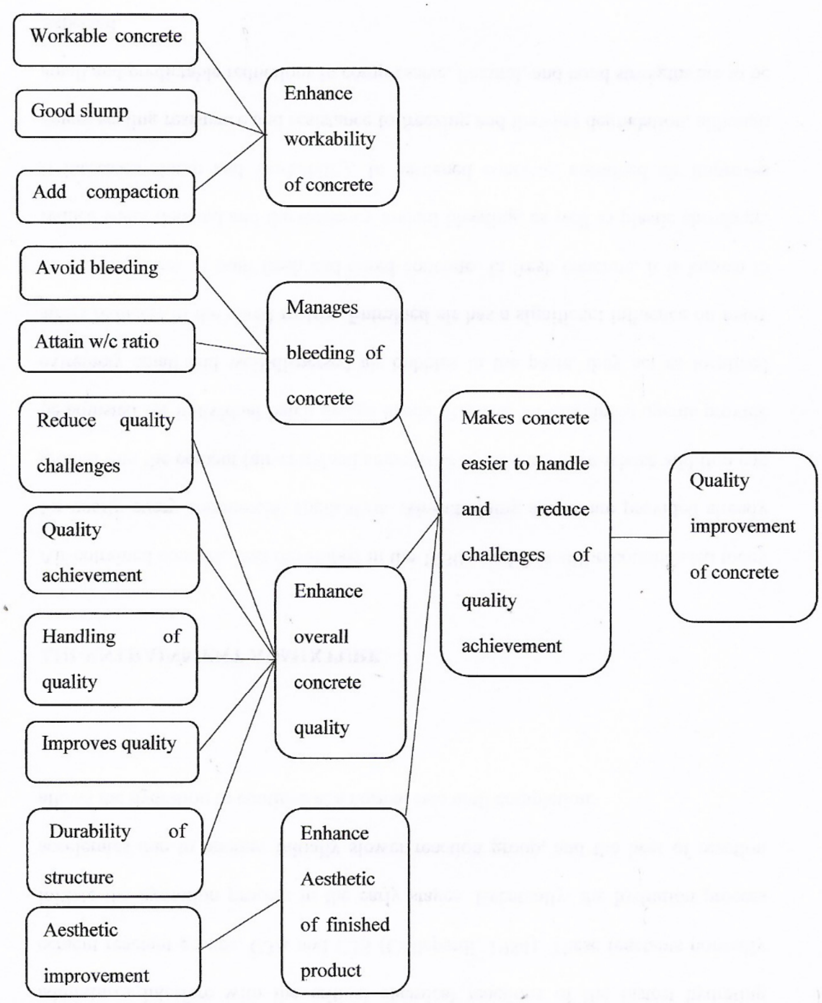
OPINIONS FOR THE USE OF CHEMICAL ADMIXTURE IN CONSTRUCTION PROJECT MANAGEMENT

Codes **Basic Themes** **Organising Themes** **Global Themes**



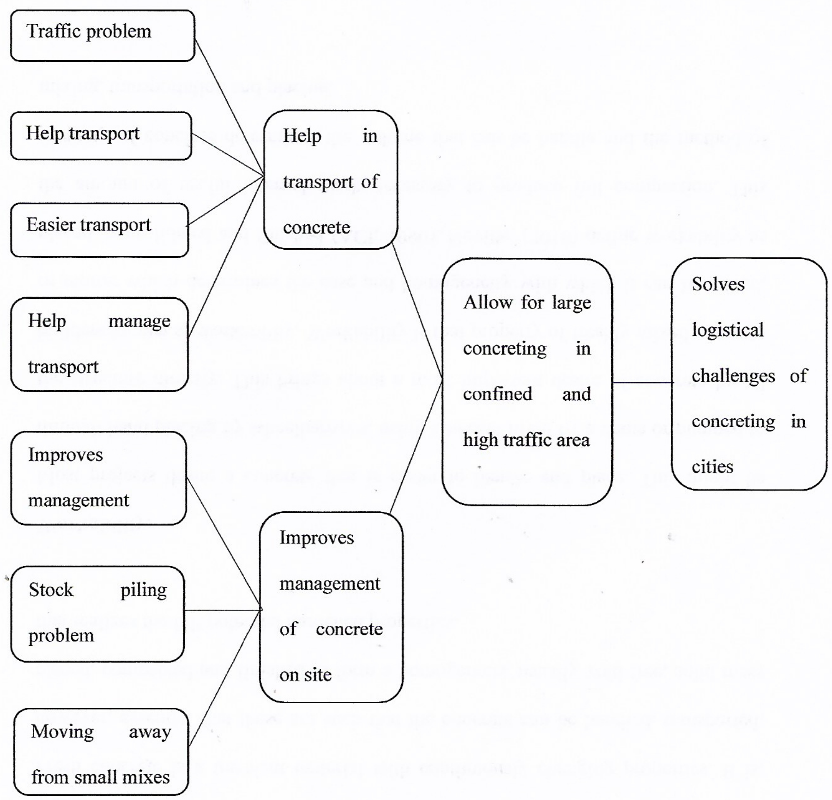
OPINIONS FOR THE USE OF CHEMICAL ADMIXTURE IN CONSTRUCTION PROJECT MANAGEMENT

Codes **Basic Themes** **Organising Themes** **Global Themes**

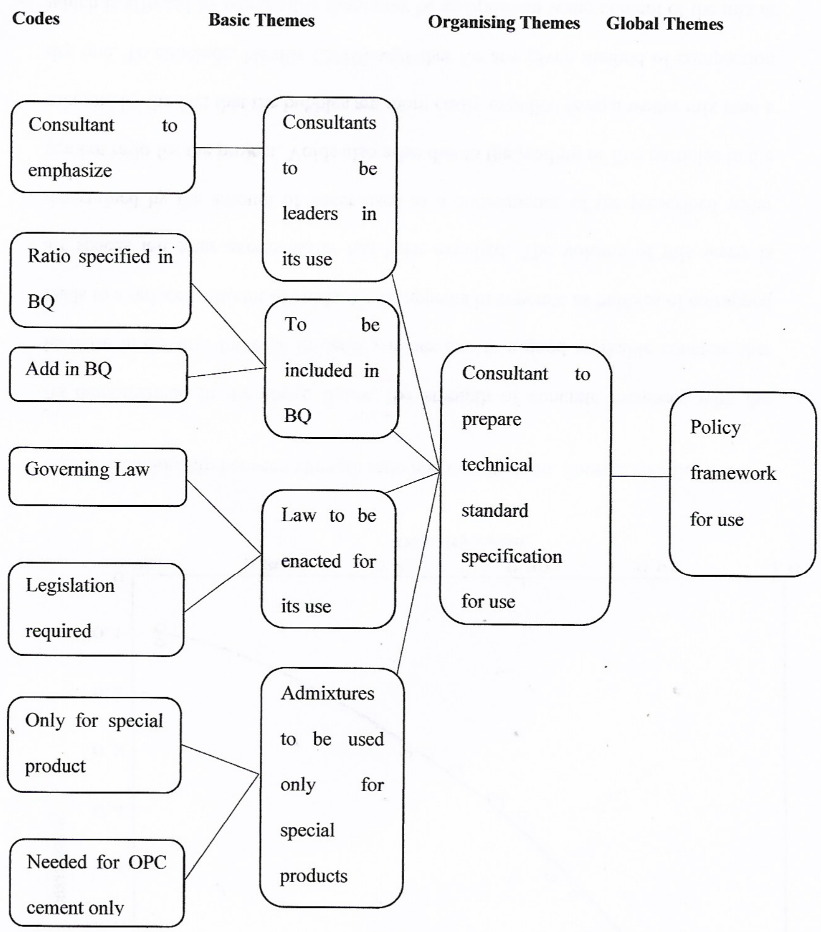


OPINIONS FOR THE USE OF CHEMICAL ADMIXTURE IN CONSTRUCTION PROJECT MANAGEMENT

Codes **Basic Themes** **Organising Themes** **Global Themes**

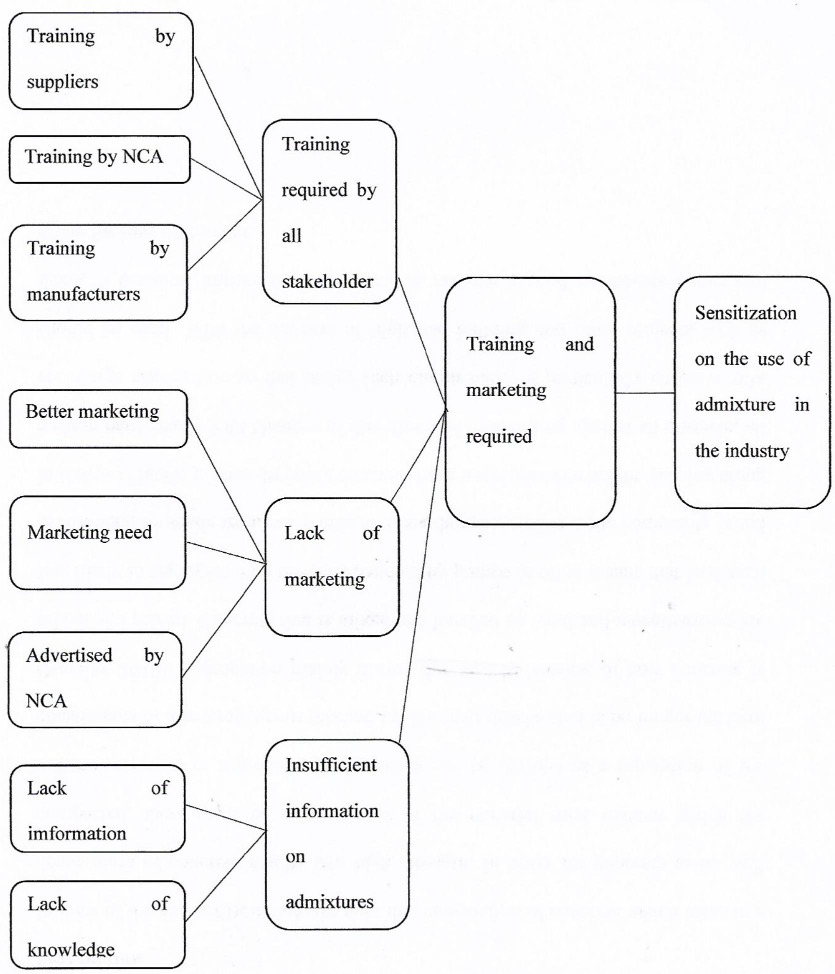


SUGGESTIONS ON ENHANCING USE OF CHEMICAL ADMIXTURES



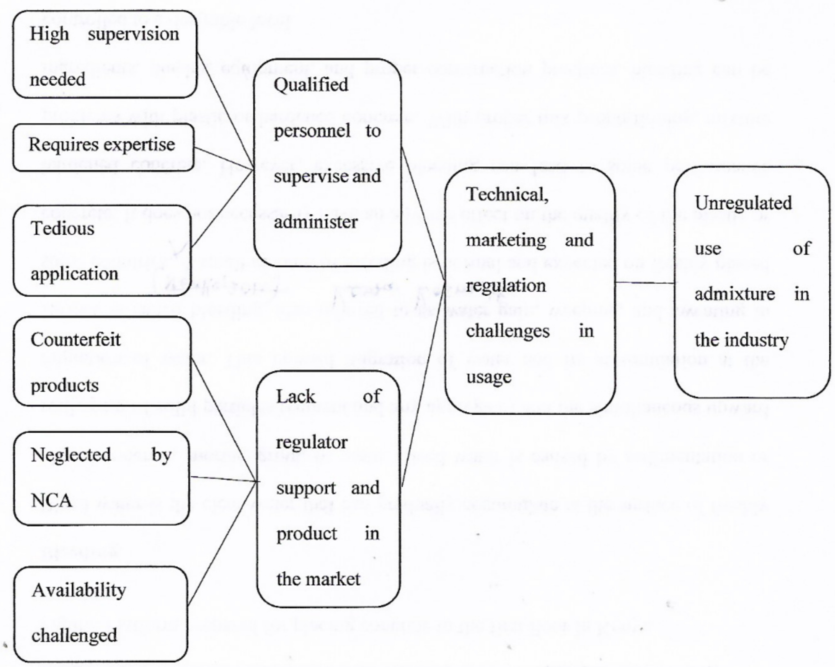
SUGGESTIONS ON ENHANCING USE OF CHEMICAL ADMIXTURES

Codes **Basic Themes** **Organising Themes** **Global Themes**



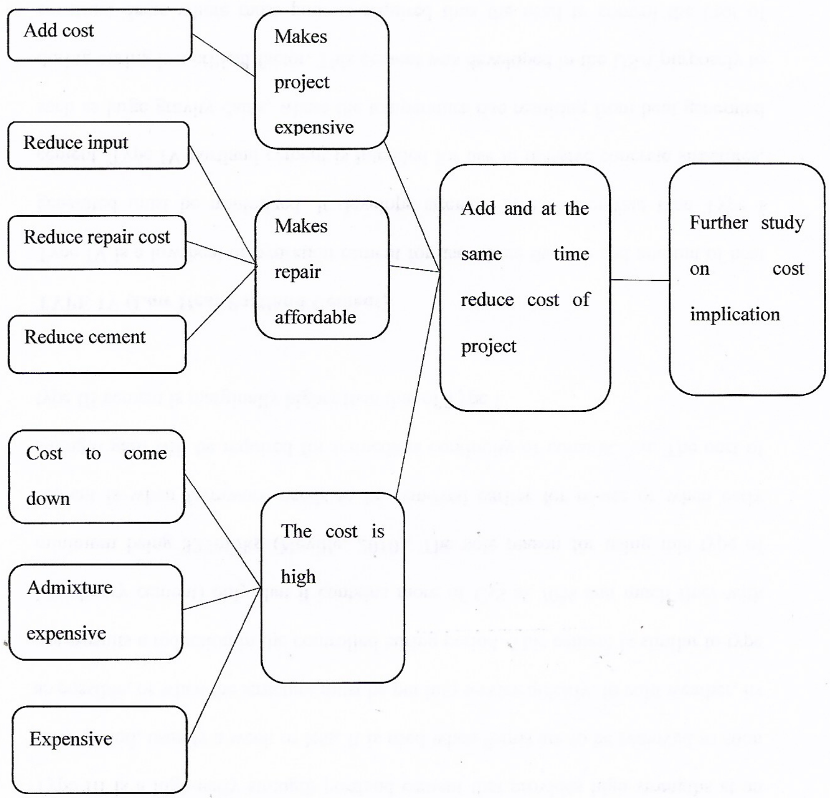
SUGGESTIONS ON ENHANCING USE OF CHEMICAL ADMIXTURES

Codes **Basic Themes** **Organising Themes** **Global Themes**



SUGGESTIONS ON ENHANCING USE OF CHEMICAL ADMIXTURES

Codes **Basic Themes** **Organising Themes** **Global Themes**



SUGGESTIONS ON ENHANCING USE OF CHEMICAL ADMIXTURES