ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

Study on Quality of Site Concrete Production and its Management Practice in Addis Ababa Housing Projects

(Case study on Koye Feche housing Projects)

A thesis submitted to

The school of graduate studies of Addis Ababa University in partial fulfillment of the requirement for the degree of Master of Science in Construction Technology and Management

Advisor: Dr. Abraham Assefa

Prepared By: Habtamu Sisay

March, 2017

Abstract

Concrete, because of its versatility in use, is a major component of most of our infrastructural facilities today. The quality of concrete is affected by its constituent materials, the equipment used and the workmanship in concrete production process. A better or poor concrete may be made of exactly the same ingredients based on the quality control practice of the production process.

The city administration of Addis Ababa is building and administering condominium buildings around the city for more than one million house seekers around different project location of Addis Ababa. Most parts of these projects are reinforced concrete structure in which concrete takes the major proportion among the consumed construction materials.

This research is carried out on the quality of concrete produced and the quality management practice to enhance concrete quality under projects administered by Addis Ababa housing project office, by taking the Koye Feche site as a case study. The research used literature review, desk study, interview with experts and analysis of compressive strength test results on samples collected from ongoing concrete production sites.

Statistical quality control based on compressive strength tests conducted on selected projects reveals that, 40.4% of the test results were found to be defective based on EBCS-2:1995 compliance criteria's. According to ACI-214 classification, 35.4% of test result based on standard deviation indicates poor quality control whereas 71.25% of the test results show poor quality control practice based on their coefficient of variations.

The investigation shows that, the use of poor gradation aggregate and high silt, clay, and dust content of sand, water with impurities, problems with batching which usually called under batching and over batching are major causes of quality problems. Furthermore, lack of attentive control on each production process, lack of management commitment and poor workmanship in quality concrete production is also the most frequent problems identified by respondents.

Key Words: AAHDPO, Coefficient of Variation, CQMP, Management Commitment, Quality Control, Standard Deviation, Statistical Quality Control, TQM and Workmanship.

Acknowledgement

First of all, i would like to thank God for helping me in the accomplishment of this thesis. Then, Dr. Abraham Assefa: Thank you for your assistance. He has been there all the way for me. I also recognize that, without him this work is very difficult to complete. Thank you Dr. Abraham!

Further thanks go to all teachers in Msc Program and special thanks for staffs of AAiT laboratories for their valuable assistance while i collect sample specimens and testing in laboratories. I also thank all stakeholders in Addis Ababa Housing for their cooperation while i collect relevant data from respective sites.

Finally I would like to thank my family and friends. You were helping me in one way or another so thank you all.

Table of Contents

List of Tables

List of Figures

Acronyms

AAHDPO-----Addis Ababa Housing Project Office

ACI-------------American Concrete Institute

ASR-------------Alkali Silica Reaction

EBCS-----------Ethiopian Building code of Standards

ES---------------Ethiopian Standards

ESA ------------Ethiopian Standards Agency

QMP------------Quality Management Plan

QMS------------Quality Management System

QC--------------Quality Control

QA--------------Quality Assurance

CQMP----------Concrete Quality Management Plan

SQC-------------Statistical Quality Control

GDP------------Gross Domestic Product

GTP-------------Growth and Transformation Plan

MSEs-----------Micro and Small Scale Enterprises

CHAPTER ONE

INTRODUCTION

Concrete, because of its versatility in use, is a major component of most of our infrastructural facilities today. It is the most widely used construction material in the world, and its popularity can be attributed to two aspects. First, concrete is used for many different structures, such as building frames, dams, pavements, building or bridges. Second, the amount of concrete used is much more than any other material in the world [1].

Concrete is produced from three basic materials namely water, cement, aggregates (fine and course aggregates) and sometimes an admixture may also be used in a certain prescribed proportion to improve some properties of concrete. The quality of the concrete is affected by its constituent materials, the equipment used and the workmanship in concrete production process. Concrete production process includes: batching, mixing, transporting and placing, compacting finishing of unformed concrete surfaces, and curing of concrete. A better or poor concrete may be made of exactly the same ingredients if there is a difference on the quality control of the production process. Hence, quality control mechanisms for concrete should be in use. Quality control in concrete production is a means of checking concrete ingredients and production processes are in compliance with the requirements stated in the specification or code of practices. In order to have a good quality of concrete it should be done as per the specification given by the designer to address the desired design objectives.

Given that the materials and proportions of ingredients are suitable and properly selected, the quality of concrete depends on the knowledge of the person(s) responsible for the concreting operations. If these people have insufficient knowledge and experience, they are likely to be unaware of the concreting problems which may seriously affect the quality. Thus, the quality of the concrete produced will be poor and may not meet the requirements of the specifications.

Concrete structures are designed and constructed so that they maintain their required serviceability, durability and performance for a sufficiently long period of time, which is expected to be in excess of 50 years. Concrete structures fail when it can no longer provide the required strength to support its designed load. The failure of concrete can sometimes be mild with visible cracks and deflections or severe, leading to partial or total collapse of the structure either during the construction or post-construction stage. To obtain quality concrete products, proper care and control has to be done during ingredient selection, checking compliance with the standards, production processes and workmanship. Repairing poor quality concrete structure is costly, undesirable, time consuming, and in many cases not possible. Therefore, every effort should be made to avoid the production of a poor quality concrete structures and it should also be reminded that all professionals and firms involved in the construction industry have to give special emphasis to quality control.

Currently, Ethiopia is registering high growth rate and construction is go through with a lot of capital investment. In major cities and towns, buildings and infrastructure construction projects are highly observed. Most of these projects are reinforced concrete structures in which concrete takes the major proportion among the consumed construction materials. This is an indication as how much the quality of concrete is important for the overall quality of a building, as the major components of a building are made with concrete such as foundations, columns, beams and slabs which are load bearing elements.

The housing challenge in Ethiopia is very high. According to a UN Habitat report in 2011, the housing deficit was between 900,000 and 1,000,000 units in urban areas, and only 30 percent of the current housing stock is in fair condition, with the remaining 70 percent in need of total replacement. According to the report, in Addis Ababa alone, 300,000 housing units are required to meet the deficit. Therefore, the government has been building condominium houses as part of its integrated housing development program and Addis Ababa has received priority due to the high demand for housing. Even though UN report says 300,000 housing unit meets the deficit, close to one million individuals that seek condos have been registered since 2012 in Addis Ababa only, according to the Ministry of Urban Works and Development. In the last few years, the city administration has completed thousands of condos in the central part of town, although most of the high raised condominium compounds have been built on the outskirts of Addis Ababa.

According to the Grand Transformation Plan II (GTP II), the government plans to construct 430 thousand housing units in all schemes and 63 thousand in partnership with private companies. The plan also intends to earmark 86 billion birr for domestic expenses and USD 1.4 billion in foreign currency and a further USD 1.3 billion to be made available for foreign real estate companies. This plan seems overstated and it is difficult to allocate such amount of money for those projects with the current country's situation. In addition to this, there is no available condominium project under construction in partnership with private companies and foreign real estate companies.

Concrete is a major construction material commonly and regularly used on those buildings. Any type of reinforced concrete framed building construction work constitute at least about 40% of the total works is concrete work [4]. Given that concrete is usually non-factory product or cast in situ product, especially in Ethiopia where it is mostly produced on site manually, it is very important and proper to study its quality and utilization.

Hence, the fact that concrete forms the load bearing parts of a building and the variability in concrete product became leading motivational factors to undertake research on the public buildings so that to identify the problems associated with the quality of site concrete production practices in Addis Ababa Housing projects and at the end to suggest ways of improving it.

1.1 Statement of the Research Problem

Due to high deficit of Housing in Addis Ababa, the government of Ethiopia and the city administration is involved in an integrated housing development program which is government led and financed housing program. The Government built and transfer more than 171,000 housing units for house seekers and still the demand is far from being fulfilled. In Addis Ababa only, more than 900,000 peoples are registered to have a condominium house and the government also planned and to earmark 86 billion birr for domestic expenses and USD 1.4 billion in foreign currency to be made available for foreign real estate companies in the second GTP. Even though all this much budget is allocated to build residential condominium houses, most of stakeholders have worry on the quality of those buildings which are completed and under construction. Fear to the collapse of condominium house at Gerji condominium site, demolished and reconstructed concrete structures at Gelan site, minor and major cracks observed on many condominiums could be good examples. Since these buildings are usually made of concrete structures which cost a significant amount out of the total cost of the project, the concrete should only become a quality material for the construction. Though there is no a research done on the quality of concrete used on those buildings that has been done till now, different stakeholders believe that the concrete they use is low quality due to impurities in sand, uncontrolled concrete production process and poor workmanship. This creates fears to the quality of this project among stakeholders. The researcher also participated on the construction of these housing projects and observed many problems in concrete production that hinder the quality of concrete. Hence, this research tries to investigate current concrete production, quality of the concrete produced and quality management practices in Addis Ababa housing projects.

1.2 Objectives of the Research

The objectives of this research are stated as follows:

- Investigate the quality of site concrete production in Addis Ababa Housing projects
- Investigate concrete quality management practices on those projects
- Examine the quality of concrete produced by considering their compressive strength via taking sample specimens from ongoing projects from selected sample sites at Koye Feche housing project.

Finally the research will set conclusion that it reaches and recommendations regarding to the quality of site concrete production and management practices in Addis Ababa Housing Projects.

CHAPTER TWO

LITERATURE REVIEW

This chapter focuses on general review of literature and concepts available on quality of concrete production process and findings from different researchers who have been published on different journals and books. The chapter will extensively review the quality concept of concrete, concrete making materials, physical and chemical properties of those materials, the production process and the workmanship that primarily determine the overall concrete quality. It further deals and review available literatures and researches which relates with concepts of quality management principles and its application in concrete production.

2.1 Quality of concrete

Quality is defined as the totality of features and characteristics of a product for service that bears on its ability to satisfy the projects functional requirements. The quality of output is always agreed upon between the supplier and the client (in case of construction project works, usually the contractor and the employer, represent the supplier and client, respectively), and the quality objective is to achieve zero defects with best quality of the project works. This is possible only by ensuring quality control at every stage of the construction process. Quality is conformity to standards and requirements to achieve excellence [7].

Quality concrete is that which is capable of meeting the requirements of the job in terms of strength, durability and appearance. Strength is often the major feature in defining the quality because strength is both easy to define and to measure. Therefore in many cases, strength is the unique measurement of concrete quality [9].

A quality concrete is that one who fits to its purpose. This means the product must meet or exceed the customer requirements and this needs improvement of concrete production. Quality improvement refers to product improvement, process improvement and people based improvement. Process improvement relates to a series of action directed towards a specific aim of quality production of concrete. People based improvement refers to the employment of personnel with adequate skill, knowledge and experience needed for accuracy and performance improvement of in-situ concrete [7,13].

Concrete is a variable material, and to meet the requirements described or its intended quality, its production, handling, compaction, finishing, and curing procedures must be controlled, as well as its ingredients. Quality of concrete can only be obtained by skilled supervisors and well trained workers who understand the science of concrete. Hence, the workmanship of concreting operations is therefore supreme in maintaining the required concrete quality. The specifications should also contain sufficient information on the workmanship requirements as well as on materials to maintain satisfactory supervision. A good level of supervision helps to improve the standard of workmanship on the site [16].

Hence, it is the aim of this chapter of the research to briefly discuss about the ingredients of concrete and its production processes in depth by referring different literatures written on this area around the world. Quality management of concrete will also be briefly discussed.

2.2 Concrete Materials

Concrete is a composite material which consists a binding medium within which are embedded particles or fragments of relatively inert mineral fillers. In concrete, the binder matrix is a combination of cement and water; it is commonly called the "cement paste and the filler material, called "aggregate," is generally graded in size from fine sand to pebbles or fragments of stone [3].The paste is composed of cementitious materials, water, and entrapped air or purposely entrained air. It constitutes about 25% to 40% of the total volume of concrete. Different literatures show that, the absolute volume of cement is usually between 7% -15% and the water between 14% - 21%. Air content in air-entrained concrete ranges from about 4% to 8% of the total volume. Aggregates make up about 60% to 75% of the total volume of concrete, their selection is important in concrete quality [2, 6, 8].

Aggregate-coarse and fine combined occupy about 70% space in a given mass of concrete and the rest 30% space is filled by water, cement and air voids [11]. The same literature asserted that, the proportions of each of concrete materials control the strength and quality of the resultant concrete. Green concrete is a plastic mass, which can be molded into any desired shape. This is its main advantage as a construction material.

2.3 Regular Concrete

Regular concrete is a term describing concrete that is produced by using cement, sand and coarse aggregate, with or without use of chemical admixtures. Mix proportions are selected as specified for nominal mix of desired characteristic strength or as determined by following a Design Mix approach. This concrete can be produced to yield desired strength of about 10 MPa to over 50 MPa, depending on the purpose, ranging from plain concrete to structural concrete [3].

Concrete, when it is fresh, should be workable and at the same time be cohesive. Good workability is required to place and compact the fresh concrete and cohesiveness is required to avoid segregation while transporting, placing and compacting. In the hardened state, concrete should be strong, durable and should have minimum voids. It must have sufficient strength, resistant to abrasion, impermeability to resist weathering, chemical attack and corrosion [3,6]. Since regular concrete is very common that is produced in Ethiopia frequently, this thesis is limited to the description of ingredients that produce regular concrete.

2.3.1 Portland Cement

Cement is a material with adhesive and cohesive properties which make it capable of bonding minerals fragments into a hard continuous compact mass. The name "Portland cement" is given originally due to the resemblance of the color and quality of the hardened cement to Portland stone – Portland Island in England [3].

The raw materials required for manufacture of Portland cement are calcareous materials, such as limestone or chalk, and argillaceous material such as shale or clay. Portland cement is the most common type of cement which is produced in all cement factories in Ethiopia.

The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300 to 1500°C, at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The product formed by using this procedure is Portland cement.

There are two processes known as “wet” and “dry” processes depending upon whether the mixing and grinding of raw materials is done in wet or dry conditions. With a little change in the above process we have the semi-dry process also where the raw materials are ground dry and then mixed with about 10-14 percent of water and further burnt to clinkering temperature. The dry process requires much less fuel as the materials are already in a dry state, whereas in the wet process the slurry contains about 35 to 50 percent water. To dry the slurry we thus require more fuel. In Ethiopia most cement factories use dry process to produce Portland cement [1,2,6].

2.3.1.1 Chemical Composition of Portland cement

The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another in the kiln at high temperature to form more complex compounds. These compounds are tricalcium silicate (C_3S), dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetra calciumaluminoferite or iron compound (C_4AF) which are usually regarded as the major constituents of cement. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement; in addition to rate of cooling and fineness of grinding [1,6].

Table 2-1 Approximate oxide composition of ordinary Portland cement. Source: [1, pp 14]

Oxide Composition	Percent Content
CaO	60–67
SiO_2	17–25
Al_2O_3	3.0–8.0
Fe_2O_3	0.5–6.0
MgO	0.1–4.0
Alkalies (K_2O, Na_2O)	0.4–1.3
SO3	1.3–3.0

2.3.1.2 Hydration of Cement

Hydration is the reaction (series of chemical reactions) of cement with water to form the binding material. In other words, in the presence of water, the silicates (C_3S and C_2S) and aluminates (C_3A and C_4AF) form products of hydration which in time produce a firm and hard mass – the hydrated cement paste [2].

The hydration process is not an instantaneous one. It is fast during the first few minutes of mixing and decreases continuously with time. Because of reduction in rate of hydration even after a long time there remains an appreciated amount of unhydrated cement. For this reason, there is hydration at any time after hardening of concrete though it is at a very lower rate [2,4,6]. The various compounds of cements mentioned previously has different rate of hydration, the rate of hydrations of C_4AF is higher than the three major compounds of cement. C_3A has higher rate than C_3S and C_2S; and C_3S has higher rate of hydration than C_2S [3].The hydration products of the major cement compounds, C_3S and C_2S, gives calcium silicate hydrates which is commonly designated as C-S-H. This hydrate product determines the basic physical properties of concrete such as setting and strength gain [1].

2.3.1.3 Heat of Hydration

The reaction of cement with water is exothermic. The reaction liberates a considerable quantity of heat, which may reach up to 500 joules per gram (120 cal/ gram). This liberation of heat is called heat of hydration. This is clearly seen if freshly mixed cement is put in a vacuum flask and the temperature of the mass is read at intervals. The study and control of the heat of hydration becomes important in the mass concrete constructions. It has been observed that the temperature in the interior of large mass concrete is higher. Similarly, the exterior of the concrete mass loses some heat so that a steep temperature gradient may be established, and during subsequent cooling of the interior serious cracking may result [2].

Due to the reason that different climatic zones exist in Ethiopia, it is better to use appropriate type of cement to an appropriate climatic zones to avoid early setting or the use of retarders on hot areas is recommendable to improve effect of early reactions. On contrary, the heat produced by the hydration of cement may prevent freezing of the water in the capillaries of freshly placed concrete in cold weather, and a high evolution of heat is therefore advantageous. It is clear then, that it is advisable to know the heat producing properties of different cements in order to choose the most suitable cement for a given purpose or environment [2].

2.3.1.4 Ordinary Portland (OPC) and Portland Pozzolana Cement (PPC)

There are many types of Portland cements that are produced around the world. These cements are used for specific intended purpose. Among different types of cements, Ordinary and Pozzolanic Portland cements, OPC and PPC, respectively, are common cement types which are mostly produced by the cement factories in Ethiopia and used for concrete production. Thus, the properties of these two cement types are discussed below.

Ordinary Portland cement is the most common cement used in general concrete construction when there is no exposure to sulfates in the soil or in groundwater. The manufacture of OPC is decreasing all over the world in view of the popularity of blended cement on account of lower energy consumption, environmental pollution, economic and other technical reasons [1]. Even though production of OPC around the world is decreasing due to blending substitutes, the production and consumption of OPC cement in Ethiopia is very high.

Portland Pozzolana cement (PPC) is manufactured by the intergrinding of OPC clinker with 10 to 30 percent of pozzolanic material. A pozzolanic material is essentially a silicious or aluminous material which in itself possessing no cementitious properties, which will, in finely divided form and in the presence of water, react with calcium hydroxide, liberated in the hydration process, at ordinary temperature, to form compounds possessing cementitious properties. The pozzolanic materials generally used for manufacture of PPC are calcined clay or fly ash. In Ethiopia, Pumice which amounts from 14 to 28 percent is the most frequently used volcanic rock material for the production of PPC in most of the cement production factories.

Portland Pozzolana Cement has considerable advantages over OPC when made by using optimum percentage of right quality of fly ash. The advantages of PPC are mainly due to the slow conversion of calcium hydroxide in the hydrated cement paste into cementitious product. PPC is economical because costly clinker is replaced by cheaper pozzolanic material. It has also durability characteristics than OPC particularly in hydraulic structures because soluble calcium hydroxide is converted into insoluble cementitious products resulting in improvement of permeability. PPC generates reduced heat of hydration and that too at a low rate. The long term strength of PPC beyond a couple of months is higher than OPC if enough moisture is available for continued pozzolanic action [1,3,4,6].

2.3.1.5 Storage of Cement

Cement being very finely ground is highly hygroscopic i.e. they absorb moisture readily from air. Therefore, it is essential to protect them from dampness before they are used, so that they may fulfill their intended functions. Even when stored under good conditions bagged cement may lose 20 percent of its strength after 2 months of storage, and 40 percent after 6 months of storage [6]. Cement can be stored in air tight bins indefinitely without deteriorating in any way, but this is impractical for site concrete production. Different literatures shows that, cement which is 4 months old and above should be classified as "aged" and vital cement tests should be rechecked for concrete production [6,13,16].

If the cement supply or stock is doubtful laboratory tests should be undertaken to be sure whether it is suitable or no longer to use. In case of laboratory tests are unattainable pointed out that, its purity and quality can be judged through simple field tests .On such conditions, the quality control team or any other professional can identify cement with dilemma. According to Gupta and Gupta (2004), the color of pure cement should be uniformly greenish gray, when cement rubbed in between thumb and fore finger, it should feel smooth hence grittiness shows adulteration. Another checking mechanism is using small quantity of cement which shall be thrown into a bucket of water and a good quality of cement will float and it will sink if the cement contains impurities [9].

2.3.2 Aggregates

Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and affect economy. Approximately three-quarters of the volume of conventional concrete is occupied by aggregate. It is predictable that a constituent occupying such a large percentage of the mass should contribute important properties to both the fresh and hardened state of the product. Aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregate and paste [1,4,6].

2.3.2.1 Physical properties of Aggregates

i. Aggregate Size, Shape and Texture

The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Generally, the maximum size of aggregate should be as large as possible within the limits specified, but in any case not greater than one-fourth of the minimum thickness of the member. Using the largest possible maximum aggregate size will result in reduction of the cement content, reduction in water requirement and reduction of drying shrinkage [4].

The aggregate shape affects the workability of concrete due to the differences in surface which are caused by different shapes. Sufficient paste is required to coat the aggregate to provide lubrication. It is difficult to really measure the shape of irregular body like concrete aggregate which are derived from various rocks. Not only the characteristic of the parent rock, but also the type of crusher used influence the shape of aggregates. Generally the most common shapes of aggregates can be irregular, angular, rounded, flaky, etc.[4].

From the standpoint of economy in cement requirement for a given water/cement ratio, rounded aggregates are preferable to angular aggregates. On the other hand, the additional cement required for angular aggregate is offset to some extent by the higher strengths and sometimes by greater durability as a result of the interlocking texture of the hardened concrete and higher bond characteristic between aggregate and cement paste. Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability. In general, excessively flaky aggregate makes very poor concrete [1].

Surface texture is the property, the measure of which depends upon the relative degree to which particle surfaces are polished or dull, smooth or rough. Surface texture depends on hardness, grain size, pore structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughened it. Hard, dense, fine-grained materials will generally have smooth fracture surfaces. Generally it has significant influence on the fluidity of fresh concrete and the bond between aggregate and cement paste of hardened concrete [4].

ii. Porosity and Absorption Aggregates

The porosity, permeability, and absorption of aggregates influence the resistance of concrete to freezing and thawing, bond strength between aggregate and cement paste, resistance to abrasion of concrete etc. The cement paste due to its viscosity cannot penetrate to a great depth into the pores except the largest of the aggregate pores. When all the pores in the aggregate are full with water, then the aggregate is said to be saturated and surface-dry [3,6]

The water absorption of aggregate is determined by measuring the increase in mass of an oven-dried sample when immersed in water for 24 hours (the surface water being removed). The ratio of the increase in mass to the mass of the dry sample, expressed as a percentage, is termed as absorption. It may be noted that gravel has generally a higher absorption than crushed rock of the same petrological character because weathering results in the outer layer of the gravel particles being more porous and absorbent. Although there is no clear-cut relation between the strength of concrete and the water absorption of aggregate used, the pores at the surface of the particle affect the bond between the aggregate and the cement paste, and may thus exert some influence on the strength of concrete [3,6].

iii. Moisture content of Aggregates

Aggregate exposed to rain collects a considerable amount of moisture on the surface of the particles and, except at the surface of the stockpile, keeps this moisture over long periods. This is particularly true of fine aggregate and the surface-or free moisture (in excess of that held by aggregate in a saturated and surface-dry condition) must be allowed for in the calculation of batch quantities. Coarse aggregate rarely contains more than one percent of surface moisture but fine aggregate can contain in excess of ten percent. The surface moisture is expressed as a percentage of the mass of the saturated and surface-dry and called moisture content.

Determining of the moisture content of an aggregate is crucial in order to determine the net water-cement ratio for a batch of concrete. If the moisture content and absorption of aggregates is not properly determined, the water added during preparing the mix becomes variable. This results in either high or low water to cement ratio. Therefore, there is no doubt that continuous measurement of moisture and automatic adjustment of the amount of water added into the mixer greatly reduce the variability of the concrete produced when the moisture content of the aggregate is variable [3,6].

iv. Bulking of Fine Aggregates

The moisture present in fine aggregate causes increase in its volume known as bulking of sand. The moisture in the fine aggregate develops a film of moisture around the particles of sand and due to surface tension push, apart the sand particles, occupying greater volume. The presence of moisture in aggregate necessitates correction of the actual mix proportions: the mass of water added to the mix has to be decreased by the mass of the free moisture in the aggregate, and the mass of the wet aggregate must be increased by a like amount [1,6].

The bulking of the sand affects the mix proportion if mix is designed by volume batching. Bulking results in smaller weight of sand occupying the fixed volume of the measuring box, and the mix becomes deficient in sand and the resulting concrete becomes honey combed and its yield is also reduced. Volume batching therefore represents bad practice and should be discouraged [13].

2.3.2.2 Deleterious substances in Aggregates

The concrete aggregates should be free from impurities and deleterious substances which are likely to interfere with the process of hydration, prevention of effective bond between the aggregates and matrix. The impurities sometimes reduce the durability of the aggregate [1].

Fine aggregates which usually obtained from natural sources are likely to contain organic impurities in the form of silt and clay. The manufactured fine aggregate does not normally contain organic materials. But it may contain excess of fine crushed stone dust. Coarse aggregate stacked in the open and unused surfaces for long time may contain moss and mud in the lower level of the stack. Sometimes excessive silt and clay contained in the fine or coarse aggregate may result in increased shrinkage or increased permeability in addition to poor bond characteristics. The excessive silt and clay may also necessitate greater water requirements for given workability [1,6].

Sand is normally dredged from river beds and streams in the dry season when the riverbed is dry or when there is not much flow in the river. Under such situation along with the sand, decayed vegetable matter, humus, organic matter and other impurities are likely to settle down. But if sand is dredged when there is a good flow of water from very deep bed, the organic matters are likely to get washed away at the time of dredging. The organic matters will interfere with the setting action of cement and also interfere with the bond characteristics with the aggregates. The presence of moss or algae will also result in entrainment of air in the concrete which reduces its strength [1,6].

The quantity of clay, fine silt and fine dust are determined by sedimentation method. In this method, a sample of aggregate is poured into a graduated measuring jar and the aggregate is nicely rodded to dislodge particles of clay and silt adhering to the aggregate particles. The jar with the liquid is completely shaken so that all the clay and silt particles get mixed with water and then the whole jar is kept in an undisturbed condition. After a certain time interval, the thickness of the layer of clay and silt standing over the fine aggregate particles will give a fair idea of the percentage of clay and silt content in the sample of aggregate under test. According to Ethiopian standards, the maximum limit of silt content is allowed up to 6%. Sand with silt content greater than 6% should be washed or rejected from concrete production.

Fine aggregate from tidal river or from pits near sea shore will generally contain some percentage of salt. The contamination of aggregates by salt will affect the setting properties and ultimate strength of concrete. Salt being hygroscopic, will also cause efflorescence and unsightly appearance. Opinions are divided on the question whether the salt contained in aggregates would cause corrosion of reinforcement. But studies have indicated that the usual percentage of salt generally contained in the fine aggregate will not cause corrosion in any appreciable manner. However, it is a good practice to wash sand containing salt more than 3% [1].

2.3.2.3 Soundness of Aggregate

Soundness refers to the ability of aggregate to resist excessive changes in volume as a result of changes in physical conditions. These physical conditions that affect the soundness of aggregate are the freezing, the thawing, and variation in temperature, alternate wetting and drying under normal conditions and wetting and drying in salt water. Aggregates which are porous, weak and containing any undesirable extraneous matters undergo excessive volume change when subjected to the above conditions. Aggregates which undergo more than the specified amount of volume change are said to be unsound aggregates. If concrete is liable to be exposed to the action of frost, the coarse and fine aggregate which are going to be used should be subjected to soundness test [1,4,6].

The physical causes of large or permanent volume changes of aggregate are freezing and thawing, thermal changes at temperatures above freezing and alternating wetting and drying. If the aggregate is unsound, such changes in physical conditions result in a deterioration of the concrete in the form of local scaling, pop-outs, and even extensive surface cracking. Unsoundness is exhibited by porous flints and cherts, especially lightweight ones with a fine textured pore structure, by some shales and by other particles containing clay minerals [1,4,6].

2.3.2.4 Alkalis and Aggregates reaction

It is known that aggregates should be inert material but researches shows that they are not fully inert. Some of the aggregates contain reactive silica which reacts with the alkali (sodium oxide Na_2O and potassium oxide K_2O) present in cement which termed as alkali Silica reaction (ASR). In Ethiopia there are different potentially reactive silica minerals and rocks that may be used for concrete production. The rocks which contain reactive constituents are siliceous limestone, trap and certain types of sandstones. These reactive constituents may be in form of volcanic glass, zeolites, opals, cherts, quartz etc, the gels produced during reaction swells by absorbing water

[35]. As this gel is confined by the surrounding cement paste, internal pressure increases resulting to disruption of concrete by expansion, and cracking of concrete and eventually failure of concrete structures takes place. The rate of deterioration may be fast or slow depending upon the conditions. It is believed that the swelling of the hard aggregate particles is most harmful to the concrete [4].

The most important factors that promote alkali-aggregate reactions are, reactive type of aggregate, high alkali content in cement, availability of moisture and optimum temperature conditions. Therefore, in order to avoid or eliminate this reaction which affects the overall quality of concrete, some control mechanisms should be provided [13]. The same study asserted that, the alkali aggregate reaction can be controlled by the selection of non-reactive aggregates, use of low alkali cement 0.6–0.4 alkali content cement, use of admixtures such as pozzolana, controlling void space in concrete and by controlling moisture and temperature [13].

Another type of deleterious aggregate reaction is that between some dolomitic limestone (carbonates) aggregates and the alkalis in cement which usually termed as alkali carbonate reactions (ACR). It is likely that the gel which is formed is subject to swelling in a manner similar to swelling clays. Thus, under humid conditions, expansion of concrete takes place. Therefore, the amount and type of the mineralogical content of aggregates used in concrete production is indispensable for determining the resulting quality of concrete [6].

2.3.2.5 Grading of Aggregates

The particle size distribution of aggregates is called grading. Grading determines the paste requirement for a workable concrete since the amount of voids among aggregate particles requires the same amount of cement paste to fill out in the concrete mixture. In making concrete, aggregates must be graded such that the smaller particles of the fine aggregate fill the voids created by the coarse aggregate. The cement paste fills the voids in the fine aggregate thus forming a dense mix. Principle of grading is that smaller size particles fill up the voids left in larger size particles. By adopting proper percentages, of various sized aggregates composite aggregate mix can be developed which will be thoroughly graded to produce dense concrete together with smaller quantities of fine aggregate and cement [2].

The way particles of aggregate fit together in the mix, as influenced by the gradation, shape, and surface texture has an important effect on the workability and finishing characteristic of fresh concrete, consequently on the properties of hardened concrete. One of the most important factors for producing workable concrete is good gradation of aggregates. Good grading implies that a sample of aggregates contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids. The grading of aggregate is determined by sieve analysis. The process of dividing a sample of aggregate into fractions of same particle size is known as sieve analysis and its purpose is to determine the grading or size distribution of the aggregate [1].

2.3.2.6 Strength of aggregates

Since aggregates ranges from 65% to 75% of concrete volume, it contributes a significant role on the strength possessed by concrete due to its higher modulus of elasticity as compared to the cement paste. To have a strong concrete, the aggregate should have high load bearing capacity and resistant to wearing and abrasion effects. To assess the strength of aggregates, a number of strength tests are carryout in laboratories. Some of these are; aggregate crushing value, aggregate impact value, Los Angeles abrasion test, ten percent fines values etc. Therefore, aggregates in use for concrete production have to be strong that satisfy standards requirement.

2.3.2.7 Handling of Aggregates

Handling and stockpiling of coarse aggregate can easily lead to segregation, more especially when the aggregate has to roll down a slope. While stockpiling aggregate at site proper handling mechanisms should be used [13]. The same study lists the following precautions for handling of aggregates:

1. Coarse as well as the fine aggregates should be stored on a hard and dry ground. It should never be dumped on loam or grass. If aggregate is dumped on loam or grass, dirt and rubbish will be carried into the concrete. If hard surface is not available, a platform of planks, or old corrugated iron sheets, or floor of brick or a thin layer of weak concrete or so should be prepared.
2. Piles of sand and coarse aggregate, as well as piles of different sized coarse aggregate should be kept separate by means of compartment walls. These fractions should be remixed in the desired proportion at the time of feeding them into the mixer.
3. Care should be taken to avoid breakage of the aggregate.

4. The bide ends, tea leaves or sugar etc. should not be allowed to be thrown into the aggregate piles. The tobacco of bidi or nicotine of tea leaves or sugar will slow down the setting of the concrete. Tree leaves or grass roots etc. will also damage the binding properties of concrete. Hence, aggregate should be kept clean.
5. While stockpiling, successive consignments should not be dropped at the same place. This will lead to segregation of aggregate.

2.3.3 Water for Concrete

Water is an important ingredient of concrete, and a properly designed concrete mixture, typically with 15 to 25% water by volume, will possess the desired workability for fresh concrete and the required durability and strength for hardened concrete. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. In practice, very often great control on properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. Since quality of water affects the strength, it is necessary to go into the purity and quality of water [1,4].

The properties of water have been found to influence the properties of concrete to a great extent. For concrete production water is used for preparing concrete i.e. for mixing concrete ingredient, curing concrete and for washing aggregates. In most cases the effect of impure water on concrete manifests gradually over time and devastating eventually whereas, in some adverse cases, the manifestation occur immediately. To prevent such irreversible negative effects of water on building fabrics it is better to properly manage it at the early stages and early detection or confirmation of its purity to ensure quick action before its full usage [13].

2.3.3.1 Quality of Water for production of Concrete (Mixing Water)

The common criteria or yardstick to the suitability of water for preparing concrete is that water fit for human consumption is also fit for concrete making. But this yardstick is not true for all conditions. Water containing 0.05% sugar by weight of cement is quite fit for drinking, but it retards cements initial setting time by 4 hours. Thus water to be used for concrete production should not contain substances which may have appreciable harmful effect on the initial setting time, strength and durability of concrete. Substances like oil, acids, carbonates, and bi-carbonates, alkalis, sugar, silt and organic materials have been found to have harmful effect on the properties of the fresh and hardened concrete. Hence concrete mixing water should be free from these impurities. The PH value of concrete mixing water should be between 6 and 8. A dark color or a smell does not necessarily mean that the water contains deleterious materials [4].

Rivers carrying large concentration of suspended solids, industrial and domestic waste, streams and wells in mining and arid alkaline areas should be viewed with suspension and the effect of such waters should be determined before the use in actual construction. This problem is highly observed in Ethiopia and most of the rivers are polluted by this factory wastes. The effluents from this paint, textile, fertilizer and sugar factories and sewage works and gas works have been found to have harmful effect on concrete. Hence the quality water that will be used for concrete production should be well known before using it for concrete production [15].

2.3.3.2 Effect of Water Impurities on Properties of Concrete

i. Carbonates and Bicarbonates of potassium and sodium: -the carbonates and bicarbonates of sodium and potassium affect the setting time of cement. The presence of sodium carbonate accelerates the setting time, while bicarbonates may either accelerate or retard the setting of the cement. The higher concentrations of these salts will reduce the concrete strength considerably. Salts of manganese, tin, zinc, copper and lead reduce the concrete strength to a great extent. Sodium salts reduce the initial strength of concrete to an extraordinarily high degree. Sodium sulphide also deteriorates the strength of concrete.

ii. Algae: - it may be present on the surface of aggregate or in mixing or washing water. It combines with cement forming a layer on the surface of aggregate and reduces the bond between the cement paste and aggregate. Also, algae have the air entraining effect in large quantities in the concrete resulting in lowering the strength of concrete

iii. Use of Sea Water in Mixing Concrete:- Sea water contains about 3.5% salinity. This salinity contains about 78% sodium chloride and 15% chlorides and sulphates of magnesium. Sea water also contains small quantities of sodium and potassium salts which can react with aggregates in the same way as alkalis in the cement. Thus if aggregates are found alkali reactive, then sea water should not be used even for the production of plain cement concrete. The use of sea water to mix concrete does not reduce the strength of concrete appreciably, but it may lead to corrosion of reinforcement in certain conditions. Sea water is known to accelerate the early strength of concrete slightly, but reduces the 28 days strength by 10–15%. Sea water containing large quantities of chlorides may cause efflorescence and constant dampness in the structure. Thus where appearance is important, seawater should not be used for concrete mixing. The use of sea water is also not advisable in plaster work where the surface is likely to be painted on a later date [1,4,6].

Table -2.2 shown below summarizes the permissible limits of impurities in water for use of concrete production.

Table 2-2 limits of permissible impurities in water Source: [6]

Type of Impurities		**Permissible percentage of solids by weight of water**
Organic Impurities		0.02
Inorganic impurities		0.3
sulphates		0.05
Alkali Chlorides	For Plain concrete	0.2
	For Reinforced Concrete	0.1

2.3.3.3 Water for Curing of Concrete

Water suitable for mixing concrete is also suitable for curing of concrete. Curing water should not produce any objectionable stain or unsightly deposition the surface. Iron and organic matter in the water are chiefly responsible for staining or discoloration and especially when concrete is subjected to prolonged wetting, even a very low concentration of these can cause staining.

The requirements for curing water are less stringent than those discussed above, mainly because curing water is in contact with the concrete for only a relatively short time. Such water may contain more inorganic and organic materials, sulfuric anhydride, acids, chlorides, and so on, than acceptable mixing water, especially when slight discoloration of the concrete surface is not objectionable. Nevertheless, the permissible amounts of the impurities are still restricted. In cases of any doubt, water samples should be sent to a laboratory for testing and recommendations. Water for washing aggregates should not contain materials in quantities large enough to produce harmful films or coatings on the surface of aggregate particles [4].

2.3.4 Admixtures

Admixtures are materials other than the basic ingredients of concrete added to the concrete mix immediately before or during the mixing process to modify one or more specific properties of concrete in fresh or hardened state. Anosike (2011) asserted that, the use of admixtures should offer improvement in the properties of concrete by adjusting the proportions of cement and aggregates. However, it should not affect adversely any property of concrete. He also further asserted, an admixture should be used only after assessing its effect on the concrete to be used under an intended situation. Tests on the representative samples of the concrete materials for a particular concrete should be conducted in order to get dependable information on the properties of concrete containing admixtures. It should also be known that admixtures are no substitute for good workmanship i.e. the effect of bad workmanship cannot be improved by the use of admixtures [4,6].

Currently there are different and many types of admixtures are produced from different suppliers around the world in order to improve various properties of fresh or hardened concrete. Such as admixtures which accelerate the initial setting and hardening of concrete, retard the initial setting of concrete, increase the strength of concrete, improve the workability of fresh concrete, improve the durability of concrete, control the alkali aggregate expansion, reduce shrinkage during setting of concrete, increase the bond between old and new concrete surfaces and also between concrete and reinforcement and etc [1,3,4,6].

2.4 Fresh Concrete

Fresh or plastic concrete is a freshly mixed material which can be moulded into any shape. The relative quantities of its ingredients such as cement, fine and coarse aggregates and water mixed together controls its properties in wet or green state as well as in hardened state. The plastic state of fresh concrete provides a time period for transportation, placing, compaction, and surface finishing. The properties of fresh concrete have a large influence on construction speed and decision making [4].

The properties of fresh concrete are short-term requirements in nature, hence they should be easily mixed and transported, shall be uniform throughout a given batch and between batches, must keep its fluidity during the transportation period and it should have flow properties such that it is capable of completely filling the forms. Since compaction plays an important role in ensuring the long-term properties of the hardened concrete it must have the ability to be fully compacted without segregation and it must be capable of being finished properly, either against the forms or by means of troweling or other surface treatment [4].

2.5 Production of Concrete

2.5.1Specifying Concrete

Concrete can be specified in one of the three common ways. These are Designed Mix, Prescribed Mix and Standard Mix.

Designed Mix: In this case, the mix is specified by a grade corresponding to required characteristic compressive strength at 28 days. In addition to stating the strength grades the purchaser must also specify any particular requirements for cement and aggregate content and maximum free water/cement ratio.

Prescribed Mix: This is a recipe of constituents with their properties and quantities used to manufacture the concrete. The concrete specifier/designer must state: the type of cement, type of aggregates and their maximum size, mix proportions by weight, the degree of workability (slump and or water cement ratio) and the application. Prescribed mixes are based on established data indicating conformity to strength, durability and other characteristics.

Standard Mix: Mix composition and details are specified by: cement to aggregate by weight, type of cement, aggregate type and maximum size, workability and use or omission of reinforcement. These mixes are most suited to site production, where the scale of operations is relatively small. They may be used where mix design procedures would be too time consuming, inappropriate or uneconomic.

2.5.2 Concrete Production Process

Production of quality concrete requires thorough care exercised at every stage of manufacture of concrete. It is interesting to note that the ingredients of good concrete and bad concrete are the same. If proper care is not exercised and good rules to produce concrete are not observed, the resultant concrete is going to be of bad quality. With the same material if intense care is taken to exercise control at every stage, it will result in good concrete. Hence, it is essential to know each stage of manufacture of concrete and preventive measures to be taken for producing good quality concrete. The various stages of manufacture of concrete are: Batching, Mixing, Transporting, Placing, Compacting, Curing and Finishing. Each stages of concrete production will be presented in succeeding sub topics.

2.5.2.1 Batching

The correct measurement of the various materials used in the concrete mix is called batching. Errors in batching are partly responsible for the variation in the quality of concrete. The accuracy of measuring the ingredients affects the quality of the concrete produced, and is largely dependent on the selected batching method [16]. There are two main objectives of batching irrespective of the batching method selected. The first is to obtain uniformity and homogeneity in the physical properties of the concrete, such as, unit weight, slump, air content, strength, and air free unit weight of mortar in both individual and successive batches of the same mixture proportions. The second is to maintain proper sequencing and batching of the ingredients. To meet these objectives, proper batching plant, adequate inspection and supervision of the batching processes are required. Generally concrete can be batched in two ways these are volume batching and mass (weight) batching.

Volume Batching: In this method, the materials are measured by volume using a gauge box. Volume batching is not a good method for proportioning the material because of the difficulty it offers to measure granular material in terms of volume. If the fine aggregate is damp or wet its volume will increase by up to 25% and therefore the amount of fine aggregate should be increased by this amount. This increase in volume is called “bulking”. Each bag of cement as delivered by the factories is packed to contain a net weight of 50kg.

In Ethiopia, volume batching is mostly adopted even for large cast in situ concreting operations and mostly they use box size 50x40x20, 18,16cm according to the grade of concrete to be produced. Hence, as far as batching by volume is practiced in the country adjustments has to be done for the moisture present in sand which results in its bulking and adjustments to the amount of water depending on the absorption capacity and the free moisture content of the sand and the coarse aggregate.

Weight Batching: In weight batching aggregates, cementitious materials and powder admixture (if any) are measured by weight; water and liquid admixtures are measured by volume or weight. This method involves the use of a balance which is linked to a dial giving the exact mass of the materials as they are placed in the scales. This is the best method since it has a greater accuracy and the balance can be attached to the mixing machine [1,2].

2.5.2.2 Mixing

Having placed the correct amount of materials into the mixer, thorough mixing is essential for the production of uniform quality concrete. The mixing should ensure that the mass becomes homogeneous, uniform in color and consistency by mixing all ingredients thoroughly. Thorough mixing means distributing the concrete ingredients uniformly and spreading the cement-water paste evenly onto the surfaces of the aggregates. If this is not achieved, the quality of the concrete discharged will not be the same throughout the mix. There are two methods adopted for mixing concrete namely hand mixing and machine mixing [1,16].

Hand Mixing: Mixing of concrete by hand is less efficient than mixing by machine but on small works hand mixing is still practiced. Concrete mixing by hand should never be done on the ground, as earth and dirt dry grass, leaves, etc will mix with it. It always should be done over an impervious concrete or brick floor.

The materials should be thoroughly mixed in the dry state before the water is added. The water should be added slowly, until a uniform color is obtained. As the mixing cannot be thorough and efficient, it usually results in poor concrete of lower strength. Hence to compensate for the lower strength it is advisable to allow an extra 10% of cement above that normally required.

Machine mixing: Mixing of concrete is almost regularly carried out by machine, for reinforced concrete work and for medium or large scale mass concrete work. Machine mixing is quicker, more efficient and produces much more homogeneous concrete. The mix should be turned over in the mixer for at least two minutes after adding the water. The first batch from the mixer tends to be harsh since some of the mix will adhere to the sides of the drum [13].

Both mixing methods are commonly practiced in Ethiopian construction industry but machine mixing using drum mixers are the most common practice for Class I concrete grades.

The workmanship of the mixing greatly affects the uniformity of the concrete produced. There are different factors that affect the uniformity of mixing. These are, the way of loading to the mixer, mixing time, discharging the mixer, capacity of the mixer, formation of cement balls, formation of head packs, mechanical conditions, design of the mixer and retempering are the most important factors which affect uniformity of concrete produced while mixing [15].

Concrete Mixing Time: On site, there is often a tendency to mix concrete as rapidly as possible, and hence, it is important to know the minimum mixing time necessary to produce concrete of uniform composition and consequently, of reliable strength. The optimum mixing time depends on the type and size of mixer, on the speed of rotation and on the quality of blending of ingredients during charging of the mixer. Generally, a mixing time of less than one to one minutes fifteen seconds (1min.-1min.15sec) produces appreciable non-uniformity in composition and a significantly lower strength; mixing beyond two minutes (2min.) causes no significant improvement in these properties [6]. Table-2.3 below shows different recommended mixing time for different capacity of mixers.

Table-2.3 Recommended Concrete Mixing Time Source: [2, pp126]

Capacity of Mixer(m^3)	Mixing Time(minutes)
0.8	1
1.5	1(1/4)
2.3	1(1/2)
3.1	1(3/4)
3.8	2
4.6	2(1/4)
7.6	3(1/4)

Generally, if mixing takes place for over a long period, evaporation of water from the mix can occur, with a consequent decrease in workability and an increase in strength. A secondary effect is that of grinding of the aggregates, particularly if soft, the grading thus becomes finer and the workability lower. In the case of air-entrained concrete, prolonged mixing reduces the air content by 1/10 of its value/hr [2].

2.5.2.3 Transporting and placing of Concrete

Even though concrete may be proportioned and mixed properly, its quality may be seriously impaired by the use of improper or careless transporting and placing methods. The method used for transportation should deliver the concrete to its final location efficiently without significantly altering its properties.

Concrete should be transported and placed at its desired position as quickly as possible without segregation, drying, etc. As soon as concrete is discharged from the mixer, internal as well as external forces start acting to separate the dissimilar constituents. If over-weight concrete is confined in restricting forms, the coarser and heavier particles tend to settle and finer and lighter materials tend to rise. If concrete is to be transported for some distance over rough ground the runs should be kept as short as possible since vibrations of this nature can cause segregation of the materials in the mix.

Concrete is usually transported through different equipments to place in its position. Some of transportation equipments are Wheelbarrow, buckets, agitating trucks, non-agitating trucks, chutes, belt conveyors, dumpers, concrete pumps, hoists etc. To guarantee good quality concrete, proper transporting and handling is required. Celik and Shetty agreed that factors which affect the quality of concrete through transporting and placing are slump loss, loss of ingredients, segregation and formation of cold joints.

i. Slump Loss: All concretes lose slump. Otherwise, concrete would never harden. The concrete first gradually loses its all slump and then proceeds to harden through the initial and final set and this is known as "normal slump loss". But when concrete loses its workability before placing to such an extent that, placing and compaction cannot be undertaken as specified, then this slump loss is abnormal and this is said to be "slump loss"[1,16].

When the slump loss exceeds the permissible limit, it usually causes significant difficulties. The production rate and the quality of workmanship both decrease. Eventually, the cost goes up and repair for imperfections will be obligatory.

When repairs become necessary, the appearance of the concrete is inevitably diminished. Thus, slump loss can be a serious construction problem. Excessive delivery times and high temperature are major causes of slump loss [1].

ii. Loss of Ingredients: During transporting and placing, the concrete ingredients may be lost. This is usually happen when we use open top transporting equipments such us wheel barrows on rough terrain. As a result, the concrete transporting container needs to be watertight and should avoid loss of ingredients which may result in poor concrete production.

iii. Segregation: Segregation can be defined as separation of the constituents of a heterogeneous mixture so that their distribution is no longer uniform. In fresh concrete, segregation is caused by differences in the size of particles and sometimes in the specific gravity of the ingredients. Fresh concrete may segregate in two ways. Firstly, the coarse particles tend to separate since they travel further along a slope or settle more than the finer particles. Secondly, the paste separates the other constituents. This may bring a poor quality of concrete which may be porous, hard to finish and poor layers formation and poor resistance to wear [1,4].

iv. Cold Joints: The rate of transporting and placing concrete should be enough to prevent the formation of cold joints in the structure. Cold joints occur when a layer of previously placed concrete hardens or sets to such a degree that, a newly placed concrete layer does not bond to it. Hence, if cold joints are unavoidable, it is recommended that, a richer thin mortar layer is placed on the hardened concrete, and then, the normal concrete is placed on that mortar layer. This soft bed reduces the voids between the two layers.

2.5.2.4 Compaction of Concrete

Compaction of concrete is the process adopted for expelling the entrapped air from the concrete. In the process of mixing, transporting and placing of concrete air is likely to get entrapped in the concrete. The lower the workability, higher is the amount of air entrapped. In other words, stiff concrete mix has high percentage of entrapped air and, therefore, would need higher compacting efforts than high workable mixes [1].

Compaction is one of the most significant concrete production phases that determines both the strength and durability of concretes. Since compaction helps to remove the entrapped air from the fresh concrete, removing this entrapped air and rock pockets will improve the strength, durability and appearance of the concrete.

A higher concrete quality can be obtained with a lower water/cement ratio provided that, sufficient compaction is maintained. However, insufficient compaction will reduce the quality of dry concrete at a higher rate than of wet concrete. Proper compaction of concrete is essential to reduce the adverse effects of entrapped air on the quality of concrete. It is well established that, each percent of entrapped air (including the entrained air) reduces the strength of concrete by about 5 to 6%. The imperfections of compaction do not only affect the strength of the concrete, but the durability and the appearance of concrete are also drastically diminished.

Improper compaction can cause troublesome imperfections. The most common compaction imperfections are honeycombing and excessive entrapped air voids which results in poor concrete production. To maintain the desired concrete quality, it is necessary to consider the selection of compaction method, equipment vibration duration, vibration techniques and re-vibration [1,2].

Re-vibration of concrete

Re-vibration is an application of vibration to compact concrete after placing and initial compaction, but preceding initial setting of the concrete. The unintentional vibration of the bottom layer while placing and compacting the successive layer is not considered to be re-vibration. Re-vibration is beneficial if the concrete is again brought to a plastic condition. It may be accomplished by internal vibrators or form vibrators and should be done as late as possible after placing the concrete, providing that, the concrete still can be in its plastic state [4].

Celik (1989) states that, re-vibration results in improving the 28 day compressive strength of concrete by about 14%, when it is carried out about 1-2 hr after placing and it also improves the reinforcement bond strength, reduces the content of entrapped air, and relieves plastic shrinkage stresses [16]. The same study states that, re-vibration is particularly beneficial for the top 500 to 1000 mm of a placement, where the water voids are the most prevalent. Wetter concretes can be improved considerably by re-vibration.

2.5.2.5 Finishing of Concrete

There are two kinds of concrete voids namely, water void and air void. Honey-combed concrete does not develop good bond with reinforcement. Water may penetrate through these voids and corrode the steel. The operations adopted for obtaining a true and uniform concrete surface are called finishing operations. A tamper usually leaves a slightly ridged surface. Thus it needs finishing [4].

Finishing is one of the most important factors that affects the quality and serviceability of a floor or slab. Without special precautions, the top surface of a concrete floor or slab can suffer from reduced quality. To avoid reduced quality for finishing floors and slabs, screeding, floating and finally trowelling process helps significantly. Screeding refers to a leveling operation which removes bumps and hollows and gives a true and uniform concrete surface. Floating is the operation of removing the irregularities from the surface of the concrete left after screeding. Trowelling is the final operation of finishing done where smooth surface is desired. Trowelling should be done after the evaporation of water from the concrete surface. Types of surface finishing's to concrete can be tamped finish, brush finish, wooden float finish and steel trowel finish. Concrete finishing plays vital role in achieving quality of concrete. Therefore, proper concrete finishing methodologies and quality control should be practiced [13].

2.5.2.6 Concrete Curing

Concrete curing is the method of maintaining suitable moisture content and a favorable temperature in concrete during the period immediately after the placement of concrete so that hydration of cement may continue till the desired properties are developed sufficiently to meet the requirements of service. The reasons for curing concrete are to keep the concrete saturated or as nearly saturated as possible, until the originally water filled space in the fresh cement paste has been filled to the desired extent by the product of hydration of cement, to prevent the loss of water by evaporation and to maintain the process of hydration, to reduce the shrinkage of concrete and to preserve the properties of concrete [1,2].

The requirement of curing comes from the fact that hydration of cement can take place only in water filled capillaries. Due to this reason, a loss of water by evaporation from the capillaries must be prohibited. Further water lost internally by self-dehydration has to be replaced by water from outside. Water required for chemical reaction with cement i.e. for hydration is about 25 – 30% of water added to the cement; the rest of the water is used for providing workability and help to continue hydration [1,13].

There are different methods are used to cure concrete. These methods of curing depend upon the nature of work and atmospheric conditions. Generally, there are two common systems of maintaining the presence of the required water for the hydration of the cementitious material which initially is furnished by the mixing water in the concrete. The first one is a moist environment from the continuous or frequent application of water through ponding, sprays, steam, or saturated cover materials such as burlap or cotton mats, rugs, earth, sawdust, straw or hay, and the second is the prevention of loss of mixing water from the concrete by means of sealing materials such as impervious sheets of paper or plastic, or by the application of a membrane forming curing compound to the freshly placed concrete. Care must be taken to ensure that saturated cover materials do not dry out and absorb water from the concrete [1, 2].

2.6 Concrete Quality Management

The quality of a finished concrete structure is affected by the quality of the freshly mixed concrete and the standard of workmanship in handling, compacting, finishing, and curing the concrete. The standard of workmanship throughout the concreting operations is therefore extremely important in construction of a good quality concrete structure. Unfortunately although materials are regularly checked, monitored and tested, the workmanship which is harder to specify and quantify is often given little attention or ignored completely. To improve quality of concrete, producers needs to put all factors that affect concrete quality together into a quality management system (QMS) and adhere to it. A quality management system establishes company policy and goals and sets actions and responsibilities for individuals within an organization with regard to quality. Stakeholders who directly or indirectly affected by the end product of concrete structures should also participate in enhancing the quality of concrete production. It is the intention of this part of the research to discuss the aspects of quality management principles which can be applied in concrete production.

2.6.1 Definition of Quality

Quality is the ability of a product or system to satisfy all the requirements it was designed to meet. Ceilik (1989) states concrete quality as the "degree of excellence", which is generally established in the project specifications. Rakish also stated that quality is not perfection but, merely fitness for the purpose. Hence the best concrete for any given purpose is the one that does the job satisfactorily at the lowest cost. Ceilik clearly states that, quality concrete is that which is capable of meeting the requirements of the job in terms of strength, durability and appearance. Strength is often the major feature in defining the quality of concrete because strength is both easy to define and to measure in concrete production. Consequently in many cases, strength is the unique measurement of concrete quality [16, 17].

Building construction project involves in an extremely complex process, relating a wide range of activities and concrete construction takes a major part of it. Therefore, enhancing the quality of concrete greatly helps the overall improvements of quality of the project. There are different factors affecting the quality of concrete construction, such as design, materials, machinery, topography, geology, hydrology, meteorology, construction technology, methods of operation, technical measures, management systems and so on. Since quality is a complex multi-component product made up of several systems, construction companies must adhere to the principle of quality first, and persist on quality standards with the core of artificial control and prevention to provide more high quality, safe, suitable, and economic composite products.

Quality should be properly managed in concrete production to obtain the intended requirements by the customer. Hence quality control is critically essential throughout concrete production. Patel, Pitroda and Rekish agreed that, if there is no quality control, there is no economic benefit obtained from any construction. They further said that implementing quality management in the course of building construction can effectively prevent the safety accidents to occur during the latter process of the use of building products. The succeeding part briefly discuss about basic principles in project quality management to improve the quality of concrete products which strongly helps to manage concrete production [17].

2.6.2 Quality Management

Quality is the degree to which a set of inherent characteristics fulfill requirements. Stated and implied needs of customers are the inputs to develop project requirements. Quality management involves a continuous search for ways to prevent defects by "doing the job right". Quality management is concerned with preventing problems by creating the attitudes and environment that make prevention possible. A critical quality management in the project context helps to turn stakeholder needs, wants, and expectations into requirements. Therefore the application of project management principles in concrete production becomes mandatory since it is major part of any building construction projects [20].

Project quality management includes all the processes and activities of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken. It implements the quality management system through the policy, procedures, and processes of quality planning, quality assurance, and quality control, with continuous process improvement activities conducted throughout, as appropriate.

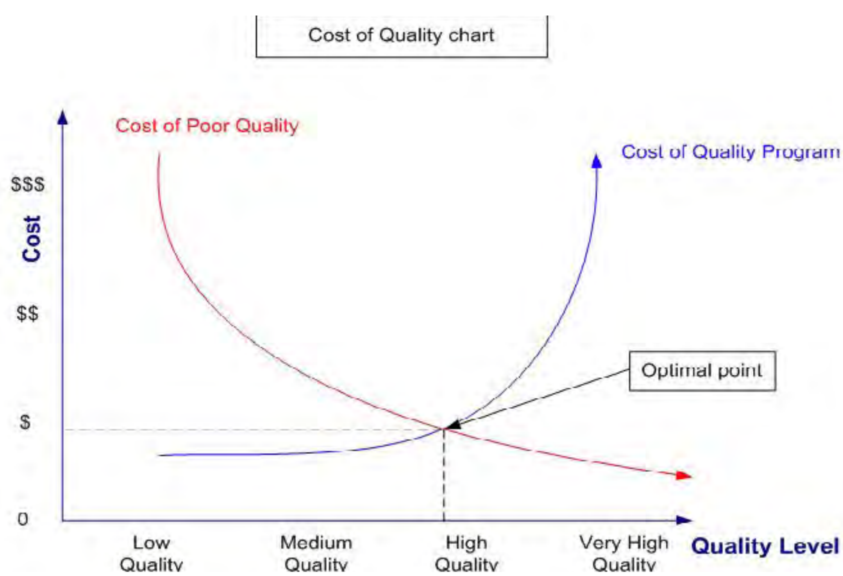
The project quality management process includes three basic stages which help in improving quality production. The first is quality planning and refers to identifying which quality standards are relevant to the project and determining how to satisfy them. The second is performing quality assurance; this stage helps in applying the planned, systematic quality activities to ensure that the project employs all processes needed to meet requirements. The third and final stage is performing quality control which greatly helps in monitoring specific project results to determine whether they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory performance. Hence, applying these three quality management processes in concrete production greatly helps to enhance the quality of concrete produced at site [7].

2.6.2.1 Quality Planning

Quality planning involves identifying which quality standards are relevant to the project and determining how to satisfy them. It is usually one of the key processes when doing the planning process and during development of the project management plan. Quality standards are usually the specification which describes the requirements of the client and stated regulatory standards. If C-30 concrete is specified by the client, to achieve this requirement proper planning for the material to be used, suitable production process ,the workmanship and other factors which affect the quality of concrete is crucial because "fail to plan is planning to fail"[13].

Quality planning shall be done in the course of developing quality management plan. Project Quality plan is a crucial document that any contractor or consultant must have. It describes all the life line of a project that will ensure the end product that is going to be delivered to client meet all the requirement and specifications. Experiences show that, most of consultants and contractors found in Ethiopia do not have any idea on how to come out with this project quality management plan. Therefore, efforts should be employed on understanding of quality management plan and its relevance.

Quality planning should consider cost-benefits tradeoffs and cost of quality (COQ). The primary benefit of meeting quality requirements is less rework, which means higher productivity, lower costs, and increased stakeholder satisfaction. Juran (2011), described quality costs as the total costs incurred by investment in preventing nonconformance to requirements, appraising the


Cost of Quality chart
Cost of Poor Quality
Cost of Quality Program
$$$
Cost
$$
$
0
Optimal point
Low Quality
Medium Quality
High Quality
Very High Quality
Quality Level

2.6.2.2 Quality Assurance (QA)

Quality assurance (QA) is the application of planned, systematic quality activities to ensure that the project will employ all processes needed to meet requirements. It is also described as evaluating overall project performance on regular basis to provide confidence that the project will satisfy the relevant quality standards [7].

In concrete production quality assurance is the responsibilities of all stakeholders who participate in the production process such as the contractor, consultant and client. Quality assurance recognizes professional bodies who participate in the project and regulatory agencies as people on production line, working as a team to achieve a common goal. Their quality control roles will require setting standards, checking and monitoring of production which will lead to a product of a consistently satisfactory standard quality.

2.6.2.3 Quality Control (QC)

Quality control in the production process is a major ingredient which involves checking and reviewing work that has been done, inspection, testing and sampling to ensure good product delivery. Performing quality control (QC) involves monitoring specific project results to determine whether they comply with relevant quality standards and identifying ways to eliminate causes of unsatisfactory results. Quality control is not a onetime duty rather it should be performed throughout the project life time. It is often performed by a quality control department or similarly titled organizational unit. In concrete production the quality control work is usually undertaken by supervisory bodies that are hired by the owner. Quality control can include taking action to eliminate causes of unsatisfactory project performance [7].

Quality control is the application of all the measures that are taken during material selection, concrete production processes and on finished concrete products to ensure the compliance of the works with the specification. The cost of achieving quality requirements during the construction phase is directly proportional to the cost of skilled labor, materials, equipment method and supervision utilized as well as to the cost of monitoring and inspecting the work to verify the output quality and to correct or repair defective work [13].

It also expressed mathematically, the cost of achieving quality at construction phase is directly proportional to the resources employed for the tasks, i.e.

$$Cq = f(x_1 + x_2 + x_3 + \cdots \ldots + x_n) \quad \text{[Eq. 2.1]}$$

$$Cq = SL + M + EM + S + MI \quad \text{[Eq. 2.2]}$$

Where, C_q = Cost of achieving quality at construction phase,

SL = cost of skilled labor,

M = cost of materials,

EM = cost of plants & equipment and method of utilization,

S = supervision, in line with specified standards and best global practice,

MI = monitoring & inspection of works in progress.

According to this study, the absence of any of these quality requirement variables for any given concrete production activity undermines the desired standard result. Another literature also agreed that, in order to achieve quality on a construction activity such as concrete work on site, stakeholders must team up to achieve the set goal. Therefore, all stakeholders who participate in concrete production should give attention for quality control of overall concrete production [10, 13].

The reason of quality control of concrete is to measure and control the variation of those operations which affect the strength or the uniformity of concrete: batching, mixing, formwork design and construction, placing, compaction, curing, and testing. According to Arum (2008), a good quality concrete can be obtained by effectively controlling both human and non-human factors. According to him, human factor refers to effective supervision and good workmanship while non-human factor refers to the materials used in concrete production.

Quality control in construction shall be done through experts who have better knowledge on construction. As different literatures agreed that, the quality of concrete is dependent on different parameters such as the quality of each ingredients, the production process and workmanship. Hence, quality control methods undertaken on each parameter are greatly crucial and strongly help to minimize the degree of obtaining poor quality concrete. The usefulness of quality control of concrete production is not only in the compliance with specifications but also in reduction of production cost for the concrete producer [16,17,18].

Generally quality management system helps to provide a quality product that fits to its purpose. Hence it is crucial to use quality management processes in concrete construction to obtain a good quality of concrete. Quality management shall be carefully planned in to a quality management plan document and all stakeholders shall work in collaboration to address the intended quality. It should be understood that quality management process is not one time end process rather it should be carefully examined and revised based on the actual problems and facts. It always needs the application of PDCA cycle (i.e. planning, doing, controlling and acting). Therefore, through serious control of quality it is possible to obtain the intended quality product.

2.6.2.4 Statistical Quality Control of Concrete

The basis for statistical quality control (SQC) in concrete production or any other industry depends upon a thorough knowledge of the sources of variation affecting the product being subjected to control [22]. In concrete production, quality control is usually done based on 28 days of compressive strength tests. The strength of concrete has an inherent variability as it depends on the variations in properties of concrete and variations due to testing methods [21]. Principal sources of strength variations are summarized in the Table 2.4 below.

Table 2.4 Principal sources of strength variations in concrete production and quality testing

Variations due to the properties of concrete	**Variations due to testing methods**
❖ Changes in w/c ratio caused by o Poor control of water o Excessive variation of moisture in aggregates or variable aggregate moisture measurement ❖ Variations in water requirement caused by: o Changes in aggregate grading, absorption, particle shape o Changes in cementitious and admixtures properties o Changes in air content	o Improper sampling procedures o Variations due to fabricated mould: poor quality, damaged or distorted moulds o Changes in curing: o Temperature variation o Variable moisture control o Delays in bringing cylinders to the laboratory o Delays in bringing standard curing

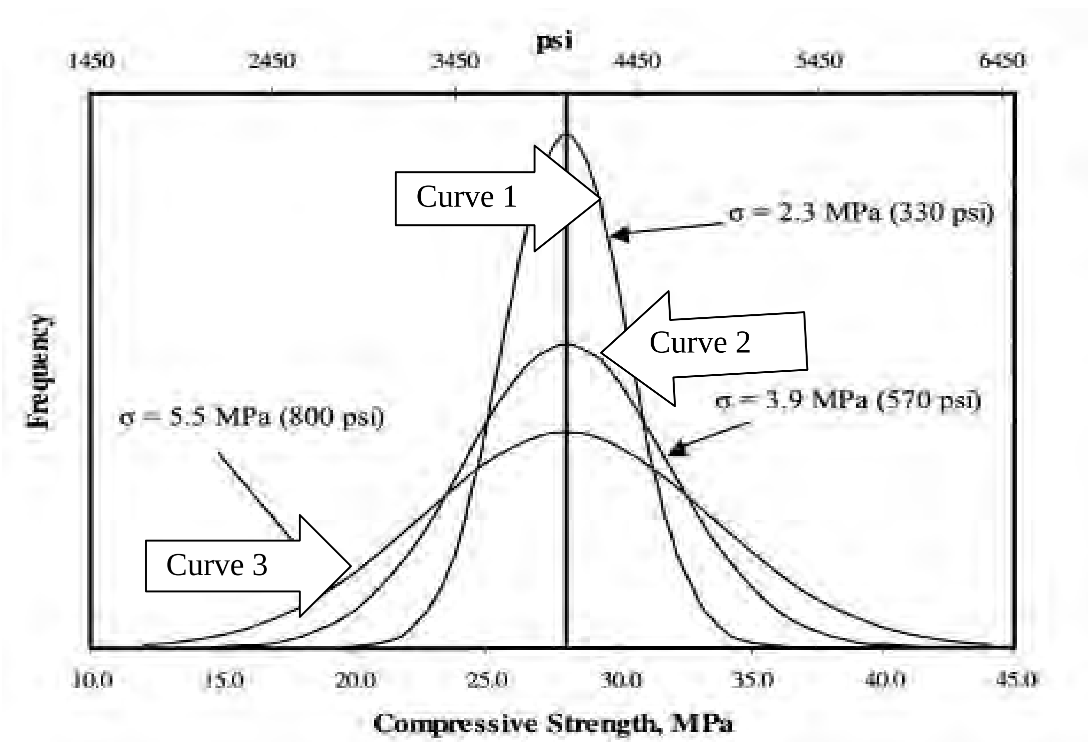
- Delivery time and temperature changes

❖ Variations in characteristics and production process:

- Variation in batching, mixing, transporting, placing, compacting and finishing.
- Variation in temperature and curing

❖ Poor testing procedures:

- Specimen preparation
- Test procedure
- Uncalibrated testing equipment



poor quality concrete. The Ethiopian building codes of standards (EBCS 2-1995) stipulates only 5% defectives are allowed and 95% of the test results should confirm above the characteristics of concrete. The normal distribution can be fully defined mathematically by two statistical parameters: the mean and standard deviation. These statistical parameters of the strength can be calculated as shown below:

$$\overline{x} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{1}{n}(X_1 + X_2 + X_3 \ldots\ldots\ldots + X_n) \text{.............. [Eq. 2.3]}$$

Where X_i the i-th strength test result and n is is the number of tests in the record.

Standard deviations(S) are the most generally recognized measure of dispersion of the individual test data from their average and it can be calculated by the formula given below.

$$S = \frac{\sqrt{\sum_{i=1}^{n} {X_i}^2 - n\overline{x}^2}}{n-1} \text{... [Eq. 2.4]}$$

Where S is the sample standard deviation, n is the number of strength test results in the records, X is the mean or average strength test results.

Coefficient of variation (*V*) is the sample standard deviation expressed as a percentage of the average strength is called the coefficient of variation and it can be calculated as

$$\mathrm{V} = \frac{\mathrm{S}}{\overline{\mathrm{X}}} * 100 \text{...[Eq. 2.5]}$$

Where V is the coefficient of variation S is the sample standard deviation and $\overline{X}$ is the sample average strength of test results.

2.6.2.5 Standard Control and Compliance Criteria's for Concrete

The principal purposes of statistical evaluation of concrete data are to recognize sources of variability. This data can then be used to determine appropriate steps to maintain the desired level of control. One simple approach of statistical control is to compare overall variability and within-test variability, using either standard deviation or coefficient of variation, as appropriate. ACI 214 states different standard control which are appropriate to concrete and the tables below summarize standard deviation and coefficient of variation for different control standards.

Table 2.5 Standard deviation for different control standards, Source ACI 214

Overall Variation

Class of operation	Standard deviation for different control standards, MPa				
	Excellent	Very Good	Good	Fair	Poor
General construction testing	Below 2.8	2.8-3.4	3.4-4.1	4.1-4.8	Above 4.8
Laboratory trial batch	Below 1.4	1.4-1.7	1.7-2.1	2.1-2.4	Above 2.4

Table 2.6. Coefficient of variation for different control standards, Source ACI 214

Overall Variation					
Class of operation	Coefficient of variation for different control standards (%)				
	Excellent	Very Good	Good	Fair	Poor
General construction testing	Below 7	7-9	9-11	11-14	Above 14
Laboratory trial batch	Below 3.5	3.5-4.5	4.5-5.5	5.5-7	Above 7

Any specified concrete strength, should have a tolerance for test results conducted for quality control. It is impractical to specify an absolute minimum strength, because there is always the possibility of even lower strengths simply due to random variation, even when control is good. There will always be a certain probability of tests falling below characteristic strength of concrete. British standard (BS 5328:1990), American Concrete Institute Association (ACI 318), Indian standards (IS 456:2000), and most other building codes and specifications establish tolerances for meeting the specified compressive strength acceptance criteria. Ethiopia also has building code of standards called EBCS-2:1995 which establish tolerance for meeting the specified compressive strength acceptance criteria. According to EBCS-2:1995, two compliance criteria's are specified.

Criterion 1: This criterion may be applied in all cases but is less suited to large scale sampling each lot is represented by three samples, the strength of which are $X_1 < X_2 < X_3$.According to the code, a lot is accepted if the following conditions are satisfied simultaneously.

$$m_3 \geq f_{ck} + K_1 \qquad \text{[Eq. 2.6]}$$

$$X_1 \geq f_{ck} - K_2 \qquad \text{[Eq. 2.7]}$$

Where, m_3 is the mean value

F_{ck} is the specified characteristic strength

K_1& K_2 are the margins of strength given in the table below.

X_1 is the average strength of the minimum strengths for the several lots

Table 2.7 Margins of Strength in MPa, Source: EBCS-2:1995

Margin of strength	First two lots	Third and Fourth	Fifth lot and above
K1	5	4	3
K2	1	2	3

Criterion 2:- this is suitable for large lots. Each lot is represented by not less than 15 test specimens and the lot is accepted if the following conditions are satisfied simultaneously.

$$m_n - \lambda S_n \geq f_{ck} \qquad \text{[Eq. 2.8]}$$

$$X_1 \geq f_{ck} - K_2 \qquad \text{[Eq. 2.9]}$$

Where m_n = is mean value

S_n is standard deviation of set of sample result

f_{ck} is the characteristics strength

K_2 is the margin of strength (may taken as 4MPa)

λ is coefficient (may be taken 1.4 MPa)

n is number of specimens

In case of the test results do not satisfy the requirements of the selected acceptance criterion, EBCS -2:1995 recommends measures to be in use.

1. By identifying the structure with defect, do necessary checking of structural safety using appropriate calculations.
2. Check tests by non-destructive methods are applicable to hardened concrete in the finished parts of a structure or in precast unit.

2.7 Concrete Production Practice in Ethiopia

Different researches show that, the construction industry in all developing countries should improve. Many writers state that governments are responsible for the construction industry development, however, Anosike (2011) argues that not only government but also construction enterprises and practitioners can contribute to efforts to improve the industry. He suggested two improvement areas; one is the need of continual reviewing of building regulations and standards drafted in the form of technical aids rather than restrictive rules and in a language appropriate to the educational background of the majority of the users. The other is the need of construction enterprises to improve their productivity, efficiency, quality of work and innovation as corporate objectives, and set up appropriate organizational structures to achieve them. Since Ethiopia is one of the developing countries in the world with the fastest growth rate, improvements in the quality of the construction industry is mandatory.

The construction industry in Ethiopia is boosting in high growth rate due to the need for infrastructures and other business sectors in the country. It contributes about 7.6% of the country's GDP as reported on 2014. Though there is a high growth rate in the construction industry of Ethiopia, most of mega projects are executed with foreign contractors due to lack of enough skilled professionals and inexperienced workmanship.

Concrete production in Ethiopia is not that much automated. Most of the building projects exist throughout the country uses cast in situ concrete for building structures but currently ready mixed concrete production and suppliers are emerging in urban areas of the country in significant amount. The production process of cast in situ concrete is accomplished on site manually. Every production processes are usually done through unqualified laborers. Even most constructors are not fully equipped and well organized. Therefore, with all those reasons the quality of concrete and overall buildings quality may greatly varies from project to project. This situation is observed commonly in public projects such as condominium projects. UN-HABITAT in its 2011 report pointed out that management of specific issues like location, built environment design, and construction quality are unanticipated challenges of the program. The same report expressed that if not addressed properly, the mentioned challenges might endanger the long-term success of the program.

The integrated housing development program is the one among available mega and government led projects in Ethiopia. One of the unique characteristics of the program is that it has a variety of large numbers of stakeholders with distinct job specifications. The AAHDPO project office manages and administers the project as a client. Assisting AAHDPO in contract administration, the consultants supervise and inspect the works. Micro and small scale enterprises (MSEs) are responsible for the production of construction material and installation works. The contractors on the other hand are responsible for the construction of major structures of the building with the material provided to them by AAHDPO and MSEs. Since all frame structures of those buildings are reinforced concrete, concrete production on those projects is practiced in significant amount. On those projects, concrete is produced with crushed aggregate, sand, cement and water. Crushed aggregates and cement is supplied by the AAHDPO and contractors supply sand due to insufficient sand suppliers from one resource [26].

The quality of concrete produced on those projects varies from good to bad and the variability in the quality of concrete production on those projects is due to lack of testing, selecting and handling of concrete making materials[14]. The study further states that, lack of proper control while producing concrete and poor workmanship also another factor which affects the quality of those projects. Abebe (2005) also listed the above factors which are highly observed in Ethiopian construction industry. He also further pointed that lack of understanding of the bulking effect of sand, moisture content of aggregates and unknown dates of cement which might be expired cements are another factor that might affect the quality of concrete produced but mostly omitted in concrete construction of Ethiopia.

Hiwot (2012) also identified the key challenges in the construction industry of Ethiopia which causes unsatisfactory quality for concrete construction. She mentioned unsatisfactory concrete ingredients and steel reinforcement, poor workmanship and lack of adequate supervision. The above studies agreed that there is a gap in the improvement of quality in overall building projects of Ethiopia. Therefore, identifying the gap from accepted standard helps in the improvement of quality of the construction sector.

The challenges with concrete production in Ethiopia are related to different factors which contribute to overall quality production. Hence studying concrete production practices and identifying the problems exist on projects helps to take corrective measures and protect those public buildings from damage and to make them serviceable and durable. To enhance the quality of concrete on those public buildings, all stakeholders should work hard by implementing quality management principles which can be applicable on concrete construction through quality planning, quality assurance and quality control.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the research design and methodology used in acquiring the necessary information to achieve the research objectives. It specifically presents the research design, describes research approach and techniques, presents sampling techniques in terms of sample size and selection, validity and reliability of the research, data collection methods and data analysis methods.

3.2 Research strategy and type

This is an assessment research with the aim of evaluating public building construction of Addis Ababa Housing Development Projects in the context of concrete quality and its management practices of constructing houses. It is emphasizing on examining the quality of concrete produced on those projects on one hand and evaluating the existing management practice for the improvement of concrete quality on the other hand.

3.3 Study design

The research uses both qualitative and quantitative data with the aim of evaluating the quality of concrete used in currently undergoing projects of Addis Ababa Housing projects and the research also tries to investigate the quality management practice for concrete by considering a case study at Kuye Feche which is located at Addis Ababa, Akaki Sub city.

3.4 Data collection methods and procedures

The research uses both primary and secondary data collection methods as a tool to gather the necessary information. The primary data was collected using different methods and mainly through in depth desk study, project site observation, interview with experts and concrete sample test results. Secondary data was obtained from journals, codes of standards and other relevant and related documents.

The study started by assessing different literatures that relates to the research. The literature review acquired different data from journals, researches that has been made on related topics, books, etc. Various standard codes for concrete such as Ethiopian Building code of standards (EBCS), American Concrete institutes (ACI) codes and others have also been referred.

Desk study on selected projects was employed to assess the current concrete production practice on those projects. The researcher also collected 44 lots (1 lot is 3 pieces of 15x15x15cm cube) sample specimens based on ES ISO 1920-1:2014 and the specimens are cured based on ES ISO 1920-3:2014 and it was stored in molds for 24hours and after this period the specimens are marked and removed from the molds and kept submerged in clear fresh water until taken out and transported for test. Then the specimens are transported to Addis Ababa institute of Technology laboratory (AAiT) for their compressive strength test to investigate the current quality status of concrete produced in Addis Ababa housing projects using concrete statistical analysis methods. A chart quality controlling method called Shewart chart is also used to determine the control level of concrete production on these projects.

Rooted in literature review, observation and desk study, well organized closed interview questionnaire was prepared and interviewed with 47 experts who are currently participating in Addis Ababa Housing projects. The respondents are selected from the client (i.e. Addis Ababa Housing Development Program Office, AAHDPO), consultants and contractors who are involved in condominium housing projects, concerning their views and experiences related to condominium housing projects.

Standard concrete quality management plan for those projects also prepared to assist the current concrete production practice.

Using all available data, interview and by applying statistical analysis method for compressive test results obtained from the selected sample projects, detailed information about the work environment characteristics, awareness and practice towards concrete production and its management to enhance the quality of concrete produced on those projects is investigated. Finally conclusion and recommendations are also drawn out based on the analyzed results and discussions.

3.5 Sample size determination and sampling technique

Sample specimens for concrete from ongoing projects are collected from two selected big projects that are found around Kuye Feche project area, which are named as Project 12 and Project 17 which have 126 and 124 blocks, and 50 and 56 contractors respectively. These two projects are selected based on the suggestion of authorized officials and experts working around there. The main reason for selecting these projects is the availability of concrete work in significant amount which helps to collect sample specimens and to investigate actual concrete production practices from ongoing concrete production sites.

3.6 Ethical clearance

Initially support letter, which expresses the identity of researcher, is obtained from Addis Ababa institute of Technology (AAiT). Then, for sample specimens, interview and data collection procedures permissions was obtained from AAHDPO main office and then branch offices. All the results of compressive strength are used only for research purpose to keep the good will of the contractors who were cooperatives while the researcher takes sample specimen from their corresponding site. Verbal consent was mandatory to obtain from every study subject before any act.

CHAPTER FOUR

CONCRETE QUALITY MANAGEMENT PLAN FOR AAHDPO PROJECTS

4.1 Introduction

Project Quality Management Plan (QMP) is an essential document that any contractor or consultant must have. It is the life line of a project that will ensure the end product that is going to be delivered to client meet all the requirement and specifications. After studying the level of quality management practice for concrete on those projects and believing that the preparation of QMP helps in the improvement of quality of concrete, the author provides a proposed quality management plan for concreting works in AAHDPO projects. The Quality Management Plan is adapted and prepared based on different quality management plans used for international projects.

The prepared project quality management plan for concreting activities (CQMP) document offers essential information about concrete materials related to quality assurance (QA) and quality control (QC) practices for Addis Ababa housing development project office (AAHDPO) condominium building projects with much significant concrete structures. It is the author's intention that, the document serves as a guide for developing a QMP for concrete construction of significant concrete structures of AAHDPO projects.

The project management team, consultants and contractors should prepare and use QMP documents (project-specific QC and QA procedures) which are appropriate and fits to a given Project. Related to the scope of the research, the author limits the quality management plan to only concreting activities where its implementation strongly helps in the improvement of concrete production. Therefore it is the intention of this chapter to discuss the contents of the prepared quality management plan documents where the full document is attached in the appendix part of this thesis.

4.2 Organization of Concrete Quality Management Plan

The quality management plan is comprised of eleven sections which are discussed in depth in the proposed quality management plan prepared. But it is the goal of this part of the thesis to outline the contents that the document covers.

4.2.1. Introduction

This section describes the project setting, the contract and related documents and the quality control plan overview. With project setting the owner of the project and other background of the project which is related to Addis Ababa Housing project is discussed in brief. The quality control plan overview briefly discuss the contractual relationships between client, contractors and supervisors in assuring the quality of the current concrete production in Addis Ababa Housing projects. It also outlines necessary checklists for storage of concrete materials, labor enforcement and equipment proposals used in concrete production of those projects.

4.2.2. Project Quality Control Organization

This section of the document deals and presents the organization and key personnel involved in the construction of Addis Ababa Housing projects to administer the projects such as Consultants and contractors. Their responsibilities and authorities of each organization in the improvement of concrete quality, the structure of the quality control organization with some suggested modification and the minimum used and suggested training and experience of the quality control officer and personnel.

4.2.3. Submittals

This section presents the procedures for processing submittal from contractors to consultants then to client. It briefly suggest important procedures to be followed in using this submittal to disseminate information among stakeholders which helps in good planning of resources used for concrete production. It further suggested the approval and disapproval procedures that can be applied in using these submittals.

4.2.4. Performance Monitoring Requirements

This section addresses quality control for performance monitoring requirements by following the projects by using progress reports and updated schedule by the contractors. Quality control reports which shall be conducted and the elements included in this reports are discussed and progress reports regarding to overall project is also briefly described and some reporting formats are suggested to encourage the use of this reports.

4.2.5. Inspection and Verification Activities

In this section the quality control, verification, and acceptance testing plans is discussed in detail. The plans will cover the type, test standard, frequency, control requirements, and assigned responsibility for inspections and tests. For the verification purpose the consultant involvement in relation to code of standards is also discussed. According to this plan the consultant's resident engineer will review and approve these plans as part of the contractor quality control plan submittals and follows its accomplishment throughout the project life. Contractor's inspection plan for testing and checklists which can be applicable in quality concrete production is also presented in this section of the QMP.

4.2.6. Construction Deficiencies

This section provides the implemented procedures for tracking concrete construction deficiencies (non-compliance and non-conformity) from identification of the non-compliance through acceptable corrective action without compromising the quality of the concrete product. It defines the prevention methods that can be applied in concrete production and how to identify or trace existing problems and procedures to be followed in taking corrective action for deficiencies. It also further states the controls related responsibilities and authorities for dealing with noncompliant concrete products.

4.2.7. Documentation

This section deals with reports which shall be documented in well-organized way to assess the quality status of the project at any point. This documentation includes daily reports of concrete and other significant work items, testing and reporting forms which simplify keeping of documents and any control of quality made at the project sites.

4.2.8. Field Revisions

This part of the plan deals with changes or revisions that can be done based on actual site condition which might be initiated by one of the stakeholders to improve the level of quality. Section nine deals with the reporting standards of the final quality control to the client. Section ten is all about the references made while preparing this proposed CQMP documents for use in AAHDPO projects. Section eleven provides appendixes composed of sample forms for qualification test schedule, inspection schedule, test schedule and typical construction forms. The completed quality management plan with its appendices is attached as appendix in this thesis.

CHAPTER FIVE

FINDINGS AND DISCUSSIONS

5.1 Introduction

This chapter consists of the research findings and discussions. The findings here are based on the analysis of collected fieldwork data for compressive strength test results conducted on concrete production sites and responses from experts through an organized interview questions.

A short description of general characteristics of the project and research respondents which participated in interview is presented at the beginning for clear understanding of these findings and analysis. Following this, statistical analysis based on compressive strength test result is done and presented. Then, analysis of the data regarding to the research interview questionnaires, desk study, and observations done at the studied sites is described. The analysis mainly deals with the current cast in-situ concrete production practices in Addis Ababa housing projects and the management practice to improve the current concrete quality to better level based on observations and respondents opinion by comparing to the standards and scientific concrete production practices. It also analyses the current concrete quality control level using one of the control chart method known as Shewart control chart method by considering the obtained compressive strength test results on those public projects as a quality measurement tool.

5.2 Project Description

5.2.1 The Project

The integrated housing development program is the one among mega and government led projects in Ethiopia. One of the sole characteristics of the program is that it has a variety of large numbers of stakeholders with distinct job specifications. The AAHDPO project office manages and administers the project as a client. Assisting AAHDPO in contract administration, the consultants' supervise and inspect the works. Micro and small scale enterprises (MSEs) are also responsible for the production of construction materials and installation works. The contractors on the other hand are responsible for the construction of major structures of the building with the material provided to them by AAHDPO, MSEs, and themselves. Since all frame structures of the program's buildings are reinforced concrete, concrete production is practiced in significant amount.

The selected projects are found in Kuye Feche housing project sites which are located in Akaki-Kality subcity. Each project averagely consists of more than 6,500 housing units which will be constructed with 53 contractors on average, and one consulting firm for each project. But sometimes two consulting firms are assigned while the number of blocks becomes unmanageable by one consulting firm which is decided and hired by AAHDPO.

5.2.2 Description of main project participants

5.2.2.1 AAHDPO

AAHDPO is the responsible body for the administering and regulating the whole construction and contract administration work. It is the one who hire and assign every consultant and contractors to the site project offices. The project office on site is responsible for the follow up and administration of the specific project site under the supervision of head office. It also follows and controls whether the consultants and contractors are working according to the contract and incase of problems occur, the project office takes corrective measures to improve the quality of work. The respondents from those offices were nine engineers from different construction follow up offices, which are located around Kuye Feche project sites.

5.2.2.2 Consultants

There are many different consulting firms in Kuye Feche site, whose consulting grade varies from grade three to one, and are responsible for construction supervision and contract administration of many blocks around the site. They are responsible for construction management issues, such as works inspection, quality control and approval, material approval, payment approval, and management of contractual issues. The respondents from the consultants were 13, which had a high level of education and have work experience which varies from two to more than eight years in construction projects of similar nature. Most of the resident engineers working in the consulting firms have at least four years of experience and upwards of 12 years. Some are also worked on other condominium projects since from the beginning.

5.2.2.3 Contractors

The contractors are responsible for the construction of major structures of the building with the material provided to them by AAHDPO, MSEs and themselves. The profile of the contractors shows that most of contractors are educated or at least they have good working experience, and have an average work experience of four years. There were 25 respondents from contractors whose educational level varies from Diploma to BSc degree in different engineering and interdisciplinary fields. The company profile of the majority of the contractors (65%) fall under the category of GC/BC grade 5-6 and only a few (35%) were under category GC/BC grade 3-4. The majority of the contractors or more than 95% of the respondents have only a foreman, storekeeper, and security guard as key personnel. Whereas the contract document requests at least a BSc holder engineer in civil engineering and other related fields who have at least four years of experiences in related or the same project level. Respondents described that most of the contractors have not participated in big projects before and some of them initially participate only in condominium projects. However, currently there are few contractors that are participating in other construction projects in addition to the condominium projects.

5.3 Personal background of respondents

Totally there were 47 respondents who participated and were interviewed to obtain necessary data to strengthen the facts obtained from desk study, site observation and compressive strength test results. Among the respondents, 9 of them (19.1%) are from client (i.e. AAHDPO), 13 (27.7%) are from the consultants, and the remaining 25 (53.2%) respondents are from contractors. When we see their educational level, 6.4% have MSc degree, 72.3% of the respondents have a BSc degree in civil engineering or other related fields, and the remaining 21.3% have a college diploma or certificate in building and concrete construction. Their experience also varies highly and 55.3% of the respondents have an experience of zero to four years, 29.8% of them an experience which varies from four to eight years, and the remaining 14.9% have an experience of more than eight years.

5.4 Statistical Quality Control of Concrete

Statistical Process (quality) Control is an analytical decision making tool which allows to see when a production process is working correctly and when it is not. It is inevitable that variation is present in any process. Hence, deciding when the variation is natural and when it needs correction is the key to quality control. This control tool greatly helps in production process of concrete by noticing variations and quality problems to enhance the production process of concrete.

In concrete production, compressive strength tests are used as an immediate quality control tool. Even if strength is a quality control tool in concrete production, the strength of concrete has an inherent variability as it depends on the variations in properties of concrete and variations due to testing methods. Therefore, proper care while taking test samples is crucial. The test samples ought to be representative of the actual mass production, the testing method should follow the right procedures which are specified in different codes of standards early from casting concretes to specimen testing. If not, the compressive test results obtained from samples might be deceptive and undependable.

Based on the objective of this thesis and understanding the level of importance of testing sample specimens in assessing the quality of concrete, sample specimens which are casted from ongoing concrete production sites of AAHDPO are collected and tested for their 28th day compressive strength though some tests are done on 29th and 30th day of casting due to weekends.

In order to evaluate the quality of concrete used in Addis Ababa housing projects using statistical quality control method, compliance and conformity criteria's found in the Ethiopian building codes of standards (EBCS2:1995), ACI- 214 and ACI-318 have been used.

According to EBCS-2:1995, there are two compliance criteria's set as it has been discussed in the literature review part of this thesis paper. As it is presented in the Ethiopian building code of standards, the values of K_1 and K_2 are variable as shown in table 2.7. For this specific analysis of test results, both the values of $K_1$and K_2 are taken to be 3MPa assuming that the lots considered in all the projects are above the fifth lot. Among the two criteria's set, criterion 1 which is applicable for small lots is used for this analysis.

While evaluating the compliance criteria's according to American standard cube results has been converted to cylindrical strength using a conversion factor of 0.8 times cubic strength.

Mathematically it is expressed as,

$$\mathbf{f_{cyk} = 0.8 f_{cck}} \quad \text{[Eq. 2.10]}$$

Where, f_{cyk}=Cylindrical strength and

f_{cck}=Cubical strength

In order to proceed with the statistical analysis shown below, equations that have been presented on this thesis are used for the determination of the mean, the standard deviation and the coefficient of variation.

Table 5.1 Compressive Strength test results and analysis, according to EBCS-2 1995 and ACI-318 of Project-12

Item No.	**Compressive Strength(MPa)**	**Mean(m^3)**	**SD(N/mm^2) for Cubic Strength**	**SD(N/mm^2) for Cylindrical Strength**	**Coefficient of Variation (%)**	**Decision According to EBCS-2: 1995**	**Decision According to ACI 318**
	25.41						
	22.38						
Hs/Kf003	30.2	26.00	3.94	3.15	15.17	Not complied	Complied
	42.54						
	40.34						
Hs/Kf004	31.03	37.97	6.11	4.89	16.09	Complied	Complied
	36.52						
Hs/Kf006	24.61	29.87	6.07	4.86	20.33	Complied	Complied

Item No.	Compressive Strength(MPa)	Mean(m^3)	SD(N/mm^2) for Cubic Strength	SD(N/mm^2) for Cylindrical Strength	Coefficient of Variation (%)	Decision According to EBCS-2: 1995	Decision According to ACI 318
	28.49						
	31.27						
	37.31						
Hs/Kf008	31.2	33.26	3.51	2.81	10.55	Complied	Complied
	28.89						
	16.67						
Hs/Kf011	23.31	22.96	6.12	4.89	26.65	Not complied	Not complied
	31.45						
	38.72						
Hs/Kf014	26.54	32.24	6.13	4.90	19.01	Complied	Complied
	31.18						
	25.93						
Hs/Kf016	27.64	28.25	2.68	2.14	9.48	Complied	Complied
	32.18						
	28.95						
Hs/Kf017	31.47	30.87	1.70	1.36	5.50	Complied	Complied
	27.16						
	24.26						
Hs/Kf020	29.41	26.94	2.58	2.07	9.58	Not complied	Complied
	30.0						
	29.54						
Hs/Kf023	27.72	29.07	1.19	0.95	4.10	Complied	Complied

Item No.	Compressive Strength(MPa)	Mean(m^3)	SD(N/mm^2) for Cubic Strength	SD(N/mm^2) for Cylindrical Strength	Coefficient of Variation (%)	Decision According to EBCS-2: 1995	Decision According to ACI 318
	36.1						
	28.82						
Hs/Kf025	31.19	32.04	3.72	2.98	11.62	Complied	Complied
	38.4						
	31.27						
Hs/Kf026	35.32	34.98	3.56	2.85	10.17	Complied	Complied
	22.7						
	16.96						
Hs/Kf029	24.12	21.24	3.78	3.03	17.80	Not complied	Not complied
	28.85						
	31.29						
Hs/Kf030	26.91	29.02	2.19	1.76	7.56	Complied	Complied
	29.85						
	28.74						
Hs/Kf032	25.81	28.13	2.09	1.67	7.42	Complied	Complied
	36.03						
	29.92						
Hs/Kf034	30.52	32.16	3.37	2.69	10.47	Complied	Complied
	19.64						
	26.21						
Hs/Kf036	22.6	22.82	3.29	2.63	14.42	Not complied	Not complied
Hs/Kf040	28.32	29.46	4.50	3.60	15.29	Complied	Complied

Item No.	Compressive Strength(MPa)	Mean(m^3)	SD(N/mm^2) for Cubic Strength	SD(N/mm^2) for Cylindrical Strength	Coefficient of Variation (%)	Decision According to EBCS-2: 1995	Decision According to ACI 318
	34.42						
	25.63						
	19.30						
	22.8						
Hs/Kf041	27.70	23.27	4.22	3.38	18.13	Not complied	Not Complied
	30.10						
	18.85						
Hs/Kf044	25.15	24.70	5.64	4.51	22.83	Not complied	Not complied

Table 5.1.a. Summary of compliance and conformity from table 5.1

Items	Compliance According to Ethiopian Standards EBCS-2:1995		Compliance According to ACI 318	
	Number	%	Number	%
Defective lots	7	35.0%	5	25.0%
Non Defective lots	13	65.0%	15	75.0%

On this project 20 Lots of concrete which brings 60 pieces of total sample specimens are collected from different 20 contractors with a specified characteristics strength of 25MPa (C-25). Based on compliance criteria's of Ethiopian standards (EBCS-2:1995) and as shown in table 5.1.a, 35% of the lots found to be defective whereas 65% of samples are non-defective and satisfies the specified requirement by the client. The same lots evaluated according to ACI 318 shows that, the number of defective lots goes down to 25% and the number of lots of non-defective goes to 75%.

All tests are conducted from ongoing concrete work of slabs, beams and columns and most of them are accepted by the consultants as they are. Therefore, non-destructive test shall be conducted on those non complying concrete structures.

The level of concrete quality control also investigated according to ACI-214. In this standard the level of control has been stated and classified based on coefficient of variation and standard deviation from excellent to poor. Tables 5.2.a and 5.2.b below summarizes the status of control on this project based on the results standard deviation and coefficient of variation respectively.

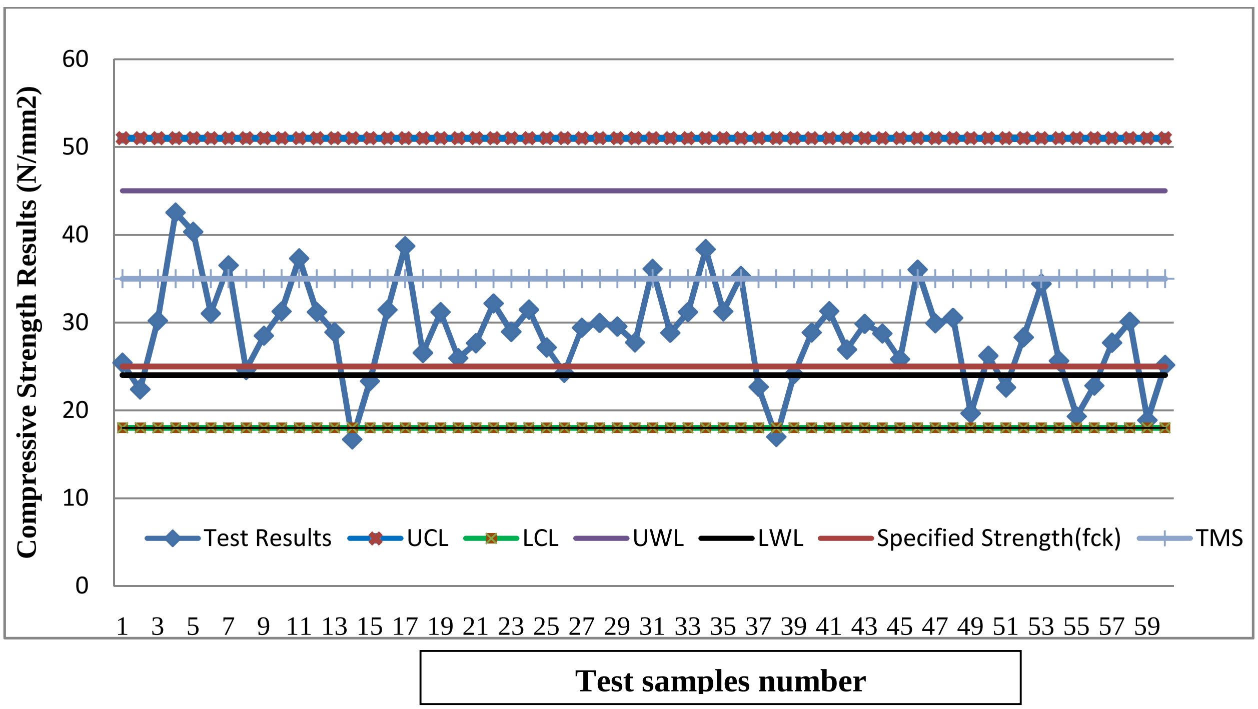
Table 5.2.a Level of control based on Standard Deviation (ACI-214)

Level of control Based on (SD)	Number of lots	Percentage (%)
Excellent (<2.8)	8	40.0%
Very good (2.8-3.4)	6	30.0%
Good (3.4-4.1)	1	5.0%
Fair (4.1-4.8)	1	5.0%
Poor (>4.8)	4	20.0%

Table 5.2.b. Level of control based on Coefficient of variation (ACI-214)

Level of control Based on (coefficient of Variation)	Number of lots	Percentage (%)
Excellent (<7)	2	10.0%
Very good (7-9)	2	10.0%
Good (9-11)	5	25.0%
Fair (11-14)	1	5.0%
Poor (>14)	10	50.0%

As it is shown on the tables 5.2.a and b above, the level of control varies greatly from poor to excellent within a project. Though the project is supervised by one consulting firm with 50 different contractors whose grade varies from five to three, the analysis reveals that, greater variations and non-conformity is available even within a project. Therefore, the level of supervision needs improvement for better concrete production on those projects. From observation and contract document it can be understand that, the number and experience of consultant's personnel for each project is not sufficient to administer and control the overall quality of the project. Hence number of supervision consultants or their personnel shall be



Compressive Strength Results (N/mm2)
60
50
40
30
20
10
0
Test Results
UCL
LCL
UWL
LWL
Specified Strength(fck)
TMS
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59
Test samples number

happen in quality concrete production. This chart which is essential in noticing poor quality production process in concrete shows comparable result with compliance criteria's provided by EBCS and ACI code of standards as discussed above. In addition to this, both the consultant and contractor are responsible for any quality problems exist on those projects. Therefore, the production process and control level of concrete on this project should be improved by taking different correction measures related to the concrete making materials, the production process and workmanship

The second investigated project found around Kuye Feche site is named as Project 17. The brief presentation of test data and analysis of the results are discussed in subsequent pages.

Table 5.3 Compressive Strength test results and analysis, according to EBCS-2 1995 and ACI-318 of Project 17

Item No.	Compressive strength(MPa)	Mean(m^3)	SD (N/mm^2) for cubic Strength	SD (N/mm^2) for Cylindrical Strength	Coefficient of variation (%)	Decision According to EBCS-2:1995	Decision According to ACI 318
	41.23						
	30.5						
Hs/Kf001	35.46	35.73	5.37	4.30	15.03	Complied	Complied
	33.1						
	30.63						
Hs/Kf002	25.7	29.81	3.77	3.01	12.64	Complied	Complied
	19.84						
	29.46						
Hs/Kf005	17.32	22.21	6.41	5.13	28.85	Not complied	Not complied
	31.2						
	38.18						
Hs/Kf007	26.16	31.85	6.04	4.83	18.95	Complied	Complied
	40.94						
	35.48						
Hs/Kf009	28.35	34.92	6.31	5.05	18.08	Complied	Complied
	19.37						
	17.67						
Hs/Kf010	25.31	20.78	4.01	3.21	19.30	Not complied	Not complied
Hs/Kf012	26.38	25.04	1.39	1.11	5.54	Not	Complied

Item No.	Compressive strength(MPa)	Mean(m^3)	SD (N/mm^2) for cubic Strength	SD (N/mm^2) for Cylindrical Strength	Coefficient of variation (%)	Decision According to EBCS-2:1995	Decision According to ACI 318
	23.61					Complied	
	25.14						
	30.24						
	24.63						
Hs/Kf013	29.38	28.08	3.02	2.42	10.76	Complied	Complied
	22.8						
	28.73						
Hs/Kf015	24.15	25.23	3.11	2.49	12.32	Not Complied	Complied
	36.32						
	26.67						
Hs/Kf018	30.83	31.27	4.84	3.87	15.48	Complied	Complied
	31.07						
	29.35						
Hs/Kf019	32.05	30.82	1.37	1.09	4.43	Complied	Complied
	19.67						
	17.95						
Hs/Kf021	23.68	20.43	2.94	2.35	14.39	Not Complied	Not Complied
	38.1						
	35.05						
Hs/Kf022	26.15	33.10	6.21	4.97	18.76	Complied	Complied
	19.8						
	28.41						
Hs/Kf024	25.35	24.51	4.39	3.51	17.90	Not Complied	Not Complied
	18.6						
	27.4						
Hs/Kf027	24.15	23.39	4.44	3.55	18.98	Not complied	Not complied
	40.3						
	35.17						
Hs/Kf028	28.10	34.52	6.13	4.90	17.74	Complied	Complied
	18.25						
	16.69						
Hs/Kf031	26.85	20.60	5.47	4.38	26.56	Not complied	Not complied
	32.76						
Hs/Kf033	27.28	32.37	4.91	3.93	15.17	Complied	Complied

Item No.	Compressive strength(MPa)	Mean(m^3)	SD (N/mm^2) for cubic Strength	SD (N/mm^2) for Cylindrical Strength	Coefficient of variation (%)	Decision According to EBCS-2:1995	Decision According to ACI 318
	37.08						
	27.53						
	21.17						
Hs/Kf035	16.9	21.86	5.35	4.28	24.49	Not Complied	Not Complied
	20.5						
	32.2						
Hs/Kf037	23.85	25.53	6.01	4.81	23.54	Not Complied	Complied
	28.4						
	26.31						
Hs/Kf038	34.64	29.79	4.33	3.46	14.54	Complied	Complied
	31.35						
	24.86						
Hs/Kf039	18.79	25.00	6.28	5.02	25.12	Not Complied	Not Complied
	31.65						
	28.74						
Hs/Kf042	24.50	28.30	3.60	2.88	12.71	Complied	Complied
	41.42						
	31.54						
Hs/Kf043	28.69	33.88	6.68	5.34	19.72	Complied	Complied

Table 5.3.a. Summary of compliance and conformity from table 5.3

Items	**Compliance According to Ethiopian Standards EBCS-2:1995**		**Compliance According to ACI 318**	
	Number	**%**	**Number**	**%**
Defective lots	11	45.8%	9	37.5%
Non Defective lots	13	54.2%	15	62.5%

On this project, 24 Lots of concrete which brings 72 pieces of total sample specimens are collected from different 24 contractors. According to the test results based on compliance criteria's of Ethiopian standards (EBCS-2:1995) and as shown in table 5.3.a, 45.8% of the lots found to be defective whereas 54.2% of samples are non-defective and satisfies the specified requirement by the client. The same lots have been evaluated according to ACI 318 and the result shows that, the number of defective lots goes down to 37.5% and the number of lots of non-defective goes to 62.5%.

All sample specimen tests for compressive strength are conducted by the author at Addis Ababa Institute of Technology (AAiT) with samples collected from ongoing concrete work of slabs, beams and columns of Addis Ababa housing projects and most of them are accepted by the consultants as they are. These results show that, as there is a gap in concrete production practice and the level of control by the consultants. Therefore, nondestructive test shall be conducted on those non complying concrete structures.

The level of concrete quality control is also investigated according to ACI-214. In this standard the level of control has been stated and classified based on coefficient of variation and standard deviation from excellent to poor as discussed in the literature review part of this thesis.

Tables 5.4.a and 5.4.b below summarizes the status of control on this project based on the test results standard deviation and coefficient of variation respectively.

Table 5.4.a. Level of control based on Standard Deviation (ACI-214)

Level of control Based on (STD)	Number of lots	Percentage (%)
Excellent (<2.8)	5	20.8%
Very good (2.8-3.4)	3	12.5%
Good (3.4-4.1)	5	20.8%
Fair (4.1-4.8)	3	12.5%

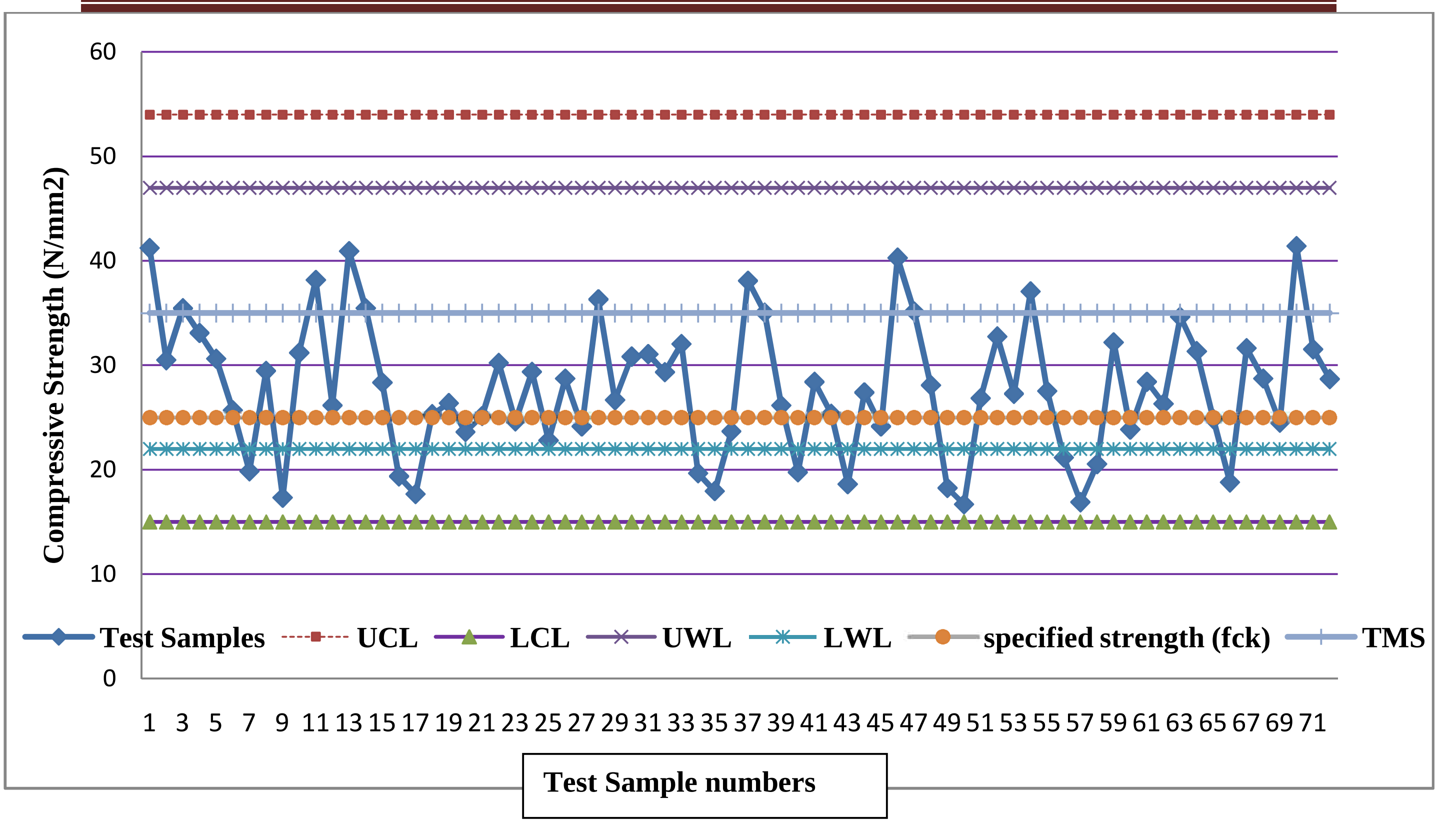
Poor (>4.8)	8	33.3%

Table 5.4.b. Level of control based on coefficient of variation (ACI-214)

Level of control based on (coefficient of Variation)	Number of lots	Percentage (%)
Excellent (<7)	2	8.3%
Very good (7-9)	0	0.0%
Good (9-11)	1	4.2%
Fair (11-14)	3	12.5%
Poor (>14)	18	75.0%

As it shown above on the tables, the level of control varies greatly from poor to excellent within a project. This project is supervised by one consulting firm with 56 contractors whose grade varies from five to three. As it can be observed from tables 5.4a and 5.4.b above the level of control on those projects varies significantly. According to ACI-214, 33% of test results based on standard deviation and 75% of them based on coefficient of variation falls under poor category of quality control. This indicates that the quality of concrete produced and the control level by the direct stakeholders (i.e. client, consultant and contractor) is poor and improvement on this area is mandatory. Since this buildings are public projects where many people live together, the buildings shall constructed with only a quality concrete which will have good strength and durability.

This project is also evaluated with the use of Shewart chart to analyze the quality of the production process. Figure 5.2 below shows the presentation and evaluation of test results using Shewart chart.


Compressive Strength (N/mm2)
60
50
40
30
20
10
0
Test Samples
UCL
LCL
UWL
LWL
specified strength (fck)
TMS
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41 43 45 47 49 51 53 55 57 59 61 63 65 67 69 71
Test Sample numbers

12 and 37.5% of project 17 are also found to be defective based on ACI-318 compliance and conformity criteria's. But it has been observed that those structures are accepted as they are with another test samples which are conducted by contractors. Interview with some experts who are involved in these projects posited that, it is common practice to prepare another good sample for test by washing sand and increasing the cement content of the mix which might improve the test result which is unrepresentative of the actual grade and quality of concrete casted on job site. This practice shall be avoided by proper supervision and control while taking sample test specimens to obtain a representative sample result of the structures of the buildings.

The level of control on both projects also investigated in preceding topics based on ACI-214 using their standard deviation and coefficient of variations. According to the result obtained, 20% of the test results in project 12 fall in poor level of control category while project 17 have 33% of poor level of control based on their standard deviations. When we compare the projects based on their coefficient of variation, 50% of test results of project12 and 75% test results of project 17 falls in poor category. This indicates that, the level of control in concrete production of those projects have a problem. Therefore, care shall be given to proper quality control and assurance of concrete structures of these public buildings.

As it has been showed in the above analysis and discussions the quality of concrete production varies greatly from poor to excellent. However, numbers of poor and defective test results are noticed in significant amount which needs production improvement and better quality control and assurance.

Observation shows that, in order to improve the quality of concrete the client uses OPC which have higher strength grade than PPC cement amounting about 360Kg/m^3. Ethiopian Standard ES1177-1:2005 specifies class 32.5 for PPC whose standard strength is between 32.5MPa and 42.5MPa and class 42.5 usually OPC with standard strength of between 42.5MPa and 52.5MPa. Hence, using OPC means that higher strength cement is in use for those projects to produce only a C-25 concrete with specified characteristics strength of 25MPa. This shows that the cost of achieving concrete quality due to the cement used is found in significant amount. Another cost is related to supervision cost which is paid for consultants to assure the quality of the overall projects. Even if with all these cement content and consultants who supervise and control quality are found, compressive strength tests conducted on the investigated projects shows that, poor and non-complied concrete is found in significant amount. Therefore, more efforts of all stakeholders are mandatory to enhance the level of quality of concrete production.

5.6 Quality Concrete Production Practices

The quality of a finished concrete structure is highly affected by different major factors which strongly affects the overall concrete quality. The first part is related to concrete materials which include selection, handling and storage of concrete making materials. The second part includes the production processes employed to concrete such as batching, mixing, transporting, placing compacting, finishing and curing. The quality of the freshly mixed and hardened concrete is affected by all the above factors. Beside those listed factors, the standard of workmanship in handling, batching, mixing, compacting, finishing, and curing of the concrete greatly affects the overall concrete quality. The standard of workmanship throughout the concreting operations is therefore extremely important in construction of a good quality concrete structure. Unfortunately, although materials are regularly checked, monitored and tested, the workmanship which is harder to specify and quantify is often given little attention or ignored completely.

Hence, the subsequent part of this thesis paper discusses and interprets the data obtained from site observations, desk study, interviews, and compressive strength test results regarding to concrete materials and its production process to investigate the level of site concrete production and the quality management practice in Addis Ababa housing projects.

5.6.1 Quality of Concrete making materials

Concrete is a composite material which consists a binding medium within which are embedded particles or fragments of relatively inert mineral fillers. It is commonly produced from cement, aggregates (coarse and fine), water, and sometimes admixtures are used when some important behavior is needed. Since, it is a composite material and composed of the above listed ingredients, the overall concrete quality produced at site is affected by the property of each ingredient. Therefore, proper selection based on test results, handling and storage of those ingredients strongly helps to improve the quality of concrete. The actual concrete making materials used in concrete production of Addis Ababa Housing projects and their level of quality investigated from site observation and interview is briefly discussed in the next subtopics.

5.6.1.1 Portland Cement

Cement is a material with adhesive and cohesive properties which make it capable of bonding mineral fragments into a hard continuous compact mass. When it is mixed with water it forms a paste to create strong bond between fillers. Hence, the qualities of this material have a great role in producing concrete.

There are two types of Portland cements which are used in Addis Ababa Housing projects supplied from different suppliers in the country. These cements are ordinary Portland cement (OPC) and Portland pozzolana cement (PPC) which is supplied from Derba, Dangote, National, Messobo, Muger, East and other cement factories which are the reliable sources of the project. Ordinary Portland cement is the most common cement used in general concrete construction when there is no exposure to sulfates in the soil or in ground water. Portland Pozzolana cement (PPC) is manufactured by the intergrinding of OPC clinker with 10 to 30 percent of pozzolanic material [2].

The use of PPC in concrete construction has an economical advantage over OPC due to an expensive clinker is substituted with 10 to 30 percent pozzolanic material. Although the use of PPC in terms of economy is more advantageous, a wide use of OPC for concrete production is observed in all Addis Ababa Housing projects. This contradicts with the concept of low cost housing advantages that can be obtained in terms of concrete production of those public buildings by using PPC.

It has been observed that, in all projects they use C-25 concrete for most concrete structures where the contract document and specification specifies a minimum cement content of 360kg/m^3. Experiences show that, currently it is possible to produce a C-25 concrete by using 280Kg/m^3 to 320Kg/m^3 (EEPCO project, Akaki Substation is good example which used 320Kg/m^3 to produce a C-25 concrete). On contrary, the use of cement in Addis Ababa Housing seems a little overstated because the specification which is part of the contract document specifies the use of minimum cement for C-25 is 360Kg/m^{3}and all contractors are struggling to produce the specified strength with allowed cement content. An interview with experts show that they agree the use of overload cement is there in the production of concrete but they associate the problem with quality issue. Even though there is an excess use of cement in producing C-25 concrete, the excess part of cement may help to improve the poor quality of concrete that arises from material quality and concrete production process. But still it misses the concept of low cost housing by increasing the cost of concrete on the projects due to the use of OPC rather than PPC which is cheaper and able to achieve equivalent strength at 28^{th} day.

Observations and the responses from interviewed respondents show that no cement test is conducted on job site or at a branch office level. The cement is supplied by the client (AAHDPO) and main office is responsible for distributing and testing of the procured cement. Cement test results and certification of the cement production factories based on ES 1177-1:2005 by Ethiopian Conformity Assessment Enterprise (ECAE) is the only references they have. But further sample tests should be conducted when it is necessary, for approval in using cement because its properties might be affected due to storage, weather and age of cements.

Cement absorbs moisture readily from air as briefly discussed on the literature review part of this research. Hence, it is essential to protect it from dampness before it is used, so that it may fulfill its intended functions. It has been observed that, big cement warehouses constructed from corrugated iron sheets are the place where cement is stacked for each project which is transported from cement factories. Earlier than two or three days when concrete work is done by contractors, all the contractors took their loads of cement into their temporary stores.

The cement bags procured in 50 Kg bags are stacked on a temporary timber platform in big warehouses constructed at project sites, as observed. Interview from one of the project storekeeper who keeps cement tells that, always cements which come first will be used first but the researcher reliably gathered in one of the stores that the latest bag of cement was stacked on top of the existing ones. Even it is difficult to know that which cement is the oldest and which one is the new produced cement as the production date is not specified. On site, they only follow first in first out (FIFO) concept but it doesn't guarantee about the age of cement because cements may be stored for longer time due to financial problems and delays on those projects.

It has been discussed on the literature review part of this thesis that cement which is 4 months old and above should be classified as "aged" and vital cement tests should be rechecked for concrete production to fulfill their intended functions. It also known that, even when we store cement under good conditions, bagged cement may lose 20 percent of its strength after 2 months of storage, and 40 percent after 6 months of storage. Hence, proper care shall be given to storage of cement. As a result, Ethiopian Standards Agency (ESA) should oblige the producers to stamp the production date of cements produced in the country. This may help to identify the aged cement with the new one and to undergo any necessary rechecking of cements by using appropriate test methods.

5.6.1.2 Aggregates

Approximately three-quarters or 60-75% of the volume of conventional concrete is occupied by aggregates. Considering the volume it can be comprehend that, as they are one of the main important constituents in concrete production and give body to the concrete, reduce shrinkage and affect economy. It is predictable that a constituent occupying such a large percentage of the mass should contribute important properties to both the fresh and hardened state of the product. Therefore, aggregates used for concrete shall be better quality to achieve the intended concrete quality and also needs proper production, storage and handling.

There are two types of aggregates used in Addis Ababa Housing projects which are crushed aggregates as a coarse aggregate and sands from river deposits as fine aggregates. The coarse aggregates are crushed aggregates which are supplied by the AAHDPO after procuring from the nearest quarry in Addis Ababa. Fine aggregates or sand is supplied by the contractors and procure it from different sources. The most common sources of sands are from Meki, Langano, Koka, Metehara, Lafesa, Sodere and Minjar. Almost all respondents agreed that, there is a big problem in getting good sand for production of concrete due to different reasons. The first is related to lack of automated and reliable suppliers for sand, most of them works manually using human power. Another reason is related shortage to river sand near Addis Ababa which leads to search fine aggregates from a distant area. Searching cheap sand by the contractors for concrete also brings the use of poor quality sands in concrete production of Addis Ababa Housing Projects.

Since aggregates used on those public projects are bought from different quarry sites or river deposits, the mineralogical contents of aggregate shall be tested. Standards and specifications also require certain properties of aggregate to be tested to accept the using of aggregate in the concrete mixes. Other properties can be required for calculating concrete mix proportions.

crushers which helps in eliminating poor aggregate gradations. The second reason is related to stockpiling of those aggregates on site which is degraded by weather when it is stored for longer period of time and loaders and dump trucks are also moving on it while loading and unloading of these aggregates at production sites.

Concrete aggregates should be free from impurities and deleterious substances which are likely to interfere with the process of hydration, prevention of effective bond between the aggregates and matrix. The impurities may also reduce the durability of the aggregate. Apart from the tests, shapes, sizes and other properties of aggregates which should be considered in production of a quality concrete, the way they stockpile aggregates on site greatly affects the overall concrete production. It has been observed that the stockpiling areas for aggregates are not good because it is just soil ground without any protection under it. This allows the silts, clays and other organic impurities found on the ground going to be mixed with other concrete ingredients and affects the properties of the produced concrete. Hence care should be given to those aggregates in the production, stockpiling and testing which give the most important concrete properties such as strength, durability, shape and economy of the final product.

5.6.1.3 Water used for Concrete Production

Water is one of the most important ingredients of concrete which plays a great role in concrete production. Generally it is agreed that, water which is used for drinking is safe to use in concrete production. If water is properly designed in concrete mixture, it will possess the desired workability for fresh concrete and the required durability and strength for hardened concrete. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully.

Drinkable ground water which is distributed for Akaki area residents is used in the production of concrete in all investigated projects of Addis Ababa Housing projects around Kuye Feche. The water used for concrete production is supplied by the client Addis Ababa project office using water trucks for transportation from the source. This transported water is distributed for all contractors who participate on those public projects. Respondents tell that, no tests are conducted for water used in concrete production. All respondents agreed that, since the water is safe to drink it is a good water to use for concrete.

observed, the resultant concrete is going to be of poor quality which doesn't satisfy the required purpose.

Freshly mixed concrete quality is influenced by its constituent materials, procedures of production, and equipment used. To obtain a good quality concrete structure, attention should be paid to all aspects of concreting operations. The quality of concrete does not only depend on the quality and uniformity of the concrete discharged from the mixer, but also on the skill and knowledge shown on the site in carrying out the various operations including batching, mixing, transporting and placing, compacting, finishing, and curing the concrete. A high standard of site workmanship is required to produce a high standard of concrete work and much depends on the skill and expertise of the supervision engineers, foreman and skilled and semi-skilled laborers. It is also undeniable that, with simple highly repetitive work good quality can still be achieved with less highly skilled labor.

The various ingredients of concrete and their current practice in investigated projects of Addis Ababa housing has been discussed above. The succeeding part of this paper briefly discusses and evaluates the current concrete production process i.e. batching, mixing, transporting and placing, compacting, finishing, and curing of concrete which practiced on those public projects.

5.6.2.1 Batching of Concrete

Batching involves measuring the quantities of the concrete making materials (cement, water, sand, and coarse aggregate, and sometimes admixtures). The correct amount of each material must be batched if the quality of the concrete is to be maintained in both individual and successive batches. Mistake in measuring the ingredients reduces the accuracy of the batching. Poor accuracy in the batching cause’s variation in the properties and the quality of the concrete produced.

Even if it is advisable to use weight batching to reduce variations related to batching and in order to get improved quality of concrete, volumetric onsite batching is commonly used in all observed sites of Addis Ababa housing projects. This method is used due to easiness in measuring the quantities of ingredients for manual concrete production. As it has been discussed above, C-25 is the frequent concrete grade used for all types of buildings commonly G+4 and G+7. A box internal size of 50x40x18cm (length, width and depth respectively) is used to measure sand and coarse aggregates used. Whereas cement which usually used ordinary Portland cement (OPC) is measured per bag where each bag weighs 50Kg and the water is measured by liters. The mix ratio used to produce a C-25 concrete in all projects is 1:2:3 which represents one bag cement (50kg), two boxes of sand and three boxes of coarse aggregates respectively and they usually uses 350 liters diesel mixer.

All of the respondents replied that no adjustment of bulking sand effect and absorption capacity of aggregates are considered. It has been observed that no water measurement for each mix is taken; the operators only balance the water by using trial and error method and they use their experienced judgment. This greatly affects the water cement ratio (w/c) and workability of the concrete. Hence, this problem adversely affects the compressive strength of concrete because w/c ratio is inversely proportional to strength of concrete; high water cement ratio refers to low compressive strength of concrete.

Two common problems of batching are observed and also listed out by respondents in concrete production of those project sites. These problems generally can be grouped into two; over batching and under batching. Over batching is observed related to the box where excess sand and aggregates are batched and additional sand or aggregates may be used due to lack of proper counting for each mix. This may leads in great variation of concrete mix and affects the overall concrete quality. The second common and major problem that creates higher variation in concrete batching is called under batching which refers to lack of the expected specified ingredient in each mix. This situation usually happened when they batch the ingredients, they may forget the added and remaining batch of each ingredient into the mixer as a result, a box of sand or aggregate may be missed. Another cause may be related to the materials thrown out of the box may not fully added to the mixer drum and fall on to the ground and this brings shortage in one mix and excess materials on the other mix which leads to greater variation in the quality of concrete.




dumped in proper and separate location. This leads to the materials to be mixed each other and as it can be seen from the picture, the labors are measuring a sand and aggregate mix as an aggregate. This brings a deficiency in one material and a surplus in the other material that directly contradict with the mix design which leads to poor concrete batching and finally poor concrete product.

Discussion with experts regarding to the above problems observed in concrete batching shows that, consultant's site inspector and the resident engineers tries to control the uniformity of batching but it is always not simple and true to follow each progress of batching. This is related to insufficient staffs by the consultants to control each and every stages of work. Therefore training and serious control of workmanship regarding to batching and other concrete production processes is mandatory by both contractor's and consultant's experts.

5.6.2.2 Mixing of concrete

Once we have batched the correct amount of materials into the mixer, thorough mixing is crucial for the production of uniform quality concrete with smaller variation. Thorough mixing means distributing the concrete ingredients uniformly and spreading the cement-water paste evenly onto the surfaces of the aggregates. If this is not achieved, the quality of the concrete discharged will not be the same throughout the mix hence high degree of variations in the mixes that leads to poor quality of concrete may be obtained.

Mixing of concrete in all observed sites is done with mixers usually by using 360 liters mixers which produces only one mix at a time (usually 1:2:3). Though respondents from all stakeholders replied that, the mixing time affects the mix of concrete, it has been given little attention to all factors that affect uniform mixing. Most of the respondents agreed that attention to mixing shall be given in mixing of concrete especially related to mixing time. Mixing shall be done for only sufficient time, if mixing takes place for over a long period, evaporation of water from the mix can occur, with a consequent decrease in workability and an increase in strength. Another effect is that of grinding of the aggregates, particularly if soft, the grading thus becomes finer and the workability lower.

As it has been observed in actual concrete production sites, no one controls the mixing time and procedures, the mixer operators who do not understand the effect of mixing time on the quality of concrete uses their judgment on mixing time. Therefore, all stakeholders who participate in concrete production of Addis Ababa housing shall give attention to concrete mixing. Consultants are always there to control the quality of concrete but lack of proper supervision of each processes of concrete production is observed in all observed sites of the projects.

5.6.2.3 Transporting and Placing of Concrete

Once mixing of concrete ingredients is completed, it should be transported and placed at its intended position or place as speedily as possible to avoid segregation, drying, etc. As it has been discussed in the literature review, once concrete is discharged from the mixer, internal as well as external forces start acting to separate the unlike constituents of concrete and if over-weight concrete is confined in restricting forms, the coarser and heavier particles tend to settle and finer and lighter materials tend to rise. This may cause segregation of particles which affects the strength and overall quality of concrete.

Observation on project sites shows that concrete is transported vertically using winches by pouring the mixed concrete in cylindrical barrels which can hold one mix at a time for superstructure and using chutes usually made of corrugated iron sheets for substructure works. Then shovels and flat open pan constructed with iron sheet usually known as "barella" is used to transport and place in position. It is eminent that if concrete is to be transported for some distance over rough ground the runs should be kept as short as possible since vibrations of this nature can cause segregation of the materials in the mix. On the investigated sites it has been observed that, concrete is not transported on rough surfaces while they use but it is poured into cylindrical barrels then transported using winches and again discharged into a rough platform then it will be transported and placed using shovels and "barrela" for superstructure works. Due to this long and labor intensive processes, slump loss, segregation, loss of ingredients and formation of cold joints may happen and also seen on some investigated sites.

It is eminent that, to avoid segregation and honeycombed concrete which usually have poor strength and durability, concrete should not be dropped from a height of more than 1.5m. Opposing this, in most of observed sites concrete is dropped from height of more than 2.8m while they cast columns which are the major critical part of the building. The figure below shows the most frequent placing method of columns in those projects.

in the form of small pores reduce the strength and density of concrete. Therefore proper compaction shall be implemented to remove all those air from the concrete.

Compaction is done with vibrators in all visited sites and also respondents inform that it is always under supervision to use vibrators. The problem observed on compaction is related to the depth they use in compaction, vibrator center to center immersion and the angle they insert vibrators. Proper use of immersion vibrators in terms of insertion time, center to center spacing of vibrators poker immersion and depth of compaction are important for better result in concrete compaction. However if there is negligence on these, bad concrete may be obtained from well designed and produced mix.

Regarding to immersion vibrators used for concrete compaction in terms of insertion time, center to center spacing of vibrators poker immersion and depth of compaction, nothing has been done on site. Most of the investigated sites use common practices in compaction of concrete. Hence attention shall be given by both contractors and consultants personnel for the compaction of concrete in order to enhance the intended strength and durability of concrete.

5.6.2.5 Curing of Concrete

Concrete curing is the method of maintaining suitable moisture content and a favorable temperature in concrete during the period immediately after the placement of concrete so that hydration of cement may continue till the desired properties are developed sufficiently to meet the requirements of service.

According to the interview with respondents, 85.1% of the respondents agreed curing is maintained from 5 to 7 days for all concrete structures. The rest of 14.9% of respondents do not agree and they revealed that the real practice of curing is not greater than three days.

According to observation on job sites, the degree of variability in sprinkling water varies from contractor to contractor based on the level of supervision engaged from the consultants. In all the investigated sites no burlaps or other covering materials is used to maintain the moisture of concrete. Due to this reason the water sprayed over the concrete is not sufficient and efficient to maintain the moisture in concrete throughout curing period. According to observation and discussion with the respondents, shortage of water and lack of commitment by the contractors to do curing is observed. The way of transporting water is also a problem to higher floors because they transport water using plastic jars for curing purpose. These may leads the laborers not to supply enough water for concrete. Hence, consultants shall oblige the contractors to use pump by to supply enough water for curing.

5.7 Concrete Quality Management of AAHDPO

Quality management is concerned with preventing problems by creating the attitudes and environment that make prevention possible. A critical quality management system in the project context helps to turn stakeholder needs, wants, and expectations into requirements. In concrete production, a quality of concrete which satisfies the required strength can be produced through good implementation of quality management elements.

As it has been discussed on the literature review, project quality management includes all the processes and activities of the performing organization that determine quality policies, objectives, and responsibilities so that the project will satisfy the needs for which it was undertaken. It implements the quality management system through the policy, procedures, and processes of quality planning, quality assurance, and quality control, with continuous process improvement activities conducted throughout, as appropriate.

Though the implementation of quality management system (QMS) helps in improving the quality of concrete and other significant feature of works, stakeholders who are responsible for these projects implement the quality management system in poor level.

Based on an interview with experts, Table 5.5 below summarizes the implementation quality management system of Addis Ababa Housing projects.

Table 5.5 Implementation of QMS in AAHDPO Projects

Implementation of QMS in AAHDPO Projects	Yes, there is	7.80%
	To some extent	70.92%

	Not, at all	21.28%

As it is shown in Table 5.5 above, 7.8% of respondents agreed with the implementation of the quality management system whereas 70.92% of respondents agreed that the implementation is to some extent and the remaining 21.28% disagree with other respondents and they say that there is no quality management system at all. From desk study and observation, the quality management system is there in some written form of the contract documents but the problem relates to the proper organization of those documents and implementation of procedures with a committed stakeholders.

Regarding to the advantages of quality management plan (QMP), 95.74% of experts agreed on the advantage obtained from QMP and the rest 4.26% of respondents do not accept the advantage and their reason is related to much of work paper. However, discussion with experts reveals that there is no quality management plan document which offers vital information and guide about any significant works related to quality assurance (QA) and quality control (QC) in practice. Usually checklists and compressive strength test results conducted on concrete are considered as the only control measure on those public projects.

Even having a written and well organized quality management system do not guarantee the improvement of quality of the product. Hence, management commitment and qualification of personnel who participate in the production of concrete is very fundamental. Bearing in mind this, in succeeding topics the author discusses the views of respondent.

5.7.1 Management Commitment

The role of quality management for a project is not an isolated activity, but intertwined with all the operational and managerial processes of the project. As it has been discussed in the introduction part of this chapter, this project is a government led project with the aim of achieving low cost but quality houses to all house seekers in the city and many consultants, contractors and SME's are participated in the construction to achieve the intended goal of the client. Therefore, the quality of concrete and the overall project quality are accomplished through an integrated effort and commitment between all levels of managers and their organization to realize the intended quality by continuously improving current performance of concrete production practice.

Regarding to management commitment to improve the current level of concrete production, the experts are interviewed and they respond as it is summarized in Table 5.6 below.

Table 5.6 Management Commitment to improve concrete production in AAHDPO projects

Organization	Management and Personnel Commitment		
	Satisfactory	Fair Satisfactory	Less Satisfactory
Client/AAHDPO	10.64%	65.96%	23.40%
Consultants	14.89%	59.57%	25.53%
Contractors	0.00%	44.68%	55.32%

As it is shown in the table 5.6 above, the efforts of those three main stakeholders in concrete quality improvement varies based on the views of respondents. According to the result, only 10.64% of respondents agreed that the effort made by the client is satisfactory and 65.96% of them say fair satisfactory and the remaining 23.4% believed as less satisfactory. When we see the efforts of consultants based on the interview, only 14.89% of the respondents stated as it is satisfactory while 59.57% of respondents state fair satisfactory and the remaining 25.53% believed as it is less satisfactory. Regarding to the contractor, none (0.0%) of the respondents satisfied with while 44.68% says fair satisfactory and the remaining 55.32% thought as it is less satisfactory.

Following the respondents comment, desk study and observation, all stakeholders have commitment problems and lack of professional ethics in the improvement of quality on those projects. Some of the respondents also posited that, there is a perception of considering condominium buildings as low quality buildings. Hence, by avoiding misleading perceptions and by applying proper management commitment within all organizations who participate in these public projects it can be possible to enhance the level of quality of site concrete production.

5.7.2 Companies and Personnel Qualification

Qualified and knowledgeable personnel in any concrete construction are essential for producing quality concrete. The contract document used in AAHDPO for both consultants and contractors define job qualification requirements, including necessary educational qualifications, experience and scope of responsibilities for personnel in supervision and construction of works. Respondent's opinion regarding to the adequacy of consulting and constructing companies in the production of concrete and its improvement based on their experience and manpower availability was collected and summarized in table 5.7 below.

Table 5.7 Adequacy of companies and personnel to enhance concrete quality of AAHDPO projects

	Adequacy	
	Yes	No
Consulting Companies	74.47%	25.53%
Construction Companies/Contractors	34.04%	65.96%
Qualified personnel including skilled and non-skilled labors	59.57%	40.43%

Based on consultant's capability, availability of professionals and their experience, 74.47% of the respondents stated that the consulting companies are adequate to enhance the quality of concrete whereas 25.53% of respondents disagree with the adequacy of the consultants.

To increase the quality of concrete, professionals who trained in higher educational institutions and have good work experience shall be participated in all concrete construction processes including the supervision and quality control. Apart from this, most of consultants hire graduate engineers who have zero year working experience as a site inspector and all the quality is controlled and approved by those fresh engineers to get cheap manpower. This problem contradicts with the contract document which specifies at least 2 years of experience and higher level education to site inspectors. According to observation and contract document, each engineer inspect at least six blocks which is difficult to control every work procedures. Hence, proper control of the consultants by the client is obliging to get a qualified professional in sufficient amount which may help in the improvement of concrete quality.

Referring to contractor's capability, resource availability and their experience in similar projects, only 34.04% of experts agreed on their adequacy in the improvement of the quality concrete where as 65.96% strongly disagree on the adequacy of contractors and their professionals. If these concrete producers are not adequate in producing concrete it is difficult to obtain a quality building product. Therefore, strong measures shall be taken by the client to improve the level of contractors. One crucial method is a capacity building program using training and certification of professionals who participate on those projects. This is done by AAHDPO but it is not in sufficient amount because if continuous improvement is needed a continuous training and support for those contractors are mandatory.

According to the contract document of this project, contractors shall have an engineer with least a BSc degree or advanced diploma in civil engineering or related fields and have at least 4 and 6 years of experience respectively. It also states a general foreman with diploma and at least 4 years of experience. This is good to specify a minimum qualification for professionals in the improvement of quality of those projects. From observation and interview on job site, most of the contractors have only Foreman's who manage and control the concrete production and other works on site. This has been seen as a major issue in concrete production by contractors which bring poor control of the production process with only one person. Hence, consultants and the client shall have a check and balance system in the availability of sufficient professionals to maintain the project quality.

5.7.3. Manpower and Workmanship

In the production of quality concrete extreme care must be exercised at every stage so as to obtain the desired results. All suitable precautions must be taken to ensure proper inspection of the ingredients, batching, mixing, transporting and placing. Quality control of concrete demands a high degree of carefulness among all personnel connected with the production.

In site concrete production, there is a high demand of manpower who participates in all processes of concrete production to have a good workmanship. Therefore, the construction industry shall respond for manpower by providing manpower of a quality and capacity to undertake this work successfully.

Observation reveals that, the actual concrete production trend in these projects is far from this and it is difficult to get qualified and trained skilled and semi-skilled laborers who do their work skillfully. According to respondents from those projects 59.57% agreed the availability and adequacy of skilled and semi-skilled laborers and the remaining 41.43% don't agree with the availability and adequacy of workmanship on these projects. Some respondents posited that, lack of this skilled manpower is related to the wages paid to them and challenges related to farness of the project which is usually at the outskirts of Addis Ababa. This is greatly affecting the workmanship of the project products from intended quality.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

From the study made on Addis Ababa housing projects regarding to the quality of site concrete production and the management practice, it have been seen that a number of problems related to concrete production and quality management practices exist on those projects. Therefore, this chapter presents the conclusion it reaches and the recommendations drawn out from the assessment carry out on those public building projects.

6.1 Conclusions

1. Statistical quality control analysis based on compressive strength test results reveals that, the quality of concrete produced on those public projects have higher uncertainties and varies from good to bad. From the compressive strength of test result, 40.4% of test results found to be defective according to compliance criteria's of EBCS-2:1995 where as 31.25% of the test results found to be defective according to ACI-318 compliance criteria's.
2. The level of quality control of concrete production has also a greater uncertainty and is not good enough. Based on ACI-214 classification and considering their standard deviations and coefficient of variations, a significant amount is fall under "fair" and "poor" categories. According to this classification, 35.4% of test result's standard deviations show the level of quality control practiced is not good and among this 8.75% are fall under "fair" range and the remaining 26.65% falls under "poor" range. Based on their coefficient of variation 71.25% of compressive test results shows the quality control is not good and among these 8.75% fall under "fair" range and the remaining 62.5% falls under "poor" range.
3. Even if these projects uses potable water for concrete production, most of the water tankers are open which are contaminated by dusts and other impurities from the surroundings which fundamentally affect the overall concrete quality.
4. Two most frequent mistakes are commonly practiced in concrete batching which related to poor precision in batching. They are commonly called under batching and over batching which leads to variations in the properties and the quality of the produced concrete. In addition to this, the use of sands and aggregates without adjustment of bulking sand effect and absorption capacity is commonly practiced.
5. Concrete for columns are placed using shovels from the height of more than 2.8m in most projects. Therefore, bad placing method of concrete is practiced that might cause the segregation of concrete ingredients and brings poor quality concrete product.

6. From observation and discussion with experts, the curing practice in AAHDPO projects varies from good to poor. No covering sheets are used at all to retain the moisture and water is sprayed using plastic jar in deficient amount.

7. Preparing and implementing quality management system (QMS) in concrete production greatly helps in improving the quality of concrete. On contrary, 7.8% of interviewed respondents agreed with the implementation of the quality management system on those

projects whereas 70.92% of respondents agreed that the implementation is to some extent and the remaining 21.28% respondents believe that ,there is no quality management system at all.

8. From observation and interview, there is lack of management commitment problems by the three stakeholders i.e., client, consultants and contractors in the improvement of concrete quality. In addition to this, lack of professional ethics and perception in understanding those public projects as low quality houses rather than aware as low cost houses are the major causes of quality problems of concrete production on those projects.

9. Be deficient in experienced construction companies and trained personnel which help in providing a quality concrete product is one cause which hinders quality concrete production. On the other hand, lack of supervision consultant's personnel experiences, which supervise and control the project, are also a problem in concrete production. In addition, problem to get qualified and trained skilled and semi-skilled labourers who do their work skilfully is the cause that related to poor workmanship which brings poor quality of concrete.

6.2 Recommendations

1. Clients and consultants must first implement a thorough investigation and testing of concrete materials i.e., water for the concrete, aggregates and cement within the project location and carry out initial laboratory investigations of the presence of deleterious substances on them and other necessary testing parameters before issuing approval for their consumption for concrete production works. Thereafter both the consultants and the contractors must collaborate to carry out detailed confirmatory laboratory tests of fitness of all such materials before bulk procurement and continuously when these retesting is needed. In addition, standard care should be given while handling and stockpiling of those concrete materials.

2. Attentive care shall be taken to all concrete production process by implementing a well-organized quality management system that can be achieved with well trained and experienced professionals who understands the rewards and consequences of each process that contribute to the quality of the final product.

3. Manual concrete production is labour intensive and needs very careful quality control at every stage of the concrete production process which is difficult to achieve such mega projects which fits to its purpose. Therefore, the use of central automated batching plants for those projects greatly helps in the production of a quality concrete product that can be controlled at the central unit. This on the other hand may help in reducing the cement consumption by reducing errors from batching and other variations caused due to the production processes of concrete.
4. There must be utilization of qualified and experienced personnel for all stakeholders participating in AAHDPO projects right at the top management level to the site manager, construction coordinators, supervisors, skilled and semi-skilled labourers and even to unskilled labourers and other categories of workers which participate in concrete production line.
5. There shall be quality policies, regulations and manual assisting the development of a quality management plan document for concrete production, which must be adhered, through a committed management system of all direct stakeholders

6. Providing a continuous capacity building program for those stakeholders who participate in Addis Ababa housing projects by AAHDPO is crucial to enhance the capacity of the consultants, contractors and their personnel.

References

1. Neville A.M. and Brooks JJ, Concrete Technology, Pearson education limited, second Edition, 2010.

2. Shetty M.S, Concrete Technology Theory and Practice, S.Chand & company ltd, First Multicolour Illustrative Revised Edition, 2005.

3. Gambhir M.L , Concrete Technology: theory and practice, McGraw-Hill Books 3rd edition, 2002

4. Zongjin Li, Advanced Concrete Technology, Published by John Wiley & Sons, Inc., Hoboken, New Jersey,2011.

5. Newman John and Bang Seng Choo, Advanced Concrete Technology – Testing and Quality, Elsevier ltd, Great Britain (2003).

6. Neville A.M, Properties of concrete, Fifth Edition, 2011.

7. A Guide to the Project Management Body of Knowledge, PMBOK third edition, an American National Standard, ANSI/PMI 99-001-2004.

8. Steven H. Kosmatka, Beatrix Kerkhoff, and William C. Panarese, Design and control of concrete mixtures, Portland cement association, Fourteenth edition, 2003.

9. Gupta, B.L and Gupta, A.(2004): Concrete Technology. A.K. John Publishers for Standard

Publishers Distributors, NaiSarak, Delhi, India.

10. Nunnally S.W, Construction methods and Management, RR. Donnelley& Sons Company, 7thedi, 2007.

11. Chudley, R and Greeno, R.(2005): Construction Technology. Third ed. Pearson Education

Limited, Edinburgh Gate, Harlow, Essex CM20 2JE, England.

12. Douglas C. Montgomery, Introduction to Statistical Quality Control, Arizona State University John Wiley & Sons, Inc ,Six edition, 2009.

13. Anosike N.M, Parameters of good concrete production, PhD thesis, Covenant University, OTA, Nigeria, 2011

14. Tesfalem T, Study on the Effectiveness of Quality Control for the Production of Reinforced Concrete and Hollow Concrete Blocks (In projects administered by Addis Ababa housing Projects, MSc thesis, Civil and Environmental Engineering Department, AAU, 2014

15. Abebe Eshetu, Concrete production and quality control in building construction industry of Ethiopia, MSc thesis, Civil and Environmental Engineering Department,AAU,2005

16. Tahir Celik, Improving concrete quality by using an expert system, Phd thesis, Loughborough University of Technology,1989

17. Rikesh Shah, Prof. Jayeshkumar Pitroda& Prof. C.G. Patel, Quality Control Management in Building Construction, Civil Engineering Department, Vasad Institute of Technology, Gujarat, India,The Indian Concrete Journal September ,2009.

18. Arum C, Quality Control and the Safety of Structural Concrete Buildings, Bahirdar University, Journal of African research Review, pp. 113-123

19. Ian Gibb and Tom Harrison, Use of control charts in the production of concrete, European Ready Mixed Concrete Organization, October 2010.

20. Landin Ann, Impact of Quality Management in the Swedish Construction Process, Department of Construction Management, Lund Institute of technology, Lund University, 2010.

21. Hana S.J and Lott A.P, application of statistical quality control procedures to production of highway pavement concrete, Purdue University Lafayette, Indiana March 6, 1964.

22. Darroch J.G, Statistical quality control studies and findings relative to highway construction, Texas A&M University College Station, Texas, 1986.

23. Juran, Joseph M. & Blanton Godfrey A. (2000), Juran's Quality Handbook, 5th Edition, International editions, McGraw-Hill.

24. Feigenbaum, Armand V. (1991), Total Quality Control (3 ed.), New York, New York:McGraw-Hill.

25. Harrington, H. James (1987), Poor-Quality Cost, American Society for Quality Control, Milwaukee, Wisconsin.

26. UN Habitat Report (2010), Condominium Housing in Ethiopia: The Integrated Housing Development Programme, Nairobi.

27. EBCS-2; Ethiopian Building Codes and standards, Structural Use of Concrete part seven & eight, 1995

28. Ethiopian standard ES 1177-1:2005; Composition Specification and Conformity Criteria for common Cements,2005.

29. American concrete institute, ACI 318-95: Building code requirements for structural concrete, 1995.

30. British standard, BS 5328:1990: part 4, Specification for the procedures to be used in sampling, testing and assessing compliance of concrete, 1990.

31. Indian standards, IS 456:2000, plain and reinforced concrete code of practice, fourth revision,

32. EU direct, Quantifying Quality Costs and the Cost of Poor Quality in Translation, Luxembourg Publications Office of the European Union, 2012.

33. United Nations Office for Project Services (UNOPS), Construction Quality management plan template and guidelines, www.unops.org. Accessed on, Aug18, 2016.

34. Hiwot Bahiru Gemeda, Effect of poor project performance on quality of housing construction: a case of condominium houses in Addis Ababa, IHS the international institute of urban management of Erasmus University, Rotterdam, Netherlands, 2012.

35. Abebe D. and Birhanu B, Alkali aggregates reactions in concrete: A review of Ethiopian situation, Department of Civil engineering, AAU, Journal of EEA, Vol.21, 2004

APPENDICES

APPENDIX-I

አዲስ አበባ ዩኒቨርሲቲ
Addis Ababa University

Dear Sir/madam

Thank you for taking your precious time to respond for this interview questions. This interview questions are a research instrument for fulfillment of my MSc thesis. My research topic title is "Study on quality of site concrete production and its management practice in Addis Ababa housing development projects: A case of Kuye Feche housing project program".

The questionnaires listed below are attempted to respond the current concrete production and management practices employed in Addis Ababa Housing projects. Hence, your responses are highly valuable to finalize my research.

I kindly need to confirm that, your responses are completely anonymous and confidential, and will not be identified by individual. Your responses are used exclusively for only this research and all responses are compiled together and analyzed as a group.

Thank you very much for taking your time to answer the interview questionnaire.

With regards,

Habtamu Sisay

1.3 Objective of the study

The purposes of this research are to:

- Investigate the quality of site concrete production in Addis Ababa Housing projects.
- Investigate concrete quality management practices on those projects
- Examine the quality of concrete produced by considering their compressive strength via taking sample specimens from ongoing projects from selected sample sites at Koye Feche housing project.

1. Please specify your field of study.

2. Please specify your highest level of education

☐ High school diploma ☐ TVET Certificate ☐ Diploma ☐ BSc ☐ MSc

3. Please specify your years of experience:

☐ < 2 years ☐ 2-4years ☐ 4-6 years ☐ >6years

4. Your current position in your company

☐ Resident engineer ☐ Site engineer ☐ Office engineer ☐ Quality Manager

Please write any other position, if any: ____________________________________

5. What is the type of organization you are working?

☐ Client ☐ Consultant ☐ Contractor

6. Please specify your company license category, grade and years of experience in building construction projects.

7. How do you control quality of concrete produced at site? Regarding materials, concrete production process and workmanship.

8. What parameters and test you check and conduct on concrete materials? Please specify if any

    a. Tests conducted on cement (soundness, age & etc.)

    b. Tests conducted on coarse aggregates? How often you take sample for test

c. Tests conducted on fine aggregates/sand. How often you take sample? Do you have any reliable source?

d. Tests conducted on reinforcement bar. How often you take sample?

e. Tests conducted on water if any. Is the water potable (drinkable) or you are using other sources for concrete production? Please specify if any,

9. What precaution measures you take in batching concrete? Related to box sizes, adjustments of bulking effect of sand, absorption capacity of aggregate and etc.

10. What precaution measures you take in concrete mixing? Regarding to mixer volume, type and status, mixing time, workmanship and etc.

11. What precaution and corrective measures you take in concrete transporting and placing? Horizontally and vertically in related to segregation, slump loss, loss of ingredients and formation of cold joints.

12. What precaution measures you take in concrete compaction to avoid honeycombed concrete or to remove the entrapped air.

13. What precaution and corrective measure you take in concrete curing? In related to the application of water spraying or covering sheets, period for curing of casted concrete while you use different type of cement like OPC or PPC.

14. In your opinion, do you think the quality of concrete used in Koye Feche sites are better-quality? Please specify your reasons.

15. In your opinion, do you think the efforts and commitments of direct stakeholders on those projects to improve quality of concrete are satisfactory? Please specify your reasons. Regarding to

    a. Client(AAHDPO office)

    b. Consultants

    c. Contractors

16. Is there any Total Quality Management (TQM) system in place to ensure quality of site concrete production on those projects?

17. Do you think concrete quality management plan is essential to improve quality of concrete produced at site?

18. Does your company have any quality management plan document for concrete and other definable work items in building construction?

19. Does your company have quality control/quality assurance policy, team or department?

20. Do you think adequate companies, professionals and skilled workmanship are available to enhance the quality of concrete produced on those public projects? Regarding to

    a. Consulting Companies

    b. Construction companies/ Contractors

    c. Professionals participating on those projects

    d. Skilled and semi skilled laborers

21. What preventive and control methods you advice in order to enhance the current concrete production practices on those public projects?

22. Please list any comment and suggestion you have.

Thank you for your cooperation!

APPENDIX-II

Addis Ababa Institute of Technology

Department of Civil and Environmental Engineering

Proposed Quality Management Plan for Concreting Works in AAHDPO Projects

Version One

March, 2017

Table of Contents

List of Figures

Glossary of Acronyms

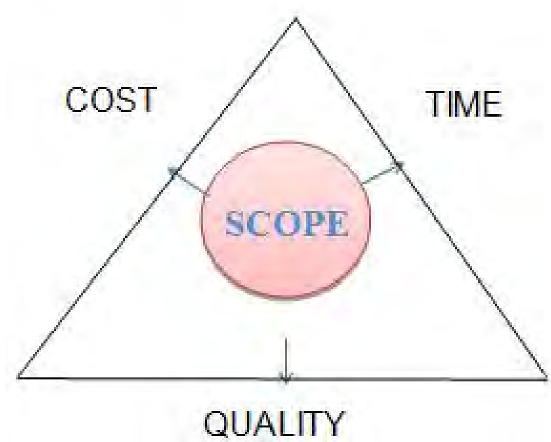
AAHDPO	Addis Ababa Housing Development project office
ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
CQA	Concrete Quality Assurance
CQAP	Concrete Quality Assurance Plan
CQCP	Concrete Quality Control Plan
CQCM	Consultant's Quality Control Manager
CQMP	Concrete Quality Management plan
EPP	Environmental Protection Plan
EBCS	Ethiopian Building Code of Standards
NCR	Non-Conformance Report
PM	Project Manager
RE	Resident Engineer
QA	Quality Assurance
QC	Quality Control
QCM	Quality Control Systems Manager
QCP	Quality Control Plan
QMP	Quality Management Plan
QMS	Quality Management System

SECTION 1
INTRODUCTION

Project Quality Management Plan (QMP) is an essential document that any contractor or consultant must have. It is the life line of a project that will ensure the end product that is going to be delivered to client meet all the requirement and specifications. This project quality management plan for concreting activities (CQMP) document offers vital information about concrete materials related to quality assurance (QA) and quality control (QC) practices for Addis Ababa housing development project office (AAHDPO) condominium building projects with much significant concrete structures. It is the researcher's intention that this document serves as a guide for developing a QMP for concrete construction of significant concrete structures of AAHDPO projects. The project management team, consultants and contractors should prepare and use QMP documents (project-specific QC and QA procedures) which are appropriate and fits to a given project. This document grants information about what to include and items to consider for QC and QA planning.

Quality is enhanced by working systematically, according to formalized procedures, designed to prevent or eliminate errors from occurring. It is the adherence and conformance to properly developed requirements. Requirements for quality design in concrete construction include conformance with applicable codes, standards, guidance, regulations, laws, and statues referenced in the specifications. Requirements for quality construction also include compliance with contract provisions, clauses, and specifications. These contract documents establish the quality requirements for construction by defining the standards, including salient and essential characteristics, of concrete materials and the acceptance criteria and necessary testing inspection of concrete construction.

It shall be the responsibility of AAHDPO Project Managers and Consultants to ensure that this concrete quality management plan (CQMP) procedures are implemented consistently and effectively and that they are reviewed regularly to reflect the requirements of the contracts throughout the durations of works. It shall be the responsibility of the quality control manager to constantly monitor the implementation of quality control plan to establish and put into practice necessary systems and procedure, and ensure adherence to the quality control plan through regular auditing.


COST
TIME
SCOPE
QUALITY

The quality control plan details the systems and controls those consultants have to put in place so that the quality of the concrete structure and overall construction will meet the requirement specified by the contract agreement. The quality of Addis Ababa housing projects will be ensured through an integrated system of quality control and quality assurance performed by assigned stakeholders and they are responsible for the day-to-day coordination of quality measures in the field.

Should there be any contradiction between the contract agreement and the quality control plan, the contract agreement shall prevail. The quality control plan establishes,

- Project procedures and general responsibilities for the quality control program, and
- Protocols to ensure that the construction plan will be executed in accordance with the related requirements

Hired consultants will be responsible for the follow up of the construction work to be carryout in accordance with the plans and specifications. Consultant's quality control plan is the systematic implementation of a program of inspections and production control to attain the required standards of quality and to prevent problems resulting from noncompliance.

Corresponding to contract's technical specification, each construction contractor will establish an independent QC program in line with the consultants CQCP and write a contractor concrete quality control plan (CCQCP). The contractor quality control plan shall provide for test and inspections pursuant to various technical specifications. It will define procedures to ensure that activities affecting quality are properly documented and accomplished in accordance with contract documents such as written instructions, codes and procedures. Furthermore, the contractor quality control plan will define methods for ensuring that activities affecting quality will be accomplished under controlled conditions.

Independently of the construction contractors, consultants' engineer will provide quality control through daily monitoring and scheduled inspections to verify the effectiveness of the contractor's quality control program and assure that the quality and contract requirements are met the contractors. The Engineer assures that the contractor's quality control is working effectively and the resulting construction complies with the quality requirements establish by contract and codes of standards established for good concrete production.

The objectives of this Concrete Quality Control Plan are to:

- Describe a quality program to be implemented so that the project concrete structures are constructed in accordance with the contract requirements,
- Describe guidelines for inspection and documentation of concrete constructions activities,
- Provide reasonable assurance that the completed work will meet or exceed the requirements of the constructions drawings and specifications, and
- Describe how any unexpected changes or conditions that could affect concrete construction quality will be detected, documented and addressed during construction.

1.3 Quality Control

The role of consultant's quality control manager is to assure that the quality requirements of Addis Ababa housing projects office have been satisfied.

The quality control plan requires that the construction contractors implement the program and use its provisions daily to control quality of the work. Effective quality control requires a serious and concentrated effort on the part of the supervisory and inspection personnel. The tools for the accomplishment of effective quality control are as follow:

- Quality control personnel are expected to have the necessary education, experience and capability.
- Before start of construction, the consultants quality control manager shall conduct a mutual understanding meeting with the contractor and discuss the contractor's quality control system, construction start will be delayed until after the mutual understanding meeting and submittal/ acceptance of at least the interim contractor concrete quality control plan. The contractor quality control plan will be critically examined.
- The consultant's quality control manager will assure that the contractor concrete quality control plan is sufficient to obtain quality of concrete construction designed in the contract plans and specifications.

1.3.1 Quality Control Plan Phases

This quality control plan will comprise the following three phases:

- **Preparatory phase meetings:** Quality control meetings will be held before each definable feature of work is executed to ensure that the documentation is complete, materials are on hand, and the construction workers, who are to perform the work, understand what they need to know about the feature of work. Both the actual contract specifications and those referenced in the contract specifications shall be in the contractor's library and available to the quality control inspections, as if the quality control inspectors do not have the required specifications, they cannot know or enforce the provisions of the specifications.
- **Initial Inspections:** Quality control inspections shall be conducted in a timely manner at the beginning of a concrete construction work. A check of the preliminary work will determine whether or not the contractor, through his contractor quality control system and the workmen involved, thoroughly understand and is capable of accomplishing the work as specified.
- **Follow-up Inspections:** Also conducted by consultant's quality control staff and contractor's quality control staff, such inspections will be done daily when concrete work is in progress and are for the purpose of assuring that the controls established in the earlier phases of inspection continue to provide work which conforms to the contract requirements. Most of the comments in both the contractor quality control and quality assurance daily reports will be generated from these inspections.

In all projects, there is work that is 'cut and cover' that is, work that cannot be inspected "after the fact". Good example for this is concrete where the size, number and location of reinforcing steel, amount of concrete materials used and production which cannot be readily determined after the concrete is placed. Hence work of this nature shall be closely controlled and monitored to avoid poor quality of product.

The consultant's CQCP has a vital role in assuring good quality and avoids poor quality from occurring. Responsibility for compliance shall not be left wholly to the contractor.

The consultant's quality control manager shall closely monitor the contractor quality control program to assure that the three-phase control system is being correctly performed and that the contractor is effectively controlling all operations. In the event that contractor quality control personnel are not capable and are not inspecting properly, the resident engineer shall be notified immediately and shall correct performance by using one or more of the enforcement tools provided for in the constructions contract. Records and reports will document all such facts.

1.3.2 Plans and Specifications

Consultant's quality control manager will monitor the preparation of design documentation including plans and specifications, and will:

- Watch for omissions,
- Watch for discrepancies between plans and specifications,
- Check plans and specifications against requirements of which problems occurred on similar jobs,
- Compare elevations, grades and details shown on plans as exiting, with those at the actual site,
- Report all errors, omissions, discrepancies, and deficiencies to the design office and resident engineer, and
- Always keep a posted and marked up set of plans and specifications convenient for ready reference.

As a consultant, quality control managers shall anticipate the construction contractor's operations by reviewing the plans and specifications for each operation before it begins, and:

- Discuss contract requirements in each preparatory phase meeting with the constructions contractor before each operation begins, and
- Highlight and/or make notes of those provisions which need special attention, such as:
    - Unusual requirements
    - Those which other contractors have overlooked
    - Repetitive deficiencies

- Use the checklists in these guides to help find significant items in the plans and specifications.

1.3.3 Pre-Constructions Conference

The quality control officer, resident engineer and contractor representative shall attend pre-construction conference, in addition to AAHDPO project manager and its designated quality assurance representatives. Minutes of the conference shall be available to each of the quality assurance/quality control representatives assigned. The subject of the proposed quality control plan shall be well documented.

1.3.4 Equipment Proposal

All equipment proposed by the contractors in site concrete production processes used in mixing, conveying, placing and compacting the concrete shall be approved by the consultants prior to its use.

All the necessary equipment for any particular pour shall be on site and proven to be in working condition before the pour commences, with backup equipment on site as determined by the consultant.

The equipment shall be well maintained, suitable in kind and adequate in capacity for the concrete work.

Consultant's checklist for equipments used in concrete production shall:

- Check appropriateness of the capacity and the speed of rotation of the mixing drum or blades of the mixers used for concrete production from manufacturers specification proposed by contractors,
- Ensure that all joints, valves and other parts of the mixer shall be maintained so that there is no leakage of water or cement paste out of the mixer drum,
- Ensure that concrete transportation equipments used shall minimize segregation that caused due to transportation and placing,
- Ensure vibrators shall be of a type and design adequate for intended use,
- Ensure sufficient number of vibrators is available to properly compact each batch immediately after the concrete has been placed in the forms.

1.3.5 Labor Enforcement

Consultants and supervisors checklist for labor enforcement shall:

- Check sufficient laborers are there for the production of concrete,
- Ensure that skilled workers understand ways of improving concrete quality,
- Promptly inform the resident engineer and contractors authorized personnel of any labor problems and disputes that may disturb the concrete working environment,
- Assist all personnel in assuring quality,
- Ensure that each laborer and equipment shall be classified in accordance with the particular work function.

1.3.6 Storage of Materials

Consultant’s checklist for storage of materials:

- Ensure that adequate space is available for the contractor’s operations and storage areas,
- Ensure all storage areas are adequate for storing concrete making materials,
- Ensure that approval has been obtained for temporary sheds, buildings, etc. which the contractor proposes to install at the site for cement and other concreting materials,
- Ensure that concrete materials and equipments are properly stored and protected,
- Ensure that safety requirements necessary for specific project,
- Ensure that all concrete making materials are available to produce desired concrete amount.

1.4 Quality Management Plan

Contractors will carry out the construction work of Addis Ababa Housing projects in accordance with this concrete quality management plan (CQMP) which will helps in managing and improving quality of concrete and other works.

1.5 Organization of Concrete Quality Management Plan for AAHDPO projects

This Concrete Quality Control Plan is organized into eleven sections.

- ***Section 1***- Introduction: Describes the project setting, the contract and related documents, and the Quality Control plan overview.
- ***Section 2-*** Project quality control Organization: Presents the organization and key personnel involved in the construction of Addis Ababa Housing projects, their responsibilities and authorities, the structure of the quality control organization and the minimum suggested training and experience of the quality control officer and personnel.
- ***Section 3***-Submittals: presents the procedures for processing submittal from contractors and vendors.
- **Section 4-** Performance Monitoring Requirements: Addresses quality control for performance monitoring requirements.
- ***Section 5-*** Inspection and verification Activities: Provides procedures for tracking construction inspection and verification activities for the contract, and construction acceptance criteria and construction audits.
- ***Section 6***- Construction Deficiencies: Describes the procedures for tracking construction deficiencies from identification through acceptable corrective action.
- ***Section 7***- Documentation: Describes the procedures for the project documents that will be managed through a combination of a secure documents filing and storage system and computerize document tracking system.
- ***Section 8***- Field Changes: Describes handling of quality plan changes to assure quality control objective are met.
- ***Section 9***- Final Reporting: Describes the quality control documentation
- ***Section 10***- References: Provides bibliographic references to key document referred to in the body of the plan.
- **Section11**- Appendixes: Provides different concrete quality control and quality assurance formats.

SECTION 2

PROJECT QUALITY CONTROL/QUALITY ASSURANCE ORGANIZATION

This section presents the responsibilities and authorities of organizations and key personnel involved in the construction of Addis Ababa housing projects, the structure of the quality control organization, the minimum training and experience of the quality control personnel and the quality control training given to all onsite works including concrete work.

2.1 Responsibilities and Authorities of Organizations

The organizations involved in the Addis Ababa Housing projects and their quality control roles and responsibilities are as follows.

2.1.1 Addis Ababa Housing Development Project Office

The AAHDPO is the lead agency responsible for observing and monitoring the progress of the projects and all administration works. It allocates portions of each project to individual contractors. It also allocates and supplies concrete construction materials such as reinforcement bar, cement, aggregate and finishing materials including electrical and sanitary fixtures. AAHDPO also assigns AAHDPO sub-branches on project site location and consultants for each project which controls and manages the allocated projects.

Each sub-branch project offices are responsible for overall project management of buildings under each project. They are also responsible and control whether consultants and contractors are working in accordance with the contract documents or not. They are organized to follow the progress of the work and overall management and take corrective measures when problems arise.

2.1.2 Consultants

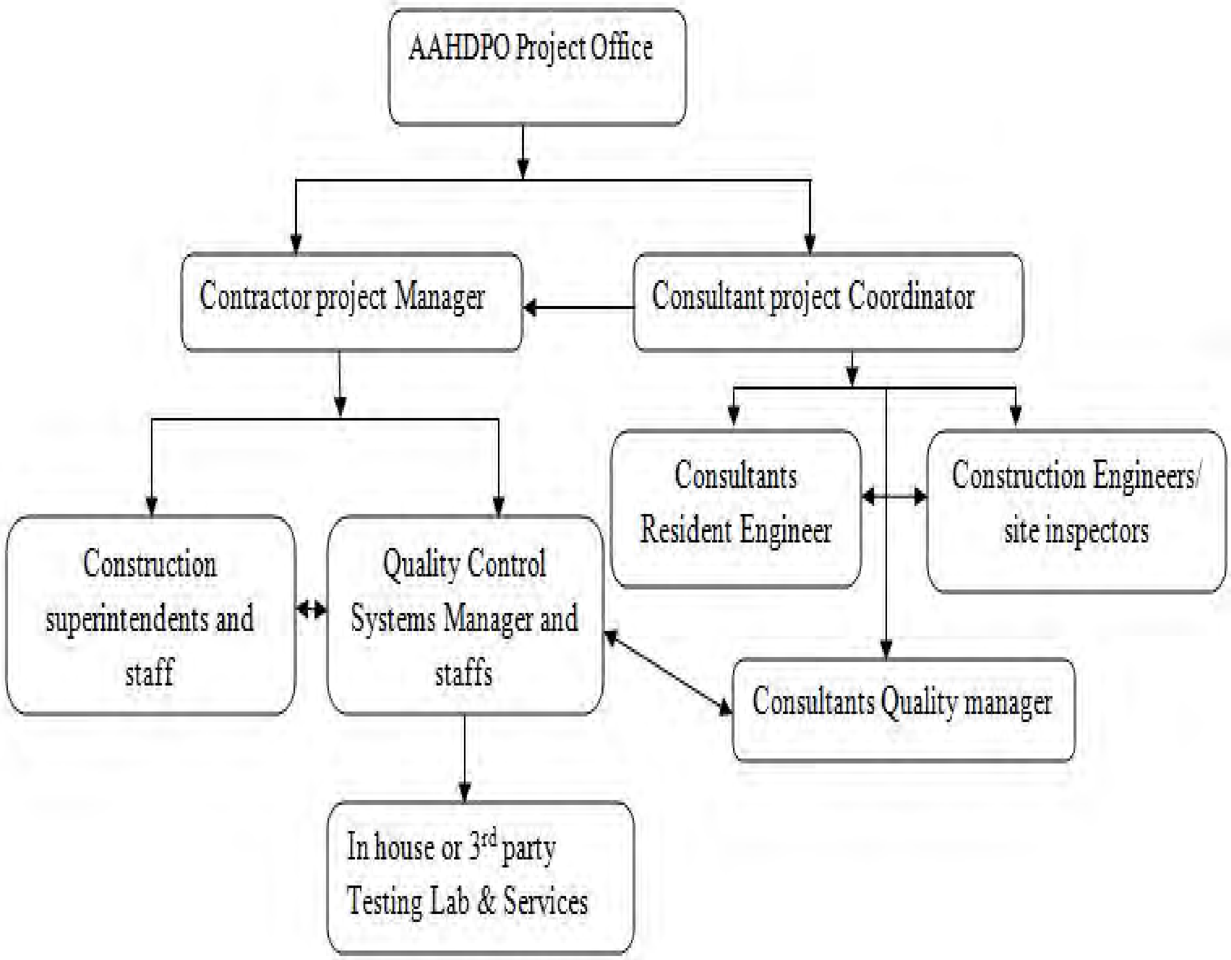
The consultant is responsible for maintaining quality control ensuring that contractors and subcontractors perform the construction works in accordance with the contract documents, specifications, and related documents. The quality control plan details the systems client and consultant have put in place in order ensure that quality requirements are met.

The consultant's resident engineer/representative provides professional construction project management and related services in connection with the project. The Resident Engineer/representative is responsible for implementation of this concrete quality control plan (CQMP). The resident engineer will manage construction contractors on behalf of the consultant and serve as the primary point of contact with the contractors for all communications to and from the contractors. The resident engineer will provide quality control and monitor the day-by-day construction quality control activities performed by construction contractors to verify compliance with the contract plans and specifications. The resident engineer will also manage, coordinate, and administer all quality control activities and requirements, including subcontractors involving in AAHDPO projects.

2.1.3 Construction Constructors/Contractors.

The construction contractors are hired by Addis Ababa housing development project office to provide the labor work. In case of concrete construction on those projects sand and equipments such as mixer and vibrators are provided by the contractor in accordance with the contract documents.

Construction contractors are responsible for the quality control of their constructed work product as well as the necessary inspections and tests required to ensure that their work complies with the contract documents. They exercise authority over their workforce, including quality control personnel and their third-party quality control support services, if any. Each contractor will have to submit a quality control organization chart developed to show all quality control personnel and how these personnel integrate with other management, production and construction functions and personnel to the consultant. All quality control staff members are subject to acceptance by the consultant. The requirement for the quality control organization includes a quality control systems manager and a sufficient number of additional qualified personnel to ensure contract compliance. The contractor is expected to provide a quality control organization that is


AAHDPO Project Office
Contractor project Manager
Consultant project Coordinator
Consultants Resident Engineer
Construction Engineers/ site inspectors
Construction superintendents and staff
Quality Control Systems Manager and staffs
Consultants Quality manager
In house or 3rd party Testing Lab & Services

2.3 Responsibilities and Authorities of Key Personnel

Quality control representatives shall be thoroughly familiar with all the provisions of the contract documents, including submittals. Plans and specifications shall include all revisions, changes, and amendments.

Key personnel involved in the project and their quality control roles and responsibilities are described below in Section 2.3.1 and Section 2.3.2. Since personnel assignments are subject to change over time, the consultant's resident engineer will maintain quality control staffing list together with personnel assignments including the description of each position, along with information on the responsible organization. When personnel changes occur, consultant's resident engineer will revise the quality control staffing list accordingly.

2.3.1 Consultant's Quality Control Personnel

Concrete deals with testing materials and ensuring the properties meet specification requirements. However, before concrete is placed, the specification requirements regarding excavation, formwork, steel reinforcement, and construction joints must be inspected. Inspectors must familiarize themselves with the specifications, including relevant drawings. Daily reports should be prepared that document observations made during the inspection of the placement of steel reinforcement and formwork. Required excavations should be verified by inspection and testing, and appropriate reports prepared. Therefore consultant's personnel should understand and critically evaluate every single step in concrete construction.

The following key quality control personnel will be identified prior to the start of any concrete construction works. A list of all quality control personnel will be provided to AAHDPO, including the following details for each personnel: name, main responsibilities, qualifications and years of work experience in the same field.

A. Consultant's Resident Engineer

The consultant's resident engineer or representative is the primary point of contact for consultant on all construction management issues. The resident engineer is responsible for the overall management of activities related to the construction program, including the implementation of the quality control plan and the health and safety program. As such, the resident engineer will exercise approval authority over contractor submittals including the quality control plan. The quality control plan shall include the names and qualifications of contractor's quality control personnel.

B. Consultant's Site Monitoring Engineer/ Senior Construction Engineer

The consultant's site monitoring Engineers manage the field implementation of the quality control plan at the project sites under control of quality control manager. The consultant's site monitoring engineers will monitor the day-to-day activities of the contractor. This includes ensuring that contractors comply with the plans and specifications, applicable building codes, good workmanship, and the quality control requirements of the contract.

As part of this effort, the consultant's site monitoring engineers will:

- Conduct independent inspections to verify the quality of the work,
- Participate in contractor three phase quality control inspections to enhance the level of quality of concrete,
- Review test and inspection reports as necessary and
- Ensure that the required documentation for QMS is submitted.

The consultant's site monitoring Engineers shall be alert of detecting, recording, and reporting any deviation from the contract documents, including calling any deficient item to the attention of the contractor's superintendent, and to the resident engineer. The consultant's site monitoring engineers shall keep accurate and detailed records of the contractor's performance and progress, delivery of materials if any, and other pertinent matters, including the daily inspection report.

C. Consultant's Quality Control Manager

The Consultant's quality control manager is full-time consultant's employee. The quality control manager shall have a minimum of five years' experience in related construction and prior quality control experience on a project of comparable size and scope to this project.

Additional qualifications for the quality control manager include one or more of the following requirements:

- Two years of related quality control experience with a Bachelor of Science Degree in Civil Engineering or Construction Technology and Management.
- The quality control manager reports directly to the resident engineer. The quality control manager will have full authority delegated by the consultant to institute actions necessary for the successful implementation of the QC program to ensure compliance with the contract plans and technical specifications (including stop-work authority). The quality control manager should be assigned to the program full time.
- The quality control manager works with consultant's resident engineer to administer and implement the quality control plan. This includes controlling this quality control plan, making revisions as necessary, and implementing systematic actions to ensure compliance with the plan. The quality control manager coordinates and oversees the consultant's construction engineers to ensure that inspection staff, third party inspection and testing firms as well as contractor quality control staff carry out the requirements of the concrete quality control plan.
- The quality control manager tracks and reports non-conformances to the resident engineer. The quality control manager also has full authority to obtain direct access to contractor quality control files.

Other quality control manager responsibilities include;

- Reviewing contractor quality control reports, tests, and inspection results,
- Facilitating the implementation of the three-phase inspection program and participating in the required inspections and
- Ensuring that quality control personnel conducting inspections, including consultant's site monitoring engineers, are adequately trained and understand assignment limits and time frames.

2.3.2 Contractor's Quality Control Personnel

The following key quality control personnel will be identified prior to the start of any construction works. A list of all quality control personnel will be provided to the consultant, including the following details for each personnel: name, main responsibilities, qualifications and years of work experience in the same field.

A. Contractor Quality Control Systems Manager

The contractor quality control systems manager is a full-time employee of the contractor, or a consultant engaged by the contractor. The quality control systems manager shall have a minimum of four years of experience in related construction, prior quality control experience on a project of comparable size and scope to the contractor's scope of work on this project and shall have Bachelor of Science degree in Civil Engineering or Construction Technology and Management. Contractor quality control staffs will be engineers or engineering technicians, and will have a minimum of two years of experience in their area of expertise. Additional experience and training may be substituted for educational requirements, subject to consultant's/Engineer's approval.

The quality control systems manager will have full authority to institute any and all actions necessary for the successful implementation of the quality control program to ensure compliance with the contract plans and technical specifications. The quality control systems manager shall report directly to a responsible project manager or officer of the construction contractor.

The contractor quality control systems manager and staff should perform the following functions:

- Inspect all materials, construction, and equipment for conformance with the technical specifications,
- Perform all quality control tests as required by the technical specifications,

SECTION 3
SUBMITTALS

This section describes the procedures for submittals. The consultant's resident engineer shall administer, control, and process submittals from the construction contractor(s). The consultant's resident engineer shall review all contractor submittals, and related supporting documents, to ensure compliance with project specifications and drawings. The submittals disposition will be noted on the submittal, which will be signed, dated and recorded. If required, consultant's resident engineer will return the submittal to the contractor for revision, incorporating the comments. The contractor shall resubmit it for review and verification for compliance. Submittals will be logged and copies will be retained in the project files.

3.1 Submittal Schedule

The construction contractor will prepare and submit a submittal schedule to the consultant's resident engineer. The schedule shall be initially submitted within 14 days after the award of the contract and updated on a monthly basis. The resident engineer shall work with the contractor to prioritize and sequence submittals so that the most critical submittals are received and processed first. The submittal schedule will become the baseline against which receipt of all required submittals will be compared.

The approved submittal schedule will be forwarded to Addis Ababa Housing Development Project Office (AAHDPO) for resource allocation planning.

3.2 Process, Review and Acceptance

Submittals will be managed as follows:

1) Contractors will number and certify the completeness of all submittals before submitting to consultant;
2) Contractors shall also complete submittal transmittal forms and submit four paper copies and one electronic copy of all required submittals to the consultant's resident engineer;

3) Upon receiving the submittal, the resident engineer will log the submittal and provide a review to ascertain whether the package is complete. If the submittal is incomplete the submittal will be returned to the contractor.
4) The original submittal transmittal and all copied attachments will be logged into the document tracking system.
5) The resident engineer shall review the submittal for general conformance with contract design documents, will coordinate concurrent discipline reviews within the design team, quality control manager, and consolidate responses into a single coordinated action.
6) The consultant will return a copy of the submittal to the contractor with an original stamp of the action required.
7) The six actions that may be taken for each submittal which are:

   i. Approved – Submittal meets contract requirements. No additional copies will be required of the contractor.
   ii. Approved As Noted – Submittal meets contract requirements with minor corrections noted. Re-submittal is not required. Contractor shall incorporate the required corrections into the work in the field. No additional copies will be required of the contractor.
   iii. Revise and Resubmit – Submittal has some selected areas that do not meet requirements. These areas can be revised to meet requirements, and the entire submittal shall be re-submitted for review and approval. No work will begin in the field until the revised submittal has been approved.
   iv. Rejected – Submittal is inadequate and does not meet contract requirements. Revise the complete submittal and resubmit for approval. No work will begin in the field until the revised submittal has been approved.
   v. For Information Only – Submitted for information only; no response action required.
   vi. Received, No Action Taken – Receipt of submittal is noted; no further action required.

8) When a submittal is to be revised and resubmitted, the contractor will revise the submittal and indicate this revision by incrementing the revision number.

9) The resident engineer is responsible for tracking the submittal package during the entire review process and advising all concerned of any schedule impacts to ensure that the review process time frame is adhered to. The resident engineer will retain copies of all submittal documents and revisions and ensure that an accurate file is available for ready retrieval during the life of the project. The resident engineer will maintain all submittal files. These files will be filed by numeric sequence. Each submittal file will contain a complete submittal copy of the submittal before and after the review process.

3.3 Storage

The resident engineer will maintain all submittal files via a combination of a secure document filing and storage system, and a computerized document tracking system. All submittal records will be available for review by all stakeholders. All submittal records will be provided to Addis Ababa Housing development project office (AAHDPO) as part of the project closeout documentation.

SECTION 4

PERFORMANCE MONITORING REQUIREMENTS

The performance monitoring requirements are applicable to all projects under Addis Ababa Housing Development Project Office. The contract technical specifications impose these requirements upon the contractors and require specific plans for contractor compliance and related work-area monitoring. The resident engineer will perform quality control oversight of contractor compliance and related work-area monitoring pursuant to the submitted plans.

4.1 Environmental Protection Plan

Environmental Protection Plan (EPP) outlines the steps that contractor will follow to minimize any adverse impact upon the environment in accordance with client requirements for the implementation of this project to realizes that there are threats to the environment from the project operations that must be eliminated or minimized. It is the contractor intention to spare no effort to prevent environmental pollution during and as a result of construction operations under this contract. Contractor should comply with all local, regional or Ethiopian government laws, rules, regulations or standards concerning environmental pollution control and elsewhere in the contract specifications.

Clauses should be written into the contract documents for the construction to ensure that the contractor is aware of their responsibilities. A summary of contractual obligations imposed on the contractor shall be presented in contract document, the contract clause ensure that the contractor adopt appropriate practices with respect to the following:

- Environmental protection,
- Minimizing negative impacts on local communities, and,
- Securing the health, safety and welfare of the workforce

Typically potential negative impacts associated with construction activities can be eliminated or minimized by good engineering practices including consultation with affected parties and thoughtful planning.

4.1.1 Contractor's Responsibilities

The Contractor shall be responsible for implementing environmentally and socially sound execution of the works (temporary and permanent) associated with the rehabilitation of the horizontal and vertical structure projects.

In particular, when providing facilities and carrying out construction activities, the Contractor must ensure the following:

- Safeguard all workers from any hazards associated with the construction activities and ensure protection of their health and safety.
- Ensure protection of the health, safety and welfare of project side communities by minimizing nuisance (including traffic disruption and pollution), friction and by establishing effective channels of communications.
- Observe the National Environmental Laws and other existing regulations of Ethiopia.
- Liaise with statutory undertakers for smooth and efficient operation and completion of projects.

4.1.2 Key Activities for Monitoring During Construction

The core issues that will be subject to environmental and social protection monitoring during construction are as follows:

- Effluent and solid waste disposal,
- General road safety management particularly with respect to diversions, construction through settlements, construction traffic and maintenance of existing road surfaces,
- Health, safety and welfare of the workforce,
- Community relations and mitigation of social tensions, and
- Impact levels of nuisance such as dust and noise.

Monitoring for compliance shall be a day-to-day affair carried out by all client's, consultant's and contractor's concerned personnel and staff.

4.2 Reporting

The monitoring data obtained by the resident engineer during construction work will be included in the weekly progress report.

4.2.1 Quality Control Report

A complete and accurate weekly report shall be prepared. The following information shall be included:

1) **Project conditions**– weather, moisture, soil conditions, etc. A detailed note on when and how adverse condition hampered or shut down a contractor's operation shall be included.
2) **Activities**– work phases, including locations. Details on description of each activity and the quality inspection phase, i.e., Preparatory, Initial, Follow-up, shall be included.
3) **Controversial matters**– disputes, questionable items, etc. A detailed note if such disputes were settled and, if so, how they were settled.
4) **Deficiencies and violations** – description, location and corrective action taken on observed deficiencies and violations.
5) **Instructions given and received**– identify recipient and source.
6) **Progress information**– report all delays, action taken or action contemplated.
7) **Equipment** – report arrival and departure of each major item of equipment by manufacturer, model, serial number and capacity; also report equipment in use and idle equipment.
8) **Reports** –make sure quality assurance reports are identified, dated and signed.

Check the quality control plan weekly report each week for accuracy and to assure that instructions received are noted. Effectiveness of the quality control plan inspections reported shall be checked during the job site visit.

4.2.2 Progress Schedules

1) Render any necessary assistance to the contractor for his/her preparation of initial and revised progress schedules.
2) Encourage contractor to submit timely updates.
3) Be familiar with the approved progress schedule and carefully watch for any slippage in progress.
4) Anticipate slowdowns and delays affecting progress.
5) Promptly report to the resident engineer and record in the daily quality control reports, all indications of any slippage in progress.
6) When construction falls behind schedule, carefully examine the construction operations for ways progress can be improved.
7) Be very careful not to direct or dictate the contractor’s operation, if needed, only the quality control manager may want to direct the contractor to take steps to improve his progress.

Keep informed of the required contract completion date and know the advance notice required by higher authorities for pre-final and final inspections.

SECTION 5

INSPECTION AND VERIFICATION ACTIVITIES

The quality control, verification, and acceptance testing plans will set out the quality control inspections and testing for implementation of technical specification applicable to the contractor's concrete related scope of work. The plans will cover the type, test standard, frequency, control requirements, and assigned responsibility for inspections and tests. The consultant's resident engineer will review and approve these plans as part of the contractor quality control plan submittals.

Ongoing quality control monitoring and oversight of contractor quality control inspections and testing will be performed by the consultant's resident engineer and other quality control staffs. In this manner, the inspections and tests required to measure compliance with the relevant portions.

5.1 General Construction Inspection and Verification Requirements

Contractors shall perform the inspections and tests as prescribed in the technical specifications for contracts. Quality control inspection and testing will be used to verify the adequacy and effectiveness of the contractor concrete quality control program. The quality control inspection and testing frequency will be at the discretion of the quality control manager based on results of quality control tests, evaluation of daily reports, audits of the quality control program and verification testing conducted by the consultant and the contractor's in-house or third party testing firm. Should information become available that indicates a potential problem, the quality control manager will review in detail all pertinent information and order additional verification testing if necessary. Contractor quality control, verification, and acceptance testing plans will set out the contractor's specific quality control testing and inspection. The different inspection forms to be used for such purposes are attached in the appendix part of this document. The forms are for illustration only and are not intended to replace or modify contract specifications that will form the basis of actual quality control plan submittals.

5.1.1 Inspections

The contractor shall establish a program for inspection of activities affecting quality of the concrete structures and shall cover all construction site and laboratory operations, including both onsite and offsite operations. Inspections shall be performed to verify compliance with documented instructions, drawings, procedures, and specifications as required by the contract. All inspections shall be conducted and documented by the contractor and consultant as required by technical specification. The checklists shown below will be used during inspection.

- **Checklists**: Please see the attached sample checklist in appendices.
- **Quality Inspection Program**: A four-phase inspection program shall be followed for each concrete work.

The four phases of quality inspection are:

1. **Preparatory Quality Inspection**: The contractor and consultant perform preparatory inspections prior to beginning any work on any definable feature of the concrete work.
    a) Ensure that preparatory inspections include a review of contract requirements.
    b) Ensure that all materials that uses for concrete production have been tested, submitted, and approved based on contract document and respective standards.
    c) Ensure that provisions have been made to provide required testing for intended quality.
    d) Examine work area to ascertain that all preliminary work has been completed before concrete production is taking place.
    e) Examine materials, equipment, and samples to ensure that they conform to approved shop drawings or submittal data, that all materials and/or equipment are on hand, and that all monitoring and measuring equipment is properly calibrated and in proper working condition.
    f) Record preparatory inspections in the contractor's quality control documentation as required by technical specification.

2. **Initial Quality Inspection:** The contractor and consultants perform an initial inspection as soon as a representative portion of the particular feature of work has been accomplished.
    a) Examine the quality of workmanship.
    b) Review control testing for compliance with contract requirements.
    c) Review dimensional aspects of the work.
    d) Record initial inspections in the contractor's quality control documentation as required by technical specification.
3. **Follow-up Quality Inspection**: The contractor and consultant perform follow-up inspections daily.
    a) Ensure continuing compliance with Contract requirements.
    b) Ensure continuing compliance with control testing until completion of particular concrete work.
    c) Contractor quality control manager records follow-up inspection in daily quality control reports.
    d) Consultant's quality control manager records follow-up inspections in their daily inspection report.
    e) Conduct final follow-up inspections and correct test deficiencies prior to the addition of new feature of concrete work.
4. **Completion Inspection**: The contractor and consultant perform a completion inspection of the work.
    a) Develop a "punch list" of items that do not conform to the approved plans and specifications.
    b) Include the punch list in the construction quality control documentation as required by technical specification. Include the estimated date by which the deficiencies will be corrected.

c) Perform a second completion inspection after punch list items have been completed and the resident engineer has been notified by the contractor.

Once all phases of inspection are completed it shall be included in the weekly inspection report. The weekly inspection reports shall identify inspections conducted, results of inspections, location and nature of defects found, causes for rejection, and remedial or corrective action taken or proposed.

Additional quality control inspections may include inspection of third-party lab testing facilities, and suppliers. Other inspections outside of the four-phase program described above will be ordered or performed by the consultant to verify compliance with building code and standards. These inspections shall be performed and conducted at various points of construction that would typically require code compliance inspections. For code references Ethiopian Building Codes of standard (EBCS-2), ACI 318 and other codes can be applied to verify compliance and conformity to the contract specification and expected quality.

When deficiencies are discovered during the four-phase or other inspection processes, focused inspection shall be considered by the quality control manager. When material or performed work, is found on the basis of focused inspections to be deficient and/or does not meet the project specifications, the quality control manager will assure deficiency correction is implemented.

AAHDPO sub-branches project office shall be allowed to participate in any and all inspections in necessary conditions to enhance the quality of concrete structures of the buildings and the office shall also check and supervise whether consultants are working on inspections and quality control to improve the quality of concrete produced of those projects.

5.1.2 Contractor Concrete Quality Control Testing

As required by the contract specifications, the contractor shall establish a test program to ensure that all required testing is properly identified, planned, documented and performed under controlled and suitable environmental conditions. Testing shall be performed in accordance with written test procedures in the quality control plan.

Such test procedures shall incorporate or reference the requirements as contained in the contract technical specifications, codes and industry standards. As per the quality control plan, the contractor shall submit the test procedures to the quality control manager for review and acceptance prior to their implementation.

The contractor shall propose a materials testing laboratory as part of the work plan. Consultant's approval of the proposed laboratory shall be provided in accordance with the following criteria:

- Qualification of key personnel and laboratory technicians.
- Calibration documentation for all testing equipment for required tests.
- Availability, condition, and capacity of facilities and testing equipment.

The contractor shall be responsible for establishing a system of periodic test reports that will record all quality control test results. Test results shall be submitted to the quality control manager prior to the start of the next concrete work period. When required by the technical specifications, the contractor shall maintain statistical quality control charts. The contractor's responsible technician shall sign the test reports. The quality control manager will review test results and identify any non-conforming test results for discussion with the contractor regarding potential corrective action.

5.1.3 Consultant's Concrete Quality Control Testing

The consultant's quality control manager will be responsible for the quality control of concrete making materials and testing program. The consultant quality control testing is provided for the verification of the adequacy and effectiveness of the contractor's concrete quality control testing. Quality control testing is assured by the quality control manager. QC testing may be performed on a pre-established schedule or as directed by the quality control manager when it is necessary. Quality control testing will be performed by or under supervision of the quality control staff to validate the contractor's quality control sampling and testing with acceptable standards. Such testing may be performed by third party testing services.

The typical test frequency will be based on the decision by the consultant based on applicable codes of standards for concrete quality testing and minimum test request on the contract document.

More frequent testing during initial startup may be necessary to verify that concrete production is under control and complies with the technical specifications of the construction contracts. In lieu of performing independent tests the quality control manager may choose to witness quality control testing or conduct tests on split samples from quality control testing. When concrete quality control test results do not compare or have wide variances with the specification, additional testing may be needed to validate the results. Additional tests to be performed by field inspectors or the third party testing services will be at the direction of the quality control manager. The need for quality control testing shall be based on the following considerations:

a) Importance of the item as to its reliability,
b) Need to perform quality checks for fabrication sequences not available for inspection at completion, and
c) Deficiencies are discovered.

QC testing shall be performed in accordance with the following:

a) The quality control manager shall develop a weekly or per necessary structure quality test and inspection schedule using the construction activity forecast as a guide. The schedule shall: identify the quality assurance test activities and identify the hold points.
b) The weekly or per necessary structure quality test schedule shall be distributed to the Engineer and Engineers field staff.
c) The contractor shall be provided a one-day advance notice of impending hold points.

Site monitoring engineers conducting the quality tests and inspections shall complete the daily construction report included in appendixes. The daily construction report shall be distributed to the quality control manager, resident engineer, monitoring engineer, contractor project manager and/or quality control systems manager. The quality control manager will review quality control tests and maintain files for all fields' quality control documentation.

5.2 Concrete Construction Acceptance Criteria

Concrete construction acceptance criteria for materials qualifications, inspection, and testing are established by technical specifications and code of standards. Ethiopian Building Code of standard (EBCS-2), ACI 318 and other relevant code of standards give guidance on acceptance criteria's for quality of concrete and its ingredients. This CQMP document illustrates concrete quality control tables included in Appendices A (materials qualifications), B (inspection), and C (testing). Criteria for concrete materials and equipment shall be set by and submitted to Addis Ababa housing development project office in accordance with the applicable codes and standards and by manufacturers' recommendations. Contractor submittals are to document conformance with acceptance criteria as detailed in their quality control plan (control, verification, and acceptance testing plan).

5.3 Compliance with Handling, Storage, Packaging, Preservation and Delivery Requirements

Consultant's field staffs will inspect the construction contractor's activities to ensure technical compliance in identification, handling, storage, packaging, preservation, and delivery of concrete making materials (i.e. cement, fine and coarse aggregate, water and additives if any) and production of quality concrete structures. Related quality records and documents will be maintained and controlled in accordance with the procedures provided in Section 7 of this concrete quality control plan document.

5.4 Material Identification and Traceability

Consultant's field staffs will monitor the construction contractor to ensure that identification and traceability requirements are met. Products and materials used in concrete production shall be traced from receipt through all project stages to installation. Documentation such as project control checklists, material receipts, material tracking forms, procedures, sample and test documentation, and reports will ensure that the applicable material item traceability is maintained.

Concrete production specifications and procedures shall define product identification and traceability requirements, which generally include the following:

a) Concrete materials or equipment intended for use in concrete construction are identified and segregated until inspection confirms that they conform to technical and quality requirements, and

b) Concrete materials are traceable to documents attesting to their conformance with technical requirements that are stated in specifications or drawings. Testing of concrete materials will also be conducted as necessary to verify conformance with concrete material specifications.

SECTION 6

CONSTRUCTION DEFICIENCIES

This section provides procedures for tracking concrete construction deficiencies (non-compliance) from identification through acceptable corrective action. It defines the controls and related responsibilities and authorities for dealing with non-compliant concrete products.

6.1 Deficiency Identification

Deficiency occurs when a concrete material or concrete production process of the performed work does not meet the plans or specifications for the project. Therefore, to avoid such deficiency, stakeholders should plan and collaborate in enhancing the quality of concrete. In this project the major stakeholders that are responsible in enhancing the quality of concrete are, the client (AAHDPO) who is the owner of the project, consultants who are hired by AAHDPO for supervision and quality control and contractors who construct the project buildings.

6.2 Quality Control Deficiency Identification and Control of concrete

When concrete materials or concrete work is found deficient, the quality control manager shall ensure that the non-conforming concrete material or concrete work is identified and controlled to prevent unintended use or delivery. The consultant will notify the contractor of non-compliance with any of the foregoing requirements. The contractor shall, after receipt of such notice, immediately take corrective action.

Minor deficiencies noted during test or inspection are be verbally reported to the contractor's representative and noted on the weekly construction report. Minor deficiencies are items that do not require significant rework or repair work to correct, and will not result in significant deviations from required quality standard if corrected immediately.

Control and disposition of such deficiencies shall be by the originator of the weekly construction report and the contractor's supervisor responsible for the work and do not require formal action by consultant. Ideally, such minor deficiencies can be corrected on the spot by agreement with the contractor's supervisor.

Non-conformances are major deviations from the contract requirement and/or accepted standard of quality, which shall be formally documented for corrective action by consultant's field staff or the third party testing group. Failure by a contractor to correct a minor deficiency after having been put on notice will also result in a non-conformance if it is not corrected within 5 days of notification. The Non-Conformance Report (NCR) is a formal notification to the contractor that work does not meet the plans or the specifications for the project. Any item of work found to be deficient, out of conformance with the construction drawings and/or specifications will be identified by the inspector on the nonconformance report as described in this section. Non-conformance reports will be included on the non-conformance log and tracked through verification that the non-conformance has been corrected.

Non conformances shall be formally documented on the NCR form and an example form is shown in Appendix D. The Non-conformance report shall be distributed to the contractor quality control manager, resident engineer, and AAHDPO sub branch office.

The consultant's quality control manager shall follow up on the Non-conformance report as required to verify that corrective action has been completed. The consultant shall verify and accept the corrected work by actual inspection.

6.3 Quality Control Deficiency Correction

When concrete material, performed concrete work is found to be deficient and/or does not meet the project specifications and standards, the quality control manager will assure and follow deficiency correction is implemented.

The quality control manager shall ensure that the non-conforming concrete material or concrete work is identified and controlled to prevent unintended use or delivery. The non-conforming concrete materials shall be discarded from production site to preclude their unintended use and concrete work shall be tagged by the construction contractor and consultant's staffs until solutions are provided for compliance and acceptance. The quality control manager is responsible for documenting the non-conformance in a NCR as specified in Section 6.2.

Contractors will implement corrective actions to remedy concrete work that is not in accordance with the drawings and specifications. The corrective actions will include removal and replacement of deficient concrete work using methods approved by the resident engineer. Removal shall be done in a manner that does not disturb concrete work that meets quality control criteria; otherwise, the disturbed concrete work shall also be rechecked by non destructive tests after removal of deficient concrete work. In case of non compliance of the concrete work it should be removed and replaced. Replacement shall be done in accordance with the corresponding technical specifications. Replacement will be subjected to the same scope of quality control inspection and testing as the original work. If the replacement work is not in accordance with the drawings and specifications, the replacement work will be removed, replaced, re inspected, and re-tested.

6.4 Preventive Actions

Preventive actions are to be taken to eliminate the cause of a potential non-conformity. For example, defects that appear on concrete during construction or within a relatively short time after completion are usually caused by poor quality materials, improper mix design, lack of proper placing and curing procedures, or poor workmanship. Contractors shall take preventive actions as necessary to eliminate the causes of potential deficiencies so as to prevent their occurrence. Contractor's concrete quality control plans are to include quality improvement practices to continually improve construction practices and address quality problems at their source. The resident engineer and quality control manager are to monitor, inspect, and audit processes used to prevent erroneous information or construction products from being passed to the owner.

The resident engineer and quality control manager have the authority to implement, verify and review the project's preventive and corrective action effectiveness. They are empowered to improve the project's work processes to eliminate the causes of potential non-conformities.

Contractor's quality control documentation shall cover all aspects of quality control program activities, and includes weekly inspection reports and test reports. After quality control plan approval by the resident engineer, the contractors will document the quality control activities pursuant to the quality control plan. Ongoing quality control oversight will also be documented by the resident engineer.

SECTION 7

DOCUMENTATION

7.1 Daily Record Keeping

Project documents will be managed through a combination of a secure document filing and storage system and a computerized document tracking system. Sufficient records shall be prepared and maintained as concrete work is performed to furnish documentary evidence of the quality of concrete construction and laboratory analysis and activities affecting quality of concrete. A consultant quality control manager shall maintain a daily log of all inspections performed for both contractor and subcontractor operations.

The daily inspection and test reports shall be signed by quality control manager or delegated authority. The resident engineer shall be provided at least one copy of each daily inspection and test report on the work day following the day of record.

7.2 Daily Construction Report

A daily construction report will be prepared and signed by the resident engineer or delegated authority. The report will include a summary of the contractor’s concrete construction activities if any. Supporting inspection data sheets will be attached to the daily report where needed. Example forms are provided in Appendix D.

At a minimum, the daily construction report will include the following information:

a) Date, project name, location, and other identification
b) Description of weather conditions, including temperature, cloud cover, and precipitation
c) Reports on any meetings held and their results
d) Record of visitors to site
e) Locations of concrete construction underway during that day
f) Equipment and personnel working in each activity, including subcontractors
g) Descriptions of work item being inspected

h) Decisions made regarding approval of concrete material or of concrete work, and corrective actions to be taken

i) Description of problems or delays and resolution

j) Communications with contractor staff

k) Construction activities completed and/or in progress

l) Progress photos, where applicable

m) Signature of the report preparer

The daily construction reports will be routed on a daily basis to the project quality control files and will be maintained as part of the permanent project record. These reports are reviewed by the resident engineer and summarized in a weekly and monthly report, and also distributed to the quality control manager.

7.3 Inspection and Testing Report Forms

Report forms will be completed for inspections and tests conducted. The forms vary depending on inspection or test type. Representative forms for concrete construction inspection and testing reports are included in Appendix D. These forms shall include:

a) Description or title of the inspection activity

b) Location of the inspection activity or location from which the sample was obtained

c) Recorded observation or test data

d) Results of the inspection activity

e) Personnel involved in the inspection activity

f) Signature of the inspector

7.4 Control of Concrete Quality Records

The quality control manager verifies concrete quality control record accuracy and maintains copies of all quality-related documentation. This includes, but may not be limited to:

a) Concrete construction quality control logs and records;

b) Inspection checklists and reports;

c) Surveillance reports;

d) Non-conformance reports;

e) Material receiving reports; and

f) Monitoring and test data.

These records will be stored in files maintained in the project document control files.

The resident engineer has primary responsibility for the centralized document control files for the project and construction documentation.

Pursuant to the contract specifications, the contractor provides an electronic or paper copy (suitable for scanning) of quality control documentation associated with the work to document control within three business days of the generation of such documents; and one electronic copy of all required submittals to the resident engineer. The resident engineer shall maintain a fire-resistant storage facility at the processing facility site. The facility shall contain all inspection reports, test records, contract documents, project, and daily field reports.

All records shall be available for inspection and audit, at any time, by Addis Ababa housing development project office.

SECTION 8
FIELD REVISIONS

Field revisions for concrete quality control will be limited to concrete quality control plan and quality control plan changes. Changes to construction processes or design plans and specifications are governed by the contract and design change order procedures.

8.1 Quality Control Plan Revisions

The resident engineer, site monitoring engineers, or quality control manager may initiate revisions to this quality control plan. The CQCP may be revised when it becomes apparent that the CQCP procedures or controls are inadequate to support concrete work being produced in conformance with the specified quality requirements or are deemed to be more excessive than required to support concrete work being produced in conformance with the specified quality requirements. Changes to quality control procedures necessitating modification to this CQCP will be initiated by the QCM for resident engineer's approval. AAHDPO review and approval will then be accomplished. Updates to quality control plan staffing will be made by consultant notification to AAHDPO sub-branch office without submission of a fully revised concrete quality control plan (CQCP).

8.2 Contractors Quality Plan Revisions

The contractor’s quality control plans required by technical specification contractor quality program requirements may require revisions as necessary to correct unsatisfactory performance. At any time after approval by the resident engineer, the resident engineer may require the contractor to make changes to the quality control plan, including personnel changes, as necessary to obtain the quality specified. Moreover, the contractor may initiate quality control plan changes to correct quality control process problems, and is required to notify the resident engineer in writing of any desired changes; all changes are subject to project manager’s acceptance. Revisions to the quality control plan will be provided to AAHDPO sub-branch office for information only.

SECTION 9

FINAL REPORTING

The following quality related documents will be generated during implementation of all Addis Ababa Housing development project office projects and will be submitted to AAHDPO.

9.1 Work Completion Report:

Once projects are completed all quality reports should be prepared and included with work completion report. The report shall include record (as-built) drawings and operation and maintenance manuals.

SECTION 10

REFERENCES

1. United Nations Office for Project Services (UNOPS), Construction Quality management plan, www.unops.org.
2. CWN Project Management Limited, Quality Control plans Template, Harcourt Centre, Block 4, Dublin, Ireland, www.cwnsas.com.
3. Construction Quality Control/Quality Assurance Plan, Phase 1 Facility Site Work Construction, Hudson River Pubs Superfund Siege Company – Parsons Project Office 381 Broadway, Bldg 40-2, Fort Edward, NY 12828, 2007.
4. Quality Management Plan Guidance for Concrete used for Construction of Significant Features, Technical Memorandum No. MERL-2015-073, U.S. Department of the Interior Bureau of Reclamation Technical Service Center Denver, Colorado, 2015.

SECTION 11

APPENDICES

APPENDIX A

QUALIFICATION TEST SCHEDULES

Table -1: Qualification Test Schedule for Concrete Making Materials

Aggregate Materials (Fine and Coarse)

Test Parameter	Test Method	Standard Title	Minimum QC Testing Frequency	Requirements (verified by CQCM)
Coarse Aggregate				
Grain-Size Distribution	ASTM C136 / -ES ISO 6274:2014	Sieve Analysis of Fine and Coarse Aggregates	At beginning of placing each mix. At least every 400 m^3 of placing a mix. At change in mix design and material source.	CoarseAggregate meets sizing requirements as per ASTM C33 -ES ISO 6274:2014
Moisture Content	ASTM C566/ ES ISO 6782:2014	Total Evaporable Moisture Content of Aggregate by drying	At beginning of placing each mix. At least every 400 m^3 ofplacing a mix. At change in mix design material source.	Verify that moisture content test is conducted with accurate method and materialat batching site. Test method as per -ES ISO 6782:2014
Fine Aggregate				
Grain-Size Distribution	ASTM C136 / ES ISO 6274:2014	Sieve Analysis of Fine and Coarse Aggregates	1 per stockpile and source change	Fine Aggregate meets sizing requirements as per ASTM C33/ ES ISO 6274:2014
Moisture Content	ASTM C566/ ES ISO 6782:2014	Total Evaporable Moisture Content of Aggregate by drying	At beginning of placing each mix. At least every 400 m^3 ofplacing a mix. At change in mix design material source.	Verify that moisture content test is conducted with accurate method and material at batching site. ES ISO 6782:2014

Note: This table is for illustration only and is not intended to replace or modify contract specifications that will form the basis of actual CQP submittals.

Table A-2

Cementations Materials (Cement)

Test Parameter	Test Method	Minimum QC Testing Frequency	Requirements (verified by CQCM)
Portland Cement			
Chemical and Physical Requirements	ASTM Cl50	Prior to use in concrete mix in absence of material certification.	In accordance with tables in ASTM Cl50 and Ethiopian Standard ES1177-1:2005

Table A-3

Concrete Mix Field Tests

Test Parameter	Test Method	Minimum QC Testing Frequency	Requirements (verified by CQCM)
Compressive Strength	ASTM C39/ ES ISO1920-4:2014	Preliminary testing of mix design; test at 28 days Take set of representative samples at least from different structural members, i.e., footing,columns,beams,slab, etc. and test 7,14 and 28 days strength	İntended compressive strength for 28 days, EBCS- 2 compliance and conformity criteria
Water/Cement Ratio	ES ISO1920-2:2014	Preliminary testing of mix design	Limit to the intended mix design.
Slump Test	ASTM C143/ ES ISO1920-2:2014	Once per batch prior to pouring concrete	Limit to the intended mix design. EBCS-2 also recommends slump margins different mixes
Concrete Cores	ASTM C42/ ES ISO 1920-7:2014	At discretion of the consultant when cube strengths fail to meet minimum requirements. The contractor shall obtain core specimens or rebound hammer test in accordance with ASTM C42 at locations directed by the consultant. With no additional cost to the client.	İntended compressive strength for 28 days EBCS-2 also recommend these tests.

APPENDIX B

INSPECTION SCHEDULE

TABLE B-1

AGGREGATE PLACEMENT / STORAGE

Inspection Parameter	Minimum QC Inspection Frequency	Acceptance Criteria (verified by CQCM)
Coarse Aggregate		
Material Characteristic	Continuous	As per standards and contract specifications
Maximum Size	Continuous	In accordance with the specification in the contract document
Suitability of Placement	Daily	In accordance with approved Work Plan. (Areas shall be free from organic impurities)
Fine Aggregate		
Material Characteristic	Continuous	As per standards and contract specifications.
Maximum Size	Continuous	In accordance with the specification in the contract document
Suitability of sand Placement	Daily	In accordance with approved Work Plan. (Areas shall be free from organic impurities)

Note: This table is for illustration only and is not intended to replace or modify contract specifications that will form the basis of actual CQP submittals.

TABLE B-2

REINFORCING, FORMWORK AND CAST -IN -PLACE CONCRETE

Inspection Parameter	Minimum QC Inspection Frequency	Acceptance Criteria (verified by CQCM)
Reinforcing Material Condition	Upon receipt at Site	No visible defects or damage due to corrosion, no unscheduled kinks or bends.
Reinforcing Bundle Identification	Upon receipt at Site	Bundled and tagged with enough information that coonform with specification
Reinforcing Material Storage	When necessary	In accordance with Manufacturer's recommendations and approved Work Plan
In-Place Reinforcing	Prior to closing forms and continuous during pouring	In accordance with approved Work Plan, free of old mortar, oils, mill scale and other encrustations or coatings
In-Place Formwork	Prior to pouring of concrete	In accordance with approved Work Plan; no excess water, hardened concrete, debris or foreign materials inside of forms, wet wood forms sufficiently to tighten up cracks
Concrete Mixer	Before Concrete batching is started	RPM of the mixer, Capacity to mix.
Surface Preparation	Prior to pouring of concrete	Fine grade earth and aggregate smooth and level
Concrete Placement	Continuous during Pouring of concrete	In accordance with approved Work Plan, height of concrete drop not to exceed 1.5m, place and compact within 60 minutes after water is first added, do not place after evidence of initial set
Formed Concrete Curing	Daily during curing of concrete	Forms maintained in wet condition until removed, concrete continuously moist for min of 7 days after pouring
Formed Concrete Finishing	After finishing of concrete	Fill holes and patch surfaces
Slabs and Flatwork Curing	Daily during curing of concrete	Concrete continuously wet for entire curing period

Note: This table is for illustration only and is not intended to replace or modify contract specifications that will form the basis of actual CQP submittals.

APPENDIX C

TEST SCHEDULES

Table c-1

TEST SCHEDULE FOR CONCRETE

Test Parameter	Test Method	Minimum QC Testing Frequency	Acceptance Criteria
Compressive Strength	ASTM C39/ ES ISO1920-4:2014	1 per 38 m^3 or fraction thereof from each day's placing; test at 7, 14 and 28 days	Intended compressive strength of 28 days EBCS -2 compliance criteria
Slump Test	ASTM C143/ ES ISO1920-2 :2014	When compression test cubes are cast	In accordance with ASTM C143.

APPENDIX-D

TYPICAL CONCRETE CONSTRUCTION FORMS

Concrete Compressive Strength Test Report form

(15x15x15cm-Cube)

Date :
Number:

Class of concrete :

Crushing date of samples:

Slump:

Temperature-

Description			**Age3 Days** If Required			**Age 7 Days**			**Age 28 Days**		
Item No.	Sample Nu.	Place & Type Of Structure	Weight (G)	Strength		Weight (G)	Strength		Weight (G)	Strength	
				KN	Kg /Cm^2		KN	Kg/Cm2		KN	Kg/Cm2
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
Specification :											

Remarks:

CONCRETE INSPECTION AND TESTING PLAN						
SUBJECT	**INS / TEST**	**ACTION**	**QUALITY CONTROL DOC.**	**VERIFICATION LOG**	**REQ. OF MONITORING**	**COMMENTS**
Controls before Concreting						
1	REINFORCEMENT: Compliance with Specs & Drwg., Rust Clearance – cleaning of elevation & axis	Site monitoring engineers / Quality Managers	Drawings Specifications	Reports, certificates Control list before concreting		
2	CONCRETE Premixed Concrete	Quality Control	Specifications	Water, material, additive reports Concrete mix & cement reports		
3	FORMWORK Elevation axes, Formwork Grease, Cleaning	Site monitoring engineers	Construction Drawings Specifications	Control list before concreting		
4	OTHERS Location of embedded elements Water Retainers, Anchorage	Group Engineers	Construction Drawings Specifications	Control list before concreting		

Concreting						
5	Taking Concrete Samples, Slump, Cubes, Temperature of the Medium, Concrete Temperature	Site monitoring engineers/ Quality manager		Test Results Recording		All the recording of a conc.work is filed all together.(control list conc, air temp. cube resistance results etc.)
6	Concreting Location Controls	Site monitoring engineers/ Quality manager		A Nonconformance report is issued if needed.		The group eng. should be present to see to it thatconcreting complies
7	Compacting Control	Site monitoring engineers/ Quality manager		A nonconformance report is issued if needed.		The group eng should attend Compacting
After Concreting						
8	Controlling Curing	Site monitoring engineers/ Quality manager		A nonconformance report is issued if needed.		
9	Fault Areas and Fixing	Site monitoring engineers		A non conformance report is issued if needed.	Should contain corrective actions suggested to correct and information stating that these actions are finalized asrequired.	Segragation, air particles opening the formwork etc.

PRE-CONCRETING INSPECTION FORM										
Explanation :				**Related Drawings** :						
Formwork Check		**Reinforcement Check**		**Surveying Check**		**Mechanical Check**		**Electrical and Sanitary Check if Any**		
Supports	☐	**Size**	☐	**Lining**	☐	**Embedments**	☐		**Embedments**	☐
Ties	☐	**Spacing**	☐	**Level**	☐	**Blockouts**	☐		**Blockouts**	☐
Waterstops	☐	**Laps**	☐	**Position**	☐	**Notes**		**Notes**		
Joint Prepare	☐	**Concrete Cover**	☐	**Sketch**	☐					
Cleanliness	☐	**Cleanliness**	☐							
Formoil	☐	**Quantity**	☐							
Embedments	☐									
Blockouts	☐									
Contractor		**Contractor**		**Contractor**		**Contractor**		**Contractor**		
Responsible Engineer **Name** **Date** **Signature**		**Responsible Engineer** **Name** **Date** **Signature**		**Responsible Engineer** **Name** **Date** **Signature**		**Responsible Engineer** **Name** **Date** **Signature**		**Responsible Engineer** **Name** **Date** **Signature**		

<table>
<tr><td colspan="6">Permission Given to Pour</td></tr>
<tr><td colspan="6">Consultant's Representative
Name :
Date :
Sign :</td></tr>
<tr><td colspan="2">Date of Concreting</td><td colspan="2">Type of Concrete</td><td>Slump</td><td>Site Manager</td></tr>
<tr><td colspan="6">Notes :</td></tr>
<tr><td rowspan="2">Controls after formwork striking</td><td rowspan="2">Curing
Line
Level
Position
Repairs</td><td rowspan="2">☐
☐
☐
☐
☐</td><td colspan="2">Consultant's Representative</td><td>Quality Control Manager</td></tr>
<tr><td colspan="2">Name :
Date :
Sign :</td><td>Name :
Date :
Sign :</td></tr>
</table>

NON CONFORMITY REPORT FORM

Nonconformity Report			**Date**:
Project			
Related Section			
Subject			
Summary of Non-conformity			
Prepared By	**Department**		
Summary of Disposition Plan			
Approved By	**Department**		**Date**
Result	☐ **Use - As – It - Is** ☐ **Repair** ☐ **Reject**		
☐	**Accepted**		
☐	**Rejected**		

CORRECTIVE ACTION COMPLETED FORM		
	Department	**Quality Control Manager**
Name		
Date		
Signature		

NON-CONFORMITIES LOG				
NCR Record No	**NCR Date**	**Brief Summary of Non-conformance**	**Disposition Date**	**Close-Out date**