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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)

A thesis submitted to
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Table of contents

List of tables

List of figure

List of abbreviations

A.A.	Addis Ababa
A.A.H.P	Addis Ababa Housing Project
ACI	American Concrete Institute
AD	Air Dry
AD	Air - Dry
ASTM	American Society for Testing and Materials
BS	British Standard
cc	Centimeter
EBCS	Ethiopian Building Code of Standard
ES	Ethiopian Standard
F.M.	Fineness Modulus
Fig	Figure
gm	Gram
HCB	Hollow Concrete Block
hr	Hour
IS	Indian Standard
Kg	Kilo Gram
KN	Kilo Newton
lb	Pound
lt	Liter
m	Meter
Max	Maximum
mm	Millimeter
MPa	Mega Pascal
NO.	Number
OD	Over-Dry
OPC	Ordinary Portland Cement
PPC	Portland Pozzolana Cement
RC	Reinforced Concrete
SABS	South African Bureau of Standard
SSD	Saturated Surface Dry
U.K.	United Kingdom
U.S.	United States
Wt.	Weight

ABSTRACT

In order to produce reinforced concrete and hollow concrete blocks with good quality which satisfy strength and durability requirements, great care have to be taken for their production starting from ingredient selection to finished product. In addition to this, every production process should follow proper scientific procedures. For this, quality control plays a significant role because qualities of these ingredients and their production process could affect the overall quality of buildings to a higher extent. Quality control comprises a combination of action and decision taken in compliance with specification and checks that these are satisfied.

Considering this, investigations focusing on quality control in reinforced concrete and hollow concrete block production has been conducted in projects administered by Addis Ababa Housing Project found in various parts of Addis Ababa located in Yeka Ayat II, Yeka Ayat III, Yeka Abado, Bole Arabsa, Kolfe keranyo, tulu dimtu and kelento sites.

The research is carried out by collecting information on qualities of ingredients and method of production through questionnaires and observation and sample compressive strength test result from consultant data file to check their compliance with the help of statistical analysis and minimum strength requirement set on recommended standards.

The findings of the investigation have shown that in all construction sites, sufficient tests are not conducted for all ingredients used for production of reinforced concrete and hollow concrete blocks. Among those ingredients, sand testes by some sites for its silt content using jar test, observation and or both. In addition to this, handling of those ingredients were very poor, during observation intermixing coarse and fine aggregate, grass grown on the top of sand, reinforcement bar rests on the ground… were shown and production process also not conducted properly as specified in the recommended standards.

According to the result of statistical analysis of concrete compressive strength test collected from consultant data files, the quality control on significant portion of the construction sites are not good. As per the classification of ACI 214, the standard deviation of 46.15 % of the compressive strength has shown that the quality control is not good. From which, none of them fall in the "fair" classification range and 46.15 % in the "poor" range; and the coefficient of variation of 76.92 % of the compressive strength has shown that the quality control is not good from which

15.38 % fall in the "fair" classification range and 61.54 % in the "poor" range. From the analysis of compressive strength test result, 35.14%, 14.86% and 21.62% of the projects has shown defective lots as per the Ethiopian, the American and the British codes compliance requirement respectively. On the other hand, 40% of hollow concrete block producers don't conduct test and the remaining 60% of them conduct a test for compressive strength, but the result collected from consultant data files, can't comply class C strength of Ethiopian standard for hollow blocks ES 596:2001.

This is an indication that the test results among a significant portion of the investigated projects have shown large variability implying the quality control is unsatisfactory. It is also observed almost one-third of the construction sites have got defective lots, which fail to satisfy the compliance requirement set on the Ethiopian building codes and standards.

Keywords: - Batching, bending, cement, coefficient of variation, compacting, cutting, curing, finishing, mineral aggregates, mixing, placing, quality control, standard deviation, transporting, tying and water.

1. INTRODUCTION

Reinforced concrete and hollow concrete blocks are building materials, these materials require more time, cost and labor force for their production as compared to other construction materials employed for building construction. And their maintenance is also difficult when certain problems such as cracking in concrete and hollow concrete blocks and corrosion of rebar occur to the extreme condition, failure may happen.

We can classify building materials used for different components of building as factory and non factory products, depending on their production such as, concrete and hollow concrete blocks are non-factory products which are mostly produced on site from three basic ingredients; namely, cement, aggregate and water sometimes admixture are used to improve some properties like workability, setting times…. Hence, there are various factors that bring variation on quality. These factors are quality of ingredients and variation in production processes. As a result, proper quality control is extremely necessitated, particularly to concrete which forms the critical part of a building such as foundation, column, and beam. On the other hand, reinforcement bars are factory products which can cause deterioration on the building due to corrosion as a result of improper handling and installation.

In order to produce reinforced concrete and hollow concrete blocks based on specified standard specification, proper care and control have to be done during proportioning of ingredients which contains two parts: these are selection of suitable ingredients and determining relative quantities and production processes such as batching, mixing, transporting, placing, compaction and curing. In addition to this, reinforcement bar requires proper handling during stocking and proper care during fabrication process such as cutting, bending, tying and fixing. This shows the importance of the care that should be taken in production process.

According to EBCS 2, 1995, quality control comprises a combination of actions and decisions taken in compliance with specifications and checks to ensure that these are satisfied. It is a means of checking that the row materials and production processes are in compliance with the requirements stated in code of practices. It contains two parts namely production control and compliance control. Quality control has cost in it; however, if the contractor is not willing to pay the controlled cost of quality during production, he will pay cost and time for correcting the defective works and reworking of unacceptable works.

To this effect, this research is carried out to study the effectiveness of quality control on this area, so that you can identify the problems associated with the quality control in production of reinforced concrete and hollow concrete blocks in building projects under construction by Addis Ababa housing agency. Finally, from the obtained results conclusions were made and recommendations were forwarded to suggest ways of improving for next phases of construction.

1.1.Objective of the research

The objective of the research is to undertake qualitative and quantitative assessments on quality control on production of reinforced concrete and hollow concrete block in building projects administered by Addis Ababa Housing Project. This objective is achieved through:

1.2.Objective of the research

The General objective of this research is to study the effectiveness of quality control for the production of reinforced concrete and hollow concrete block in building projects administered by Addis Ababa Housing Project. This objective is achieved through:

1. Investigating the current practices of quality control in construction sites and looking at whether or not there is a gap between the existing practice on site and the recommended scientific approaches stipulated on literatures and code of standards.
2. Assessing the level of quality control being undertaken after performing statistical analysis on sample test results collected from construction sites and after checking the compliance of these compressive strength test results with Ethiopian, British and American standards.
3. Checking if the test results of HCB compliance criteria are full filled with the Ethiopian standards.

Finally; after making the above qualitative and quantitative assessments on the quality control for production of reinforced concrete and hollow concrete block, conclusions and recommendations are drawn.

1.3.Statement of the problem

It is generally known that quality control is the most significant step in producing good quality of products. In case of RC and HCB productions there are two distinct but equally important activities one is related to material and the other is the related to the process involved in its production. In order to produce good quality of products care has to be taken for both steps.

- If care is not taken for materials on their quality and handling mechanism, poor quality of products is obtained no matter how the production process is proper. For instance those problems listed below can result from poor handling of materials.
    - When Cement stored in contact with damp air or moisture sets more slowly and has less strength than cement that is kept dry [1]. As a result, poor quality concrete will be occurring.
    - Presence of soft particles in aggregate may form a coating and may weaken the bond between cement paste and aggregate.
    - Improper handling of reinforcement bars may result corrosion. Corrosion leads reduction of cross section of reinforcement as a result cracking and splitting of concrete cover can be occurring. The load carrying capacity of steel decreases in addition to this the elongation properties and fatigue strength may be reduced more substantially by small reduction in cross section.

- If care not taken for process involved in production, again poor quality of products is obtained even from materials fulfilling specifications. For example those problems listed below can result from poor production process.
    - Using excess water during mixing to improve workability.
    - Under or over vibration.
    - Insufficient curing.
    - Improperly tied reinforcement bars.

Therefore the practices and its effectiveness have to be studied. And the aim of this research is to assess level of effectiveness of quality control for production of reinforced concrete and hollow concrete block in projects administered by Addis Ababa housing project.

1.4.Significance of the study

This paper mainly importance of the practitioners in the construction of condominium buildings such as consultants, contractors and government. And this helps the consultants in specifying the effective and suitable quality control system. Because quality control is one of the significant factors that affect the quality of products. Selecting efficient quality control system helps to assure the strength of the structure, safety of occupants and to increase the quality of product, reducing the cost incurred due to poor quality of work and material.

1.5. Scope and Limitation of the study

The research addresses the objectives and tries to investigate the quality control on production of reinforced concrete and hollow concrete block in building projects administered by Addis Ababa Housing Project based on the existing theories and principles. Investigation is undertaken on randomly selected sites located in Addis Ababa. The sites in which the research is conducted are Yeka Ayat II, Yeka Ayat III, Yeka Abado, Bole Arabsa, Kolfe keranyo Tulu dimtu and klento. Those sites currently extensive building construction projects has been executed by construction of hundreds of blocks for condominium building and they are owned by Addis Ababa housing Agency.

Due to financial problems and lack of willingness by consultants, the research hasn't been done in all construction sites. Therefore the effectiveness of quality control assessed for specific constructions sites those are listed above.

1.6.The structure of the thesis and process of the study

The thesis is organized into five chapters; Chapter 1 deals with the Introduction of the research, Chapter 2 deals with Literature Review; Chapter 3 deals with Methodology; Chapter 4 deals with result and discussion; Chapter 5 deals with Conclusions and Recommendations, and lastly, references and appendices are included.

2.LITERATURE REVIEW

2.1.Reinforced concrete production

Reinforced concrete is a strong durable building material that can be formed into many varied shapes and sizes. It is achieved by combining the best features of concrete and steel because concrete is a brittle, composite material that is strong in compression and weak in tension. Cracking occurs when the concrete tensile stress in a member reaches the tensile strength due to externally applied loads, temperature changes, or shrinkage. Concrete members that do not have any type of reinforcement in them will typically fail very suddenly once the first tension crack is formed as there is nothing to prevent the cracks from propagating completely through the member. So it becomes desirable to reinforce the concrete with reinforcement bar which provide greater resistance to tensile and shear forces [1].

Reinforced concrete building is unique, the following sequence of events occurs in the production of any cast-in-place reinforced concrete building those are casting of fresh concrete on the properly placed and tied reinforcement bar on the erected formwork. But each production process has its own sequence of production. For instance, concrete requires batching, mixing, transporting, placing, compacting and curing. On the other hand reinforcement bar requires cutting, bending, tying and fixing. Therefore, quality control in every step of production is important in order to produce reinforced concrete as specified in the specification.

2.1.1.Concrete Production

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in hard matrix of material (the cement of binder) that fills the space between the aggregate particles and glue them together [2]. In concrete the binder or matrix is a combination of cement and water; it is commonly called the "cement paste. Aggregates are essentially filler materials that can be separated into fine and coarse aggregates. In addition to aggregates and binders, there is another material called additive which may be used in concretes to improve certain of its properties [3].

The production of concrete involves two distinct but equally important activities. One is related to material required for concrete production such as selection and proportioning of ingredients and the other is the process involved in its production such as batching, mixing, transportation, placement, compaction and curing [2]. To produce concrete as economically as possible with appropriate workability, strength and durability so that care has to be taken during concrete production because poor quality of concrete even from well designed mix can be happen due to lack of attention in production [2].

A good and a bad concrete may be made from exactly the same ingredients if there is a difference on the quality control during production. The importance of quality of concrete is being increasingly realized to derive the optimum benefit from the materials employed. Quality control does not merely signify testing of concrete cubes at 28 days; rather it actually permeates all aspects of the choice of materials, design, and workmanship—it commences much before any concrete is available for testing at 28 days [4].

According to EBCS 2, 1995, Quality control is defined as an action and decisions taken to ensure the compliance of works with the specification. It consists of two distinct, but interconnected parts, namely, production control and compliance control. Production control is a measure taken during production to obtain a reasonable assurance that the specifications will be satisfied which compliance control is a check is made to ensure the compliance of the product with the specification.

2.1.1.1.Composition of Concrete

Concrete is basically a mixture of two components: aggregates and paste. The paste binds the aggregate into rocklike mass because of the chemical reaction between cement and water, sometimes mineral and chemical admixtures may also be included in the paste [5]. The quality of the concrete depends upon the quality of the paste and aggregate, and the bond between them. In properly made concrete, each and every particle of aggregate is completely coated with paste and all of the spaces between aggregates are completely filled with paste [5].

2.1.1.1.1.Portland cement

Portland cement is made by carefully blending of selected raw materials to produce a finished material meeting the requirements of ASTM C150 for one of eight specific cement types depends on constituents of the four major compounds [lime (CaO), iron (Fe_2O_3), silica (SiO_2), and alumina (Al_2O_3)] and two minor compounds [gypsum ($CaSO4 \cdot 2H_2O$) and magnesia (Mg O)] [6].

The calcareous (CaO) materials typically come from limestone, calcite, marl, or shale and the argillaceous (SiO_2 and Al_2O_3) materials are derived from clay, shale, and sand [6]. Those materials are used for the manufacture of any specific cement and their manufacturing process classified as dry and wet process depends on condition of materials burn in the kiln to form clinker at clinkering temperature of about 1400 to 1500˚C [5]. The cement clinker then passes through clinker coolers. Having cooled sufficiently, the clinker is ground to the required degree of fineness. During the grinding, gypsum is added in small amounts to control the temperature and regulate the cement setting time. The material that exits the ball mill is Portland cement. It is normally sold in bags or in bulks [5].

The major constituents of raw materials used in Portland cement production; mainly, lime, silica, alumina and iron oxide compounds interact with one another in the kiln to form a series of more complex products. Table 2.1 gives approximate oxide composition limits of Portland cement [7]. Those various constituents listed in table 2.1 combine in burning and form cement clinker. The compounds formed in the burning process have the properties of setting and hardening in the presence of water [4]. Which are usually regarded as the major compounds (active component) of cement, these are the tricalcium silicate (C_3S), Dicalcium silicate (C_2S), tricalcium aluminate (C_3A) and tetracalcium alumino ferite or iron compound (C_4AF) and their reaction with water also known as hydration.

The rate of reaction of those compounds with water is different. So that due to very fast reaction of C_3A with water it retards the hydration of C_3S and C_2S results flash set [5]. However, calcium sulphate ($CaSO_4$) present in the clinker dissolves immediately in water and forms insoluble calcium sulphoaluminate. It deposits on the surface of C_3A forming a colloidal membrane and consequently retards the hydration [4].

Table 2.1 Approximate limits of oxide composition in cement [4]

Oxide	Function	Content in percent (%)
CaO	Control strength and soundness. Its deficiency reduce setting time and strength	60-67
SiO_2	Gives strength. Excess of it causes slow setting	17-25
Al_2O_3	Responsible for quick setting, if excess, it lowers the strength	3-8
Fe_2O_3	Gives color and helps in fusion of different ingredients	0.5-6
MgO	Impart color and hardness, if excess it causes cracks in mortar and concrete and unsoundness	0.1 - 4.0
A1kalis	Those are residues, and if excess causes efflorescence and cracking	0.2 - 1.3
SO_3	Makes cement sound	1-3

I. Physical Properties of Cement

Specifications for cement place limits on both its physical properties and often chemical composition of cement. Tests of the physical properties of the cements should be used to evaluate the properties of the cement, rather than the concrete these tests are; fineness test, setting time test, soundness test, consistency test, strength test etc [5].

A. Particle Size and Fineness -Fineness of cements is very important during hydration to accelerate strength development of concrete and to reduce bleeding particularly during vibration, so that approximately 95% of cement particles are smaller than 45 micrometers, with the average particle around 15 micrometers [5]. Besides this as cement is more finer it reacts more strongly in alkali reactive aggregate and it require higher water requirement and workability will be more leading to higher drying shrinkage and cracking [4].

B. Soundness- It is a very important test to assure the quality of cement since unsound cement produces cracks, distortion and disintegration, ultimately leading to failure due to large change in volume after setting [4]. According to Ethiopian standard ES1177-1:2005 and Indian standard IS 8112:1989, soundness or expansion of cement is limited to 10 mm. In case failing to meet the above requirement Indian standard recommends to conducting further test on another portion of the same sample after aeration, the aeration shall be by being spread out to a depth of 75 mm at a relative humidity of 50 to 80 percent for the total of 7 days and their expansion shall not more than 5 percent.

C. Consistency and setting time of Portland cement- This is a test to estimate the quantity of mixing water to form a paste of normal consistency defined as that percentage water requirement of the cement paste, the water requirement for various tests such as soundness and setting time of cement depend upon the compound composition and fineness of the cement [4]. Determine by penetration of 10 ± 1 mm of the Vicat plunger [5].

The object of the setting time test is to determine the time that elapses from the moment water is added until the paste ceases to be fluid and plastic which indicate beginning of solidification (called initial set) to define the limit of handling but must not occur too early and the time required for the paste to acquire a certain degree of hardness to solidify completely (called final set) to defines the beginning of development of mechanical strength but must not occur too late in order to resume construction activity within a reasonable time after the placement of concrete [2]. Ethiopian standard (ES1177-1:2005) specify minimum initial setting time of 75, 64 and 45 minutes for cements 32.5, 42.5 and 52.5 classes of standard strengths for both N and R type of early strength. On the other hand, Indian standard recommend initial and final setting time are 30 minutes and 600 minutes for all class strength of cements.

D. Early Stiffening (False Set and Flash Set)

Both are a condition losing of plasticity of concrete or mortar after mixing within short period of time but the difference is the former one occurs without evolution of heat and it can regain its plasticity by remixing but the latter one is accompanied by rapid evolution of heat primarily due to rapid reaction of aluminates and cannot regain its plasticity by mixing [5]. Indian standard recommended for cement exhibits false set, the ratio of final penetration measured after 5 minutes of completion of mixing period to the initial penetration measured exactly after 20 seconds of completion of mixing period, expressed as percent, shall be not less than 50.

E. Compressive Strength

Strength of the mortar and concrete depends on the type and nature of cement because it binds together aggregates by adhesion. So that it should develop a minimum specified strength (compressive and tensile) if it is to be used in structures [4]. The strength of cement is greatly influenced by the degree of burning, the fineness of grinding, and the aeration it receives subsequent to final grinding. An under burnt cement is likely to be deficient in strength.

Ethiopian Standard ES1177-1:2005 specify three classes of standard strength having two types of early strength such as N type (ordinary early strength) and R type (high early strength). The standard compressive strength of cement shall conform the requirements in the Table 2.2 below

Table2.2. Compressive strength of cement [ES 1177-1:2005]

Class	Compressive strength MPa			
	Early strength		Standard strength	
	2 days	7 days	28 days	
32.5N	-	$\geq$ 16	$\geq$ 32.5	$\leq$ 52.5
32.5R	$\geq$ 10	-		
42.5N	$\geq$ 10	-	$\geq$ 42.5	$\leq$ 65.8
42.5R	$\geq$ 20	-		
52.5N	$\geq$ 20	-	$\geq$ 52.5	-
52.5R	$\geq$ 30	-		

F. Loss on Ignition (LOI)

Normally, a high loss on ignition is an indication of pre-hydration and carbonation, which may be caused by improper or prolonged storage or adulteration during transport. The test for loss on ignition is performed in accordance with ES1177-1:2005 is limited to 5%.

G. Density and Relative Density (Specific Gravity) and Bulk Density

The density of cement is defined as the mass of a unit volume of the solids or particles, excluding air between particles. The particle density of Portland cement ranges from 3.10 to 3.25, averaging 3.15 kg/m^3. The density of cement, determined by ASTM C 188 (AASHTO T 133) is not an indication of the cement's quality; its principal use is in mixture proportioning calculations [5]. For mixture proportioning, it may be more useful to express the density as relative density (also called specific gravity).

The bulk density of cement is defined as the mass of cement particles plus air between particles per unit volume. The bulk density of cement can vary considerably depending on how it is handled and stored. Portland cement that is fluffed up may weigh only 830 kg/m^3 when it is consolidated by vibration, the same cement can weigh as much as 1650 kg/m^3. For this reason, good practice dictates that cement must be weighed for each batch of concrete produced [5],

II. Transportation, Packaging and Storage of Cement

Cement is also bagged for convenient use at construction sites and for small jobs. Most Portland cements are transported by truck. Cement is a moisture-sensitive material; if kept dry, it will retain its quality. Cement stored in contact with damp air or moisture, sets more slowly and has less strength than cement that is kept dry [5] so that all cracks and openings in walls and roofs should be closed. Cement bags should not be stored on damp floors but should rest on pallets and stacked close together to reduce air circulation but should never be stacked against outside walls. In addition to this Bags should be covered with tarpaulins or other waterproof covering when stored for long periods and its arrangement should be follow first in are the first out method.

On small jobs where a shed is not available, bags should be placed on raised wooden platforms (pallets) above the ground. Waterproof coverings should fit over the pile and extend over the edges of the platform to prevent rain from reaching the cement and the platform. Rain-soaked platforms can damage the bottom bags of cement. Cement stored for long periods may develop what is called warehouse pack. This can usually be corrected by rolling the bags on the floor. At the time of use, cement should be free flowing and free of lumps. If lumps do not break up easily, the cement should be tested before it is used in important work. Standard strength tests or loss-on ignition tests should be made whenever the quality of cement is doubtful.

Indian standards limit the height of height of stacks not more than 15 bags to prevent lumping up under pressure but in case stacks over 8 bags height, bags shall be arranged alternatively lengthwise and cross-wise so as to tie stocks together to minimize danger of toppling over and its width shall not more than four bag length or 3 meters but Ethiopian standard [ES 1177-1:2005] limit 8 bags high and protected by waterproof structure. On the other hand ACI 2009 recommended 14 and 7 layers depends on their storage period in stock of less than or greater 60 days by providing proper air circulation.

Ordinarily, cement does not remain in storage for a long time but it can be stored for long periods without deterioration; Bulk cement should be stored in weather tight concrete or steel bins or silos. Dry low-pressure aeration or vibration should be used in bins or silos to keep the cement flow able and avoid bridging. Due to fluffing of cement, silos may hold only about 80% of rated capacity. but Indian standard recommended for Cement remaining in bulk storage at the mill, prior to shipment, for more than six months, or cement in bags, in local storage in the hands of a vendor for more than 3 months after completion of tests, may be retested before use and may be rejected if it fails to conform to any of the requirements.

2.1.1.1.2. Aggregates

Aggregates are the materials basically used as filler with binding material in the production of concrete and provide concrete with better dimensional stability and wear resistance. They are derived naturally from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag, etc [4]. It is therefore significantly important to obtain right type and quality of aggregates (fine and coarse) because aggregates occupy 60% to 75% of the concrete volume (70% to 85% by mass) and strongly influence the concrete’s freshly mixed and hardened properties, mixture proportions, and economy [4]. So that to proportion suitable concrete mixes, certain properties of aggregate which influence the paste requirement of fresh concrete such as shape and texture, size graduation, moisture content, specific gravity and bulk unit weight must be known [5]. In addition to these, aggregates should be hard, strong, dense, durable, clear and free from veins and adherent coating; and free from injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, flaky and elongated pieces should be avoided [8].

All standards specify their own requirements for aggregate used for concrete production, for instance ES 81:2001, SABS 1083 specify aggregate requirements by limiting on their grading, soundness, fineness and amount of deleterious matter in addition to these requirements, Indian standard [IS: 383- 1970] included aggregate crushing value, aggregate impact value. On other hand British standard [882:1992] consider flakiness index, shell content and acid soluble sulfate as requirement.

Aggregates can be classify based on their origin, based on their size, based on their shape and based on their unit weight [4] but most specifications such as Ethiopian, Indian and South African standards classified aggregates based on their sizes as fine and course aggregate depends on their most particles retained or passed on 4.75 mm sieve. But British standard uses 5 mm sieve size for classification. In addition to this, aggregates can be classified as light weight, normal weight and heavy weight depending on their unit weight [2].

I. Properties of Aggregate

Most properties of aggregate depends on the properties of parent rock e.g. chemical and mineral composition, petrographic classification, specific gravity, hardness, strength, physical and chemical stability, pore structure, color, etc. in addition, there are properties of aggregate absent in the parent rock: particle shape and size, surface texture and moisture content. All properties may have a considerable influence on the quality of fresh or hardened concrete [9]. Among these properties such as shape and texture, size graduation, moisture content, specific gravity and bulk unit weight are important to proportion suitable concrete mixes [2].

Aggregate properties can be seen by categorizing in to three such as Mechanical property which includes bond, strength, toughness and hardness, Physical property which includes specific gravity, bulk density, porosity and absorption, moisture content, bulking of sand, soundness and Thermal property [9].

The properties of an aggregate to be considered while during selection of aggregate for concrete works are grading, shape, texture, specific gravity, bulk density, voids, porosity, moisture content, bulking and strength [4]. Those properties of aggregate affects significantly the resulting concrete quality produced as briefly explained under.

A. Grading, shape and texture

Particle size distribution of an aggregate known as grading and it is determined by percentage of passing on each sieve size. Specifying grading and grading limit of aggregates are very important to maintain uniform quality of concrete from batch to batch with suitable workability and economy because it determine paste requirement for workable mixes [2]. If aggregates doesn't conform grading requirements of ASTM C 33 grading limit the concrete may require more paste and liable to segregate during handling and placing [2]. Ethiopian standard ES 81:2001 specify grading requirements for fine and coarse aggregates as shown in Table 2.3 and 2.4 below.

Table 2.3. Grading requirements for fine aggregate [ES 81:2001]

Sieve	Percentage passing
9.5 mm	100
4.75 mm	95-100
2.36 mm	80-100
1.18 mm	50-85
600 µm	25-60
300 µm	10-30
150 µm	2-10

Table 2.4 Grading requirements for course aggregate [ES 81:2001]

Nominal size of graded aggregate mm	Percentage Passing through test sieves having square opening						
	75 mm	63mm	37mm	19mm	13.2mm	9.5mm	4.75mm
38.5	100		95-100	30-70		10-35	0-5
19.5			100	95-100		25-55	0-10
13.5				100	90-100	40-85	0-10

The choice of nominal maximum aggregate size is determined by job conditions. If the aggregate size is too large, the concrete at any given cross section of a member may not be representative of the entire material because of location of an overly large aggregate particle. To guard against this possibility, the maximum size shouldn't be greater than one-fifth of the smallest dimension between sides of forms, for slabs one-third of the thickness and large aggregate particles may also get obstructed at narrow openings between reinforcing bars, between bars and formwork, and cause undesirable segregation during placement. To avoid this problem, the nominal maximum size shouldn't exceed three-fourths of the minimum clear spacing between reinforcing bars and forms.

Shape and surface texture of an aggregate influence the properties of freshly mixed concrete more than the properties of hardened concrete [5] because those property relatively affect workability and void content of concrete for instance rough-textured, angular, elongated particles require more water to produce workable concrete than do smooth and rounded aggregates. In addition to this, aggregate should be relatively free of flat and elongated or at least limited to about 15% by mass of the total aggregate particles [5] because such aggregate particles require an increase in mixing water and thus may affect the strength of concrete, particularly in flexure, if the water-cement ratio is not adjusted. On the other hand, mixing water and cement requirement tend to increase as aggregate void content increases because voids between aggregate particles increase with aggregate angularity this can affect concrete strength and economy.

B. Specific gravity and bulk density of Aggregates

Specific gravity of aggregates generally is indicative of its quality because aggregates greatly influence the strength and absorption of concrete [4]. A low specific gravity may indicate high porosity and therefore poor durability and low strength because concrete density will greatly depend on specific gravity. On the other hand, bulk density of aggregate is mass or weight of the aggregate required to fill a container of a specified unit volume that occupied by both aggregates and the voids between aggregate particles. It is depends upon their packing, the particles shape and size, the grading and the moisture content. For coarse aggregate a higher bulk density is an indication of fewer voids to be filled by sand and cement.

C. Porosity, absorption and moisture content and bulking of Aggregates

The entrapped air bubbles in the rocks during their formation lead to minute holes or cavities known as pores [4]. Due to those pores and higher proportion of aggregate, concrete becomes permeable and ultimately affects the bond between aggregate and cement paste, resistance to freezing and thawing of concrete and resistance to abrasion of aggregate. The porous aggregate absorb more moisture, resulting in loss of workability of concrete at a much faster rate. Since aggregates contain same porosity, water can absorbed in to the body of the particles. Also water can be retained on the surface of the particle as a film of moisture. Thus stockpiled aggregates can have variable moisture content. It is necessary to have information about the moisture content, since if there is a tendency for the aggregates to absorb water, it will be added to the paste and w/c ratio of the concrete will be higher than desired.

There are four moisture states the only two, the OD (over-dry) and SSD (saturated surface dry) states, corresponds to moisture contents, and either those states used as reference states for calculating moisture contents, the AD (air - dry) and wet states represent the variable moisture contents that will exist in stockpiled aggregates [2].

Stock piling of course aggregate is generally, in AD state with effective absorption of less than 1 % , However, fine aggregate is often in wet state, with a surface moisture typically in the range of 2 to 6 % [2]. The reason for high surface-moisture values for the fine aggregate is that, in addition to thin surface films of moisture, additional water can be held in the interstices between fine particles as the result of formation of menisci. The formation of those menisci creates thicker films of water between aggregate particles, pushing them apart and increasing apparent volume of aggregate this phenomenon is known as bulking can cause substantial errors in proportioning by volume. Hence, aggregate is nearly always batched by weight and measurements of unit weight are usually made on oven-dry aggregate. When sand is saturated with water, the menisci are destroyed and the volume returns to normal. Coarse aggregate show much less bulking since the particle size is large compared to the thickness of water film the effect of menisci is slight [2].

D. Strength and Hardness

Aggregates contribute the significant proportion of strength possessed by concrete due to their higher modulus of elasticity as compared to the cement paste [2]. 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 undertaken 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 [4]. According to IS 383:1970 aggregate strength limit such as aggregate crushing value, aggregate impact value, aggregate abrasion values are specified in the Table 2.7 below based on the concrete requirement.

Table 2.5 Aggregate strength limit [IS 383:1970]

Aggregate strength limit	concrete for wearing surface	Other than wearing surface
aggregate crushing value	45%	30%
aggregate impact value	45%	30%
aggregate abrasion value	30%	50%

The hardness of the minerals that make up the aggregate particles and the firmness with which the individual grains are cemented or interlocked control the resistance of the aggregate to abrasion and degradation. Soft aggregate particles are composed of minerals with a low degree of hardness. Weak particles have poor cementation. Neither type is acceptable because of reduction in concrete strength.

E. Potential harmful materials

Aggregates are potentially harmful if they contain compounds that react chemically with Portland cement and produce any of the following: significant volume changes of the paste, aggregates or both, interference with the normal hydration of cement and otherwise harmful bi products [2].

Harmful substances that may be present in aggregates include organic impurities in the form of peat, humus, and organic loam may not be as detrimental but it should be avoided because it causes delay in setting and hardening of concrete, may reduce strength gain,

Materials finer than the 75-µm (No. 200) sieve specially silt and clay, shale, coal, lignite, and certain lightweight and soft particles may form a coating on the aggregate particle and may weaken the bond between cement paste and aggregate. If certain types of silt or clay are present in excessive amounts, water requirements may increase significantly.

Porous and weak aggregates containing undesirable extraneous matter undergo excessive volume changes under favorable conditions this is also termed as soundness, freeze-thawing can cause local scaling to surface cracking and certain chemicals such as alkalis from cement leads abnormal expansion (map cracking of concrete) [2].

On the other hand iron oxide and sulfide causes stains in concrete. In addition; rocks and minerals such as some cherts, strained quartz and certain dolomite limestone are alkali reactive. Gypsum and anhydrite may cause sulfate attack. Certain aggregates, such as some shale, will cause popouts by swelling (simply by absorbing water) or by freezing of absorbed water [2]. Most specifications limit the permissible amounts of these substances. For instance the amount of deleterious substance for coarse and fine aggregates according to Ethiopian ES 81:2001 are listed in Table 2.5 and 2.6 below.

Table 2.6 Permissible limits for deleterious substances in fine aggregates [ES 81:2001]

deleterious substances	Maximum percent by mass
Friable particles Clay	1.0
fine silt (passing 63 µm sieve)	3.0
Concrete subject to abrasion	5.0
All other concrete coal and lignite	1.0

Table 2.7 Permissible limits for deleterious substances in coarse aggregates [ES 81:2001]

deleterious substances	Maximum percent by mass
Friable soft fragments	3.0
coal lumps	0.25
Materials finer than 63 µm sieve	1.0
including crusher dust	1.5

Another harmful substance for concrete is caused by the reaction between silica in aggregate and alkalis in the cement is known as alkali aggregate reaction sometimes called concrete cancer it is accompanied by extensive expansion and may lead in bad cases to complete disruption and disintegration of the concrete [2].

II. Handling and storing of aggregates

Aggregates should be handled and stored in a way that minimizes segregation and degradation and prevents contamination by deleterious substances. Stockpiles should be built up in thin layers of uniform thickness to minimize segregation. The most economical and acceptable method of forming aggregate stockpiles is the truck-dump method, which discharges the loads in a way that keeps them tightly joined. The aggregate is then reclaimed with a front-end loader. The loader should remove slices from the edges of the pile from bottom to top so that every slice will contain a portion of each horizontal layer [2]. Indian standard recommended to stock fine aggregate and coarse aggregate separately on hard dry and level pitch of ground if such surface is not available a platform of planks or old corrugated iron sheets or floor of bricks or thin layer of lean concrete shall be made to prevent the admixture of clay, dust and vegetables or other vegetable matter specially fine aggregates must stocks in a place where loss due to the effect of wind is minimum.

2.1.1.1.3. Water

The purpose of using water with cement is to cause hydration of the cement. Water in excess of that required for hydration acts as a lubricant between coarse and fine aggregates and produces a workable and economical concrete [4]. In addition to this water is also used for washing aggregates and curing.

The amount of water must therefore be limited to produce quality concrete required for a job. For instance excess water weakens bond between the successive lifts of concrete, produce honeycombed concrete and make concrete porous. On the other hand lesser water makes it difficult to work with concrete.

I. Quality of mixing water

Potable water is acceptable for the concrete mix such water needs no testing but water that is unsuitable for drinking must be tested by taking a sample of minimum 5 liter within two weeks of sampling for its suitability for concrete production [10] because excessive impurities may affect setting time, strength, durability and may cause efflorescence, surface discoloration, and corrosion of steel. The effects of impurities in water are mainly expressed in terms of setting time of Portland cement [4]. In addition to this British standard BS 3148 recommends surface water for concrete works by infiltration or impounding to allow suspended matter to settle if it is free from undesirable organic contents or an acceptable content of inorganic salts.

According to Ethiopian Standard ES 2310:2005 water used for concrete shall fulfill chemical requirement listed on the Table 2.8 below for chlorides, sulfates and alkali and other harmful contamination (sugar, phosphates, nitrates, lead and zinc) or the requirement for setting time mean compressive strength requirements by specify initial setting time obtained in the specimens made with water shall be not less than one hour and not differ by 25 % from initial setting time obtained from specimens made with distilled water and final setting time shall not exceed 12 hours and not differ more than 25% from final setting time obtained from specimens made with distilled water is supposed to be acceptable in addition to this the mean compressive strength at 7 days of the concrete specimens prepared with water shall be at least 90% of the mean compressive strength of concrete specimens prepared with distilled water.

Table 2.8 Chemical requirements of water used for concrete [10]

Chemicals	mg/l
Maximum Chloride content - used for prestressed concrete or grout - concrete with reinforcement or embedded metal - concrete without reinforcement or embedded metal	 500 1000 4500
Maximum Sulphates content	2000
Maximum Alkalis (sodium oxide content)	1500
Harmful contamination (maximum) - sugar - phosphates expressed as P_2O_5 - nitrates expressed as NO_3^- - lead expressed as Pb^{2+} - zinc expressed as Zn^{2+}	 100 100 500 100 100

II. Effect of mixing water from different sources

Natural ground water seldom contain more than 20 to 30 ppm (parts per million) of iron. However, acid mine waters may carry rather large quantities of iron [4]. Iron salts in concentrations up to 40,000 ppm do not usually affect mortar strengths adversely. Sea water may be used if suitable fresh water is not available. The sea water generally contains 3.5 per cent of salts with about 75 per cent of sodium chloride, about 15 per cent of chloride and sulphate of magnesium. It has been found to reduce the strength of concrete by 10-20 per cent and slightly accelerate the setting time [4]. Sea water may lead to corrosion. Therefore, British standard BS 3148 doesn't recommend sea water for reinforced or prestressed concrete and its chloride content must be restricted to use for plain Portland cement concrete and to make mortar for plastering to prevent plastered surface from efflorescence.

2.1.1.1.4.Admixtures

Admixtures are those ingredients in concrete other than Portland cement, water, and aggregates that are added to the mixture immediately before or during mixing to maintain quality of concrete. Admixtures are classified in two broad classifications such as mineral admixtures Fly ashes, pozzolans, and micro silicates and Chemical admixtures used in concrete generally serve as water reducers, accelerators, set retarders, or a combination.

An admixture should be employed only after an appropriate evaluation of its effects on the concrete that is intended to be used is made. It is often necessary to conduct tests on the representative samples of the materials for a particular job under simulated job conditions in order to obtain reliable information on the properties of concrete containing admixtures. The properties of concrete commonly modified are workability, rate of hydration or setting time i.e. either accelerating or retarding the setting time, and air entertainment. Admixture is generally added in a relatively small quantity. A degree of control must be exercised to ensure proper quantity of admixture, as an excess quantity may be detrimental to the properties of concrete. In using any admixture, careful attention should be given to the instructions provided by the manufacturer of the product. The major reasons for using admixtures are:

1. To reduce the cost of concrete construction because admixtures help for effective use of cement.
2. To achieve certain properties in concrete more effectively than by other means such as to make concrete more workable at lower amount of water.
3. To maintain the quality of concrete during the stages of mixing, transporting, placing, and curing in adverse weather conditions.
4. To overcome certain emergencies during concreting operation

2.1.1.2.Specification of Concrete

Mixture proportioning refers to the process of determining the quantities of concrete ingredients, using local materials, to achieve the specified characteristics of the concrete such as acceptable workability of the freshly mixed concrete, durability, strength, and uniform appearance of the hardened concrete & Economy. As a result, various standards have set mix their own design procedures for instance the American (ACI) and the British method of mix design, commonly called DOE method and India standard of mix design (IS), but ACI and DOE are the most common.

According to EBCS 2, 1995 and BS 5328 part II-1997 concrete specifications classified in to three but Indian standard IS 456:2000 recommend Designed mixes for concrete grades above C-20 and Nominal mix for concrete grades C-20 or lower.

1. **Designed mixes.** With this method the required compressive strength is specified, together with any other limits that may be required in fresh as well as hardened concrete, such as workability and finishing characteristics in fresh concrete and durability in hardened concrete by specifying maximum aggregate size and minimum cement content. The minimum cement content requirements serve to ensure satisfactory durability and finishability, to improve wear resistance of slabs, and to guarantee a suitable appearance of vertical surfaces [5]. The Ethiopian building code of standard has specified minimum cement content as shown in table 2.9.

2. **Prescription mixes.** With this method the designer assumes responsibility for designing the mix and stipulates to the producer the mix proportions and the materials which shall be employed.

3. **Standard (or Nominal) mixes**. Those standard mixes are rich in cement and are intended for use, where the cost of trial mixes or of acceptance cure testing is not justified may be used without verification of compressive strength by testing. Ethiopian standard EBCS 2, 1995 specify nominal mix proportion for grades C5 to C30 may be taken from Table 2.10

but Indian standard recommended nominal mix for concrete having grade of C-20 or lower.

Table 2.9.Minimum cement content in kilogram per m^3 of concrete to ensures durability of concrete under specified conditions of exposure [11].

Exposure	Reinforced Concrete					Plain Concrete				
	Nominal maximum aggregate size				Max W/c	Nominal maximum aggregate size				Max W/c
	40	30	20	10		40	30	20	10	
Mild: E.g. Completely protected against weather or aggressive environmental conditions, during construction	230	260	280	300	0.65	220	230	260	280	0.7
Moderate: E.g. sheltered from rain, buried concrete and concrete continuous under water	270	300	330	350	0.55	230	260	290	310	0.6
Sever: Exposed to sea water, during main alternate wetting and drying. Subject to heavy condensation of corrosive fumes	330	370	400	420	0.45	280	320	340	370	03

Table 2.10.Standard (Nominal) mixes for ordinary structural concrete per 50 kg bag of cement [11]

Concrete grade	Nominal max.size of aggregate (mm)	40		20		14		10	
	Workability	medium	High	Medium	High	Medium	High	medium	High
	Limits of slump that may be expected (mm)	30 to 60	60 to120	20 to 50	50 to 100	10 to 30	30 to 60	10 to 25	25 to 50
C5	Total aggregate (kg)	640	550	540	480				
	Fine Aggregate (%)	30-45	30-45	35-50	35-50				
	Vol.of finished concrete (m^3)	0.212	0.275	0.277	0.252	-	-	-	-
C15	Total aggregate (kg)	370	330	320	280				
	Fine Aggregate (%)	30-45	30-45	35-50	35-50				
	Vol.of finished concrete (m^3)	0.200	0.183	0.178	0.160	-	-	-	-
C20	Total aggregate (kg)	305	270	280	250	255	220	240	200
	Fine Aggregate (%)	30-35	30-40	30-40	35-45	35-40	40-50	40-50	45-55
	Vol.of finished concrete (m^3)	0.165	0.155	0.156	0.143	0.146	0.130	0.137	0.121
C25	Total aggregate (kg)	265	240	240	215	220	195	210	175
	Fine Aggregate (%)	30-35	30-40	30-40	35-45	35-45	40-50	40-50	45-55
	Vol.of finished concrete (m^3)	0.147	0.137	0.137	0.127	0.130	0.118	0.124	0.110
C30	Total aggregate (kg)	235	215	210	190	195	170	180	150
	Fine Aggregate (%)	30-35	30-40	30-40	35-45	35-45	40-50	40-50	45-55
	Vol.of finished concrete (m^3)	0.134	0.127	0.124	0.115	0.115	0.106	0.109	0.097

2.1.1.3.Concrete production process

2.1.1.3.1. Introduction

Good quality concrete is essentially a homogeneous mixture of cement, coarse and fine aggregates and water which consolidates into a hard mass due to chemical action between the cement and water. Each of the four constituents has a specific function. The coarser aggregate acts as a filler. The fine aggregate fills up the voids between the paste and the coarse aggregate. The cement in conjunction with water acts as a binder. Most of the properties of the hardened concrete depend on the care exercised at every stage of the manufacture of concrete. A rational proportioning of the ingredients of concrete are the essence of mix design. However, it may not guarantee of having achieved the objective of the quality concrete work. The aim of quality control is to ensure the production of concrete of uniform strength from batch to batch [4]. This requires some rules to be followed in the various stages of concrete production such as, batching, mixing, transportation, placing, compaction, finishing and curing are important in attaining the desired quality.

2.1.1.3.2. Batching

Batching is the process of measuring concrete mix ingredients by either mass or volume in order to produce concrete of uniform quality [5]. There are two prevalent methods of batching materials, the volume batching and the weigh batching. The factors affecting the choice of batching method are the size of job, required production rate, and required standards of batching performance. For most important works weigh batching is recommended by using weigh batchers such as manual batching, Automatic and semi automatic batching should be used, but volume batching is carried by using standard box known as gauge box it is generally recommended for small jobs only [4].

Among the concrete ingredients, water and liquid admixtures can be measured accurately by either volume or mass[5], but other ingredients such as cement, coarse aggregate and fine aggregate shall be measured by weight, by adjusting to allow moisture content but aggregates for Class II concrete (not greater than C-20) or for standard mixes may be measured by volume [11]. Indian standard recommended volume batching for materials their bulk densities are accurately known and allowance for bulking shall be made.

ACI 304-00R and Indian Standard IS 4925-1968 requires that materials be measured for individual batches based on required weight of material being weighed within the following percentages of accuracy: cementations material ±1%, aggregates ± 2%, water ±1% and admixtures ± 3%. Equipment should be capable of measuring quantities within these tolerances for the smallest batch regularly used as well as for larger batches the accuracy of scales and batching equipment should be checked periodically and adjusted when necessary [5].

2.1.1.3.3. Mixing concrete

All concrete ingredients should be mixed thoroughly until it is uniform in appearance, If concrete ingredients has been adequately mixed, samples taken from different portions of a batch will have essentially the same density, air content, slump, and coarse-aggregate content [5]. The mixing is done either by hand mixing used for small jobs, it is desirable to add some more cement (10%) to provide for the possible inferior concrete produced by this method or for quality works mixing is carried out by machines called mixers [4].

Mixers can be broadly classified as batch mixers and continuous mixers. The batch mixers used to produce concrete batch by batch with time interval specially for small and medium size works, those mixers are available up to 9m³ in size in the form of pan type or drum type and the drum type may be further classified as tilting, non-tilting, or reversing type based on the technique of discharging of mixed concrete, whereas continuous mixers are used to produce a concrete in large size of works continuously till plant is working e.g., dams [5].

Careful attention should be paid to the required mixing time. Many specifications require a minimum mixing time of one minute plus 15 seconds for every cubic meter, unless mixer performance tests demonstrate that shorter periods are acceptable and will provide a uniform concrete mixture but Indian standard IS 456:2000 recommended minimum 2 minute. Short mixing times can result non homogenous mixtures, poor distribution of air voids (resulting in poor frost resistance), poor strength gain, and early stiffening problems [5]. Indian standard IS 4925:1965 specify minimum mixing time for each batch after all material except full amount of water are in the mixer. Mixing time for different capacity of mixers is specified in the table 2.11. Ethiopian standard EBCS 2, 1992 recommended on the consistency of the fresh concrete to be checked periodically with the slump test and during concreting, checks shall be made on the deformations of the formwork and its supporting structure and on any leakage of water.

Table 2.11 mixing time for each of concrete for different capacity of mixers [IS 4925:1965]

Capacity of mixer (m^3)	Time of mixing (min)
Up to 2	1½
Up to 3	2
Up to 4	2½

ACI 304R-00 recommended performance of mixers for maintaining a uniform mixture, particularly with a uniform consistency such as visual observation of the concrete during mixing and discharge from the mixer, consistency-recording meters and The most positive control method for maintaining batch-to-batch uniformity, however, is a regularly scheduled program of tests of the fresh concrete, including unit weight, air content, slump, and temperature. All plants should have facilities and equipment for conveniently obtaining representative samples of concrete for routine control tests in accordance in ASTM C 172

According to ACI 2009 mixing time should be measured from the time all cement and aggregates are in the mixer drum, provided all the water is added before one-fourth of the mixing time has elapsed under usual conditions, up to about 10% of the mixing water should be placed in the drum before the solid materials are added. Water then should be added uniformly with the solid materials; leaving about 10% to be added after all other materials are in the drum. Where the mixer is charged directly from a batch plant, the materials should be added simultaneously at such rates that the charging time is about the same for all materials. [5]

2.1.1.3.4. Transporting and handling of concrete

Delays, early stiffening and drying out and segregation of concrete should occur during handling and placing as a result of consequences of improper handling and transportation, this could seriously affect the quality of the finished work [5]. Concrete shall be transported from the mixer to the formwork as rapidly as practicable by methods and equipment which will prevent the segregation or loss of any of the ingredients, and maintain the required workability. It shall be deposited as nearly as practicable in its final position to avoid re-handling [11] and maintain concrete’s desired properties associated with w/cm, slump, air content and homogeneity.

Concrete can be transported by a variety of methods and equipment, such as pipeline, hose, conveyor belts, truck mixers, open-top truck bodies with and without agitators, or buckets hauled by truck or railroad car. Various conditions should be considered when selecting a method of transportation, such as: mixture ingredients and proportions; type and accessibility of placement; required delivery capacity; location of batch plant; and weather conditions. These conditions can dictate the type of transportation best suited for economically obtaining quality in-place [ACI 304R-00]. Indian standard IS 456:2000 recommend concrete to transport in deep container or other suitable methods to reduce the loss of water by evaporation in hot weather or heat loss in cold weather.

2.1.1.3.5. Placement of Concrete

Concrete placement has an important effect on its quality in related to bond with previous placed concrete. Delay during placing of concrete and method of placing are main factors which affect concrete quality during placement. In addition to this care has to be taken during placement of concrete to avoid displacement of reinforcement from their correct position and standing of water which reduce strength of concrete due to increase water to cement ratio and absorption of water from concrete by the formwork. Dirty and loose particles should be removed from the surface in which the concrete is placed.

Delay in placement of concrete varies with the richness of the mix and the initial slump .When concrete in a lift hardens before the next lift can be placed, a weak layer called cold joint or construction joint is formed. This is one of the serious problems of extreme delay of concrete placement.

During placing of concrete to lower elevation, chutes and drop chutes are used to move the concrete without segregation. If the forms are not sufficiently open and clear or not suitable in vertical fall, but the end of chutes must be supported by baffle to control the flow of concrete onto sloped surfaces in which segregation can occur. As per the Ethiopian building code EBCS 2, 1995, the free fall height of concrete mass is restricted to a maximum of 3 meters but Indian standard recommended 1.5m. In addition to this sub grade should be compacted and thoroughly dampened to prevent loss of moisture from concrete

During Placing of concrete in higher elevation or in tall forms, bleeding must be prevented specially for non entrained concrete by placing more slowly and using stiffer consistency particularly in lower portion of the form. The delay should be short enough to allow the next layer of concrete to knit with the previous layer by vibration, thus preventing cold joints and honeycombing [5].

Deposition of concrete also very important, in order to place the concrete without segregation (as a result of damping in separate or individual piles, or at higher distance) and flow lines, seams, and planes of weakness or cold joints (that result from placing freshly mixed concrete on concrete past its initial set) [2]. In order to place the concrete in slab construction, placing should be started along the perimeter at one end of the work with each batch discharged against previously placed concrete.

2.1.1.3.6. Compaction of Concrete

Stone pockets, honeycombing and entrapped air are eliminated by compaction around compacting fresh concrete to mold it within the forms and around embedded items and reinforcement [5] it has been found from experimental studies that 1 percent of air in concrete approximately reduce the strength by 6 percent [12], so that the volume of entrapped air is in the range of 5 to 20%. Consolidation should remove practically all of the entrapped air, which is important because of its adverse effect on concrete properties [13]. However; over vibration brings excess paste to the surface, enhances bleeding, and causes loss of entrained air and under vibration leads honey combing, excess entrapped air [5].

Consolidation by vibration is best described as consisting of two stages—the first comprising subsidence or slumping of the concrete in which honeycomb has been eliminated; the large voids between the coarse-aggregate particles are now filled with mortar. The concrete behaves somewhat like liquid containing suspended coarse-aggregate particles and the second a de-aeration (removal of entrapped air bubbles). The two stages may occur simultaneously, with the second stage under way near the vibrator before the first stage has been completed at greater distances.

Compaction can be achieved by using either manually method such as hand rodding, temping rod or other suitable materials especially for plastic, highly plastic and flowing concretes consistency having a slump in the range of 75mm to 190 plus mm [13] and other than class I and C-20 grade of concrete [11] and or mechanical methods using Internal and external vibrations for C-20 and class I concretes grades [11].

For very stiff mixtures with the low water-cementitious materials ratios and high coarse-aggregate contents associated with high quality concrete and same times in combination of Internal and external vibrations are useful. In addition to this ACI 304R-00 recommended to use spading to improve the appearance of formed surfaces by inserted and withdrawn adjacent to the form and this forces the larger coarse aggregates away from the forms and assists entrapped air voids in their upward movement toward the top surface to escape.

The effectiveness of an internal vibrator depends mainly on the head diameter, frequency, and amplitude of the vibrators [13]. For efficient consolidation, vibrators should allowed to sink in to concrete under its own weight by gravity and should penetrate any underlying of fresh concrete by at least 150 mm at regular spacing interval approximately 1-1/2 times radius of influence [2]. The time required for proper consolidation varies with vibrator and concrete but typically ranges 5 to 30 seconds [2]. The height of each layer or lift should be about the length of the vibrator head or generally a maximum of 610 mm [13].

But In case of thin slabs, the vibrator should be inserted at an angle or horizontally in order to keep the vibrator head completely immersed. For slabs on grade, the vibrator should not make contact with the sub grade but in heavily-reinforced sections where an internal vibrator cannot be inserted, it is sometimes helpful to vibrate the reinforcing bars by attaching a form vibrator to their exposed portions. This practice eliminates air and water trapped under the reinforcing bars and increases bond between the bars and surrounding concrete [5]

External vibrators such as vibrating tables or surface vibrators are useful to use for consolidating concrete members that are very thin or congested with reinforcement, to supplement internal vibration and for stiff mixes where internal vibrators cannot be used [14]. But external vibration is less effective than internal vibration because it consumes more power and requires extra strong formwork [12].

2.1.1.3.7. Curing Of Concrete

Proper curing will improve durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicers [5]. Freshly mixed concrete normally contains more water than is required for hydration of the cement but the surface is particularly susceptible to insufficient hydration due to evaporation, absorption of water by aggregates, form work or sub grade. However, it is important for water to be retained in concrete to prevent reduction of hydration due to evaporation. In addition to this, exposed concrete including exposed edges and joints, must be protected from losing water because it makes the concrete to shrink and surface cracking can result if these stress develop before the concrete has attained adequate tensile strength [5].

Hydration dependent not only in water but it is also dependent in temperature for instance when temperature of concrete is much low the development of hydration will be much slower, in case of temperatures below 10°C unfavorable for the development of early strength and if it is below 4°C the development of early strength is greatly retarded; and at or below freezing temperatures, down to -10°C little or no strength develops [5]. But the temperature of curing water shouldn't more than 11°C cooler than concrete to prevent thermal cracking [5]. Sudden drop of temperature can produce a strain of about 100 millionths which approximates the typical strain capacity of concrete [14].

There are various methods adopted for curing the most effective method for curing concrete depends on the materials used, method of construction, and the intended use of the hardened concrete. Those are achieved by using a method for maintaining the presence of mixing water in the concrete including ponding or immersion, spraying or fogging, and saturated or methods that reduce the loss of mixing water from the surface of the concrete by covering the concrete with impervious paper or plastic sheets, or by applying membrane-forming curing compounds and the last technique is accelerate strength gain by supplying heat and additional moisture to the concrete with live steam, heating coils, or electrically heated forms or pads. Since the 28 day strength could be obtained in hours or few days.

ACI 2009 recommended three stages of curing these are initial curing provided between placement and final finishing, intermediate curing implemented when finishing is completed, but before the concrete has reached final set and final curing refers to procedures implemented after final finishing and after the concrete has reached final set.

Care should be taken for curing a concrete having of lower water cement ratio 0.4 or higher amount of cement due to reduction internal humidity specially if it is less than 80%, it can leads to self desiccates (dry out) causes hydration to stop this may influence desired concrete properties if no external water is provided . Even moist curing is once interrupted and start again cannot replace the original potential of strength development [5] and during form removal, care shall be taken to provide wet cover to newly exposed surfaces to avoid exposure to hot, sun and wind. As per Ethiopian standard EBCS 2, 1995 at the end of the prescribed curing period (10 days is recommended), the covering shall be left in place without wetting for at least four days during hot weather, so that the concrete surface will dry slowly and be less subject to surface shrinkage cracking.

The water used for curing and materials used for protection of concrete surface from losing of water such as coverings should be free from any substances that will cause stain or discoloring of concrete and water for ponding and immersion also, ambient temperature and relative humidity also very important for curing concrete especially by fogging and Sprinkling of water. As ambient temperature above freezing and humidity is low sprinkling is very effective while continues spraying of fine fog are important to raise relative humidity.

Exposed surfaces of concrete containing ordinary or standard Portland cement be kept continually moist cured for at least 7 days. Concretes containing high early strength cements require less time, about half the time required for OPC, and it is 3 days [5].

Since the rate of hydration is influenced by cement type and the presence of supplementary cementing materials, the curing period should be prolonged for concretes made with cementing materials possessing slow-strength gain characteristics. If the mass concrete contains a pozzolan, minimum curing time for unreinforced sections should be extended to 3 weeks [5].

ACI 2009 recommended minimum duration of curing for concrete mixture as shown in Table 2.12 below

Table 2.12 Recommended minimum duration of concrete curing [13]

Type of cement used for concrete production	Minimum curing period
ASTM C 150 Type I	7 days
ASTM C 150 Type II	10 days
ASTM C 150 Type III or when accelerators are used to achieve results demonstrated by test to be comparable to those achieved using ASTM C 150 Type III cement	3 days
ASTM C 150 Type IV or Type V cement	14 days

2.1.1.4. Quality control in concrete production

The importance of quality of concrete is being increasingly realized to derive the optimum benefit from the materials employed. Quality control does not merely signify testing of concrete cubes at 28 days; rather it actually permeates all aspects of the choice of materials, design, and workmanship it commences much before any concrete is available for testing at 28 days [4]. Normally, Test specimens indicate potential rather than actual strength of a structure; so that the strength reduction can occur in concrete due to certain factors which makes significant the importance of quality control such as. [2].

- ✓ Materials this include variability in the cement itself, grading, moisture content, mineral composition, physical properties and particle shape of aggregate and in the admixture used.

- ✓ Production process which involves types of batching plant and equipment, method of transporting concrete to the site, and procedures and workmanship used to produce and place the concrete. And

- ✓ Testing during sampling procedures, the making and curing of test specimens, and the test procedures used may cause strength reductions which are not reflected in the cube strength results. Therefore, this variability in properties must be considered when preparing concrete specifications.

Quality control is defined as an action and decisions taken to ensure the compliance of works with the specification. It contains two parts, namely, production control and compliance control. Production control is a measure taken during production to obtain a reasonable assurance that the specifications will be satisfied while compliance control is a check made to ensure the compliance of the product with the specification [11].

2.1.1.4.1. Statistical interpretation of cube results

A number of factors such as variability in material, production process and testing procedure can influence the results of the cube test. Even results obtained from different cubes cast from the same concrete at the same time cured and tested in similar way may also show different result. There for, evaluation of test results, with the help of statistical approach is required [12]. It is done by plotting test results on histogram and the results follow normal distribution curve, when carrying out tests on concrete, we are trying to evaluate the distribution in strength of all the concrete in the structure, based upon a limited sample size. Clearly enough test data must be collected so that the tests are truly representative of the concrete in the structure. However it has to be known that, the test results are only estimates of the strength of concrete in the structures.

Degree of quality control can be seen from normal distribution curve in the figure 2.1, When there is good control, the strength test values will tend to cluster near to the average value as shown in curve A, that is, the histogram of test results is tall and narrow. As variation in strength results increases, the spread in the data increases and the normal distribution curve becomes lower and wider as shown in the curve B [ACI 214].

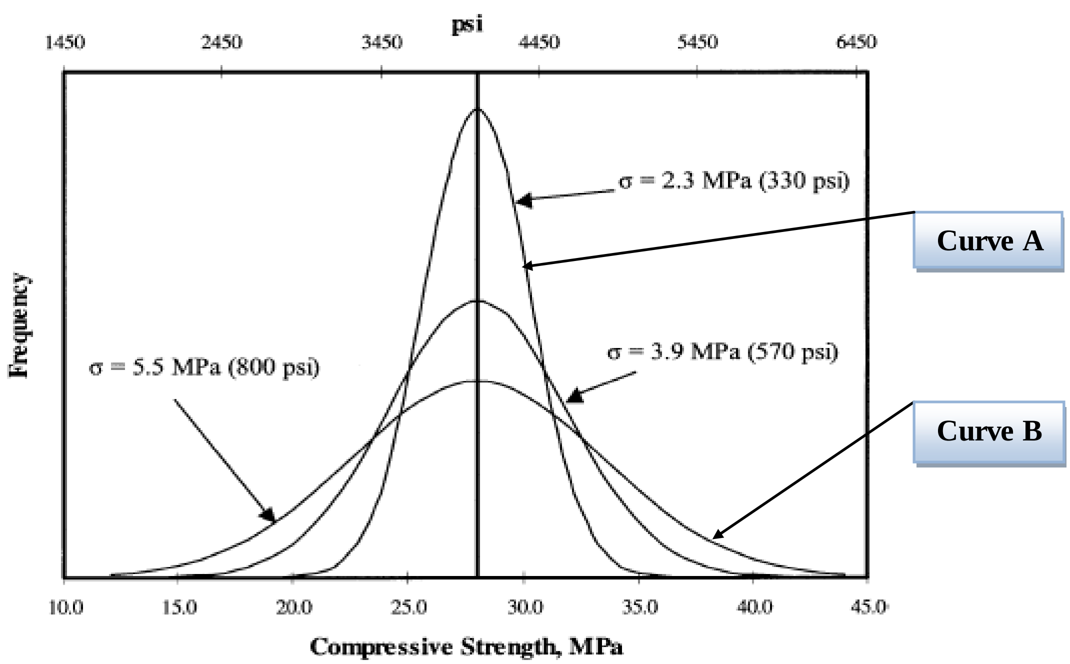

Fig 2.1 - Normal frequency curves for three different distributions with the same mean but different variability [ACI 214].

From the behavior of normal distribution curve 50% of cubes only give the strength higher than mean strength but the rest cubes have lower value so that it is not acceptable because 50% cubes have lower strength as shown in figure 2.2. In order to increase the number of cubes having strength greater than or equal to the mean strength place it on the left side of mean value at a distance of K x S instead of the mean strength known as target mean strength which helps to obtain desired strength. Where K value is dependent on the percentage of cube we want to have a strength equal or more than the desired strength Therefore, we must arbitrarily decide what constitutes an acceptable percentage of specimens falling below the "minimum" design values. The Ethiopian building code and standards [EBCS 2, 1995] specifies a 5% defective or fall below the design values.

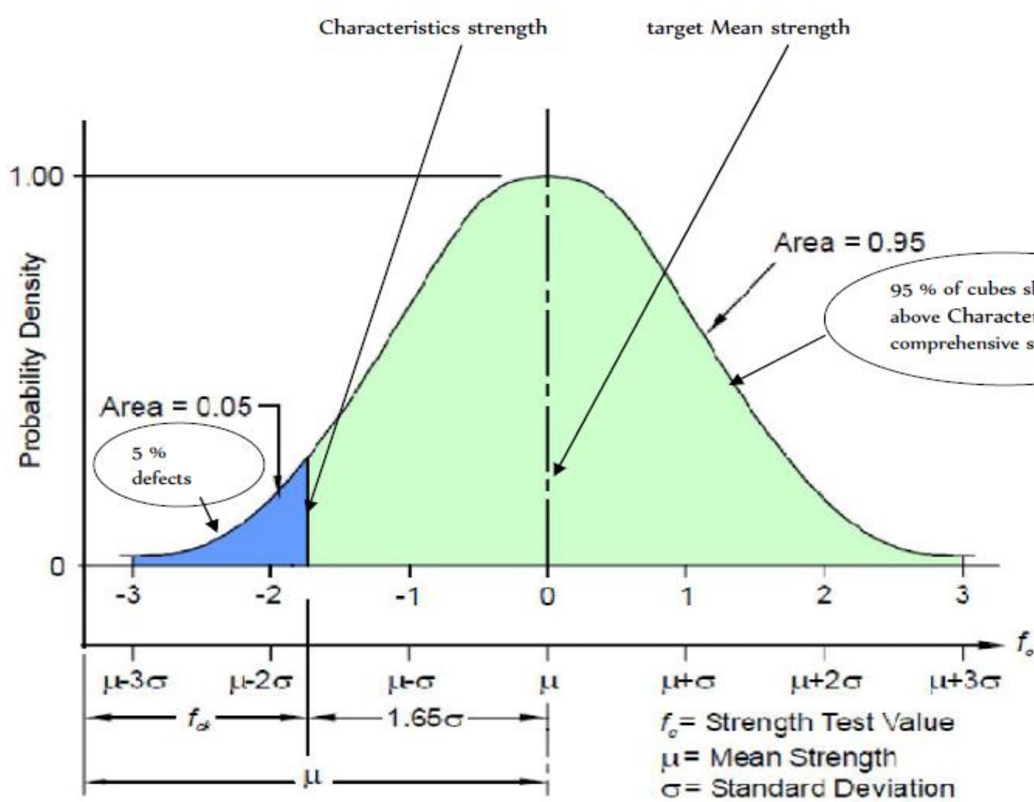

Fig 2.2. Characteristics strength and target mean strength [13]

2.1.1.4.2. Measurement of variability

It has been found that the distribution of concrete strengths can be approximated by the normal or Gaussian distribution. Such a distribution is defined by two parameters; Arithmetic mean value of ´n´ cubes represented by x strengths which stands µ and the standard deviation (S.D) stands S [2] then.

$$\mu = \frac{\sum_{i=1}^{n} xi}{n} \quad \ldots\ldots 2.1$$

And the standard deviation which is the measure of dispersion or variability of the values and Standard deviation can be calculated by formula given below

$$S = \sqrt{\frac{\sum_{n-1}^{n}(xi-\mu)^2}{n-1}} \quad \ldots\ldots 2.2$$

The variation of results about the mean can also be expressed by the coefficient of variations which is a non-dimensional measure of variation and is given by:-

$$V = \frac{S\,x\,100}{\mu} \quad \ldots\ldots 2.3$$

2.1.1.4.3. Application of measure of variability to concrete

The above statistical parameters; namely, standard deviation and coefficient of variation are useful in the design and quality control of concrete, assuming that variations in concrete properties is to be described by normal distribution by considering compressive strength as a reference the following implications are observed [2].

i. We can't design on the basis of mean strength or all concrete strengths can't be above the design value because concrete strengths are approximately normally distributed. Therefore, we must arbitrarily decide what constitutes an acceptable percentage of specimens falling below the "minimum" design values. The Ethiopian building code and standards specifies a 5% defective or fall below the design values [11]. Using this percentage, and knowing or assuming the standard deviation in strength that can be expected, we can then determine the required mean strength for which to design the concrete mix. In addition to this, we can evaluate the distribution in strength of all the concrete in the structure, based upon a limited sample size but the test data must be truly representative of the concrete in the structure.

ii. Because variations in concrete strengths are due not only to mix variations, but also to sampling variations, there are two risks that must be balanced. The "producer's risk" that satisfactory concrete will be rejected and the "consumer's risk" that bad concrete will be accepted. This consumer's risk can be large indeed if insufficient testing is carried out. On the other hand, same plan of action should be followed for concrete not complied with specification because certain proportion of test cylinder below design strength of concrete may be much less risky due to compensation low strength of concrete by continues gain of strength beyond 28 days strength actually in service or considerable redistribution of stress by reinforcement in the structure [2].

One of the primary purposes of statistical evaluation of concrete data is to identify sources of variability. Either the standard deviation or the coefficient of variation can be used to evaluate the level of control of conventional-strength concrete mixtures [13]. Depending on the quality of control measures taken in construction sites or in laboratories, there are values of standard deviation and coefficient of variation assigned to each class of activities (ACI 214) as shown in table 2.13 a & b.

Table 2.13 ACI standard of concrete quality control

a. Using standard deviation [13]

Class of Operation, Over all variations	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 batches	Below 1.4	1.4-1.7	1.7-2.1	2.1-2.4	Above 2.4

b. Using coefficient of variations [13]

Class of Operation, Over all variations	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 batches	Below 3.5	3.5-4.5	4.5-5.5	5.5-7	Above 7

2.1.1.4.4.Variability of concrete strength and their Acceptance criteria

Due to the variability inherent and the normal distribution assumed in concrete strength, we should require a strength which is higher than the specified strength as mentioned above. Various codes have their own approaches or criteria set for the required strength in such a way that to ensure low probability of the compressive strength obtained below the design strength. In this paper the Ethiopian standard (EBCS 2, 1995) , American concrete association (ACI 318), British standard (BS 5328: 1990) and Indian standard (IS 453-2000) codes approaches and acceptance criteria of test results are discussed.

2.1.1.4.4.1.Acceptance and compliance according to Ethiopian standard (EBCS 2, 1995)

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 $x_1 < x_2 < x_3$.

The lot is accepted if the following conditions are satisfied simultaneously.

$m_3 >= f_{ck} + K_1$……………………………………………………….……………...… [2.4]

$X_1 >= f_{ck} - K_2$…………………………………………………………………………. [2.5]

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 2.14 below.

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

Table 2.14. Margins of strengths in MPa EBCS2, 1995

Margin of strength	First two lots	Third and fourth	Fifth lot and above
K_1	5	4	3
K_2	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.

$m_n – \lambda S_n >= f_{ck}$……………………………………………………………..…2.6

$X >= f_{ck}-k_{2s}$…………………………………………………………………2.7

Where = m_n is mean value

S_n = is standard deviation of set of sample result

f_{ck} = is characteristics cylindrical strength

λ = lamda is coefficient (may be taken 1.4 Mpa)

n = is number of specimens

The lot could be defined as the quantity of concrete produced in the same essential conditions and subjected to individual assessment. There is a minimum requirement set on the size of lot and frequency of sampling (EBCS-2, 1995) as given hereunder.

(a) No individual sampling can represent, on the average, more than 100 mixes or 100 m^3.

(b) For each grade of concrete, at least one sample shall be taken every week.

(c) For each grade of concrete, at least two lots shall be made.

If the test results do not satisfy the requirements of the above acceptance criteria, there are recommended measures to be taken. The measures include

- Structural safety shall be checked by appropriate calculation.
- Checking the strength by taking drilled cores or by non-destructive methods such as rebound hammer test. However; the results of this test will be affected by surface finish, rigidity, moisture content and direction of impact [2].

2.1.1.4.4.2.Acceptance and compliance according to ACI 318

After testing concrete, the strength has to be checked whether the specified strength, f'_c is obtained or the probability of compressive strength falling below f'_c is small enough. For this ACI 318 provides two acceptance criteria.

For laboratory cured specimens of job concrete

1. Every arithmetic average of any three consecutive strength tests must equal or exceed f'_c ; and
2. No individual tests (average of two cylinders) may fall below fc` by more than 3.5 Mpa when fc` is less than or equal to 35 MPa or by more than 0.1 f'_c if f'_c is greater than 35 Mpa.

Failure to satisfy either of the acceptance criteria requires changes in the mix proportions and construction procedures to increase concrete strength. Failure to meet the second criterion requires an investigation of the strength of the concrete in the structure.

Frequency of testing - The following three criteria establish the required minimum sampling frequency for each class of concrete [13]:

(a) Once each day a given class is placed.
(b) Once for each 110 m^3 of each class placed each day.
(c) Once for each 460 m^2 of slab or wall surface area placed each day.

In calculating surface area, only one side of the slab or wall should be considered. Criteria (c) will require more frequent sampling than once for each 115 m^3 (150 yd^3) placed if the average wall or slab thickness is less than 25 cm (9-3/4 in).

2.1.1.4.4.3.Acceptance and compliance according to British standard BS 5328:1990

According BS 5328: 1990, compliance with the characteristics strength is based on groups of consecutive test results, as well as on single test results. Each result is the average of two cubes, made in the specified manner from concrete which is sampled at a prescribed rate, and normally tested at 28 days. Compliance is assumed if both of the following requirements are satisfied:

(a) The mean strength determined from the first two, three or four consecutive test results or from any group of four consecutive results complies with the limits of table 2.15 below.

(b) No individual test result falls short of the specified characteristics strength by more than the value given in table 2.15

Table 2.15: compliance requirements for compressive strength according to BS 5328: 1990

Specific characteristics strength (grade)[MPa]	Group of results	Minimum value by which the mean strength of the group of test results should exceed the grade strength [MPa]	Maximum value by which any individual test result falls short of the grade strengths [MPa]
7.5 to 15	First two	0	2
	First three	1	2
	Any consecutive four	2	2
20 and above	First two	1	3
	First three	2	3
	Any consecutive four	3	3

If only one result (average of two cubes) fails to meet the second requirement, we can assume that the result represents only the particular batch of concrete from which the cubes were made, provided that the average strength of the group satisfies the first requirement. If the average strength of any group of four consecutive test results fails to meet the first requirement, then all the concrete in all the batches represented by the test cubes is deemed not to comply with the strength requirements. In such a case, the mix proportions of subsequent batches of concrete should be modified to increase the strength.

2.1.1.3.1.1. Acceptance and compliance according to Indian standard IS 456:2000

According to Indian standard IS 456:2000; the test results of sample shall be the average of the strength of three specimens the individual variation shouldn't be more than $\pm$15 percent of the average. The individual and mean strength determined from any four consecutive test results complies with the appropriate limit specified below.

(a) the mean strength determine from any group of four consecutive test results should comply with the following condition

(i) For C-15

Mean $\geq f_{ck} + 0.825 \times S$ or

$f_{ck} + 3\ N/mm^2$ which is greater

(ii) For C-20 and above

Mean $\geq f_{ck} + 0.825 \times S$ or

$f_{ck} + 4\ N/mm^2$ which is greater

(b) any individual test result shouldn't have values less than

$\geq f_{ck} - 3\ N/mm^2$ for C-15 and

$\geq f_{ck} - 4\ N/mm^2$ for C-20 and above

Where, S is standard deviation, it is assumed 3.5, 4, 4.5 N/mm^2 for concrete grades 10-15, 20-25 and 30-50 MPa.

2.1.2. Reinforcement bar

2.1.2.1. General

Metals are building materials which derived from ores by removing impurities such as oxides, carbonates, sulphides and phosphates and used for engineering purposes as ferrous metals, with iron as the main constituent, e.g. pig iron, cast iron, wrought iron and steel and others like aluminum, copper, zinc, lead and tin in which the main constituent is not iron as non ferrous metals [4].

Steel is the most suitable building material among metallic materials; this is due to a wide range and combination of physical and mechanical properties that steels can have. On the basis of carbon content steel may be classified as under in the table below Table 2.16 [4]. As carbon content increases steel gives high degree of hardness and strength but decrease the malleab ility and ductility of the metal and it shows brittleness behavior.

Table 2.16 classification of steel basis of carbon content [4]

Type of steel	Carbon content (%)
Dead mild steel	< 0.15
Mild steel	0.15 – 0.3
Medium carbon steel	0.3 – 0.8
High carbon steel	0.8 – 1.5

Reinforced concrete is a versatile, economical and successful construction material. It can be molded to a variety of shapes and finishes. Usually it is durable and strong, performing well throughout its service life. However, sometimes it does not perform adequately as a result of poor design, poor construction, inadequate materials selection, a more severe environment than anticipated or a combination of these factors [15]. The corrosion of reinforcing steel in concrete is a major problem.

Corrosion of reinforcement may result reduction of cross section of reinforcement, as a result cracking and splitting of concrete cover can occur. The load carrying capacity of steel decreases, in addition to this, the elongation properties and fatigue strength may be reduced more substantially by small reduction in cross section. Corrosion of reinforcement in rare case, sudden failure can occur without causing of cracking and spalling of concrete.

It is essential understanding of the physical properties of steel reinforcement, the reasons for its particular location and factors regarding concrete cover. On the job site the supervisor will be concerned with planning and controlling the sequence of operations and he must, therefore, be familiar with the activities and skills of cutting, bending and fixing steel. Methods of site handling and storage of steel are also extremely important [1]. In addition to this, Ethiopian building and transport construction design authority (BaTCODA) technical specification recommends a test to verify the properties of reinforcement bars for their ultimate tensile stress, yield point stress, elongation and cold bend test.

2.1.2.2. Reinforcing steel bars

Concrete being extremely weak in tension requires reinforcement, which is steel reinforcement; it is available in the form of bars of specific diameters with different chemical composition, e.g., mild steel and high tensile steel and surface characteristics, e.g., plain or deformed. Reinforcing steel should not have carbon content of more than 0.25%, sulphur content of no more than 0.05% and phosphorus content of no more than 0.05% for grade 460 and 0.25%, 0.6% and 0.6% for grade 250 as stated in British standard BS 4449-1997.

2.1.2.3. Purposes and types of reinforcing steel

Reinforced concrete was designed on the principle that steel and concrete act together in resisting force. Concrete is strong in compression but weak in tension. The tensile strength is generally rated about 10 percent of the compression strength [16]. For this reason, concrete is good for comprehension member, when it is used for tension members it must be reinforced to attain the necessary tension strength. Steel is a material used to reinforcing the concrete because the properties of expansion for both steel and concrete are considered being approximately the same; that is, under normal conditions, they will expand and contract at an almost equal rate but at very high temperatures, steel expands more rapidly than concrete and the two materials will separate [16].

The bond strength is proportional to the contact surface of the steel to the concrete. In other words, the greater the surface of steel exposed to the adherence of concrete, the stronger the bond. A deformed reinforcing bar adheres better than a plain, round, or square ones because it has a greater bearing surface. In fact, when plain bars of the same diameter are used instead of deformed bars, approximately 40 percent more bars must be used as stated in IS 1139-1966. Reinforcing steel can be used in the form of bars or rods that are either plain or deformed [16].

- Plain bars are round in cross section. They are used in concrete for special purposes, such as dowels at expansion joints, where bars must slide in a metal or paper sleeve, for contraction joints in roads and runways, and for column spirals. They are the least used of the rod type of reinforcement because they offer only smooth, even surfaces for bonding with concrete.

- Deformed bars differ from the plain bars in that they have either indentation in them or ridges on them, or both, in a regular pattern. The twisted bar, for example, is made by twisting a plain, square bar cold. The spiral ridges, along the surface of the deformed bar, increase its bond strength with concrete. Other forms used are the round and square corrugated bars. These bars are formed with projections around the surface that extend into the surrounding concrete and prevent slippage. Another type is formed with longitudinal fins projecting from the surface to prevent twisting.

2.1.2.4. Classification of reinforcing steel

Steel for reinforcing bars can be classified according to its use. For impacts and suddenly applied loads, mild steel reinforcement may prove to be a better choice since high yield steels are more brittle and may fail under such conditions [4].

Indian standard [IS 432 (Part-1)-1982 and IS 1133 (Part-1)-1966] classify steels as mild steel (Grade I and II) and medium tensile steel for plain bars and mild, medium and high tensile steels for deformed bars as shown in the Table 2.17 and 2.18. But mild steel grade II are not recommended to use in earthquake zones subjected to sever damage and for structures subjected to dynamic loading (other than wind loading) such as railway and highway bridge.

Other standards such as British standard BS 4449- 1997 covers plain round steel bars in grade 250, and deformed (type 1 and type 2) high yield steel bars in grade 460, the latter in two ductility categories, 460A and 460B.

Table 2.17. Type and grade of plain reinforcement bar [IS 432 (Part-1)-1966]

Types of steel	Ultimate tensile stress, N/mm^2 min	Yield stress N/mm^2	Minimum elongation (%)
Mild steel grade- I			
- Up to and including 20mm	410	250	23
- Over 20 mm up to and including 50mm	410	450	23
Mild steel grade- II			
- Up to and including 20mm	370	225	23
- Over 20 mm up to and including 50mm	370	215	23
Medium tensile steel			
- Up to and including 16mm	540	350	20
- Over 16mm up to and including 32 mm	540	340	20
- Over 32mm including 50mm	540	330	20

Table 2.18. Type and grade of deformed reinforcement bar [IS 1133 (Part-1)-1966]

Types of steel	Ultimate tensile stress N/mm^2 for all sizes	yield stress N/mm^2	Minimum elongation %
Mild steel - Up to and including 20mm - Over 20 mm up to and including 40mm - Over 40 mm	420	260 240 240	For all sizes 23
Medium tensile steel - Up to and including 20mm - Over 20 mm up to and including 40mm - Over 40 mm	550	360 345 330	For all sizes 20
High yield strength bars - Up to and including 16mm - Over 16mm up to and including 32 mm - Over 32mm including 50mm	15% greater than measure yield stress	425 425 425	For all sizes 14.5

2.1.2.5. Transporting, storage and protection of reinforcement bars

Reinforcement shall be transported to the site of work or to the place of storage by such means and in such a manner that the reinforcement is neither damaged nor deformed. The unloading of the reinforcement shall be done at the nearest convenient place, where it is to be processed further. Particularly in cases where unloading is required to be done by hand, it is important that the vehicle should be brought as close as possible to the stacking or bending place in order to avoid carrying over long distances. As far as possible, at the time of unloading the bars should be separated by sizes and lengths as stated in Indian standard.

Reasonable care should be exercised during unloading or handling reinforcement bars to avoid kinking or otherwise damaging them. Long bars should be supported at several points on top of an arrangement of timber sleepers or the like, when being handled and should not be dragged on the ground. When the bars are unloaded, they should be placed on suitable blockings, well off the ground, in an area that has been cleared from grass, and other growth, and which will be kept drained [17]. In addition to this, Indian standard IS 4082-1977 recommended to reinforcements to coat with cement wash and to stocking above 150 mm from the ground level to prevent scaling and resting.

Uncoated bars which are to be stored for a long period of time should be protected to minimize rusting. Rust, itself, should not be cause for rejection; but rusting to the extent that the bar becomes pitted reduces its strength and is definitely caused for rejection. Normal handling of the bars will usually remove rust which is loose enough to cause loss of bond.

Reinforcement bars which have become irreparably damaged due to improper handling, storage, or for any other reason, or which have become excessively rusted or pitted, should be rejected and removed from the site. Bars may be checked for loss of section by weighing [1]. If heavily rusted bars (which may result from improper storage for a long time exposed to rusting conditions) are discovered at the time of placing, a quick field test of suitability requires only scales, a wire brush, and calipers. In this test, a measured length of the bar is wire-brushed manually and weighed. If less than 94% of the nominal weight remains, or if the height of the deformations is deficient, the rust is deemed excessive. In either case, the material may then be rejected or penalized as structurally inadequate [1].

2.1.2.6. On site Fabrication of reinforcement bar

The fabrication of reinforcing steels, into shapes suitable for fixing into the concrete formwork, is normally performed by bar benders on the site, the basic fabrication processes are cutting, bending, tying and fixing. The actual processes employed in the bending and cutting of reinforcing steel depend principally on the form of material being processed, whether bar or coil. In addition to this, tying and placing and fixing are important to prevent the bars movement from their original position and to provide sufficient cover to prevent from aggressive environmental effects such as corrosion.

2.1.2.6.1. Cutting and bending of reinforcing bars

Stock lengths of reinforcement bars require cutting into the required cutting length for fixing into the concrete formwork. During cutting allowance is essential for the losses in bending and draw-in (the way in which the machine draws the bars into the mandrels as bending proceeds). This must be determined by the production and checking of trial bends [1].

Bending should be carried out by mechanical methods, at constant speed without jerking, with the aid of mandrels so that the bent part has a constant curvature. If the ambient temperature is lower than a specified value, additional precautions may be needed, therefore, it requires adequate supervision, skilled workmanship and efficient equipment; and any attempt to carry out the work with unskilled labor and inefficient tools will undoubtedly result in unsatisfactory work.

It can carried out either in hot bending or cold bending for instance, Indian standard IS 2502-1963 recommends hot bending (not exceeding 850^{o}c) for bars larger than 25 mm diameter, but hot bars not to be cooled by quenching. In addition to this, different equipments are recommended for bending. These are claw used for bars under 12 mm diameter, simple bar bending machine for bar size up to 16mm diameter and geared bending machines used for bars larger than 16mm diameter. But bars having a size of 36mm diameter and above require special equipment such as power operated benders.

Steel is an elastic material, which means that, when it is stretched it will return to its original length (spring back) after the load is released, because it is still in the elastic range. This is true up to the ‘yield point’. When stretched in tension beyond the yield point, the increase in length of the bar becomes permanent. The bar’s tensile strength has not been reduced. However, if this ‘stretched’ bar is stretched again it may, under some circumstances, recover its elastic properties and possibly also have a new yield point [16].

Excessive bending can be classified as having a pin diameter at or below the bend-test diameter. This can change the metallurgical structure of the steel and can also crush the deformations thus initiating a zone of weakness. The diameter of a bend should not be so large that the hook cannot fit inside the concrete or that it will pull out rather than act as a hook. Nor should it be so small that the pressure between the bend and the concrete will crush the concrete [16]. British standard recommends tolerances for cutting and/or bending dimensions shall be in accordance with Table 2.19 and radius of bending in Table 2.20 shall be taken into account when completing the schedule.

Table 2.19 Tolerances of Cutting and bending processes [BS 8666:2005]

Cutting and bending processes	Tolerance mm
Cutting of straight lengths (including reinforcement for subsequent bending)	±25
Bending:	
< 1 000 mm	+5, -25
>1 000 mm to < 2 000 mm	+5, -10
>2 000 mm	+5, -25

Table 2.20. Maximum limit for which a preformed radius is required

Bar size (mm)	**Radius (**mm)
6	2.5
8	2.75
10	3.5
12	4.25
16	7.5
20	14
25	30
32	43
40	58

Despite claims made about the degree of bending which can be sustained by some steels in a laboratory, treatment on a building site can be much more severe. For this reason Australian standard AS3600 prohibits the use of small diameter pins at or below the bend test sizes. Cold weather bending and the occasional on-site 'adjustment' also require larger pin sizes. Coated bars are bent about larger pins than uncoated bars [16].

Re-bending or straightening bars is a common practice on-site if such bending will not be needed. Any on-site cold bending should only be done with a proper bar bending tool. Pulling the bar against the edge of the concrete, hitting the bar with a sledge hammer or using a length of pipe damages the surface of the reinforcement, reduces its ductility, can cause breakage of the steel and may cause premature failure of the concrete element. When reinforcement is bent about a curve smaller than the recommended minimum pin diameter, or bent against an edge, the steel is excessively strained on the compression and tension faces. An attempt to straighten a bar bent too tightly may lead to bar failure [16]. Ethiopian standard recommended re-bend test to verify ageing property of bent bars after testing, the bars shall show neither rupture nor cracks in the bent portion

2.1.2.6.2. Tying, placing and fixing of reinforcement bars

Tying, placing and fixing of reinforcement into the forms for the structure are one of the most important aspects of the construction of a structure. Special care should be taken to ensure that the reinforcement is tied, placed and fixed in accordance with the design.

Bars crossing each other should be tied for installation into the form work normally it is carried out using soft iron wire having a size of not less than 0.9 mm [17]. A number of tie arrangements can be used mainly designed to secure the steel prior to and during concrete placement without allowing slip or displacement, but tie wire adds nothing to the strength of the steel. Forces imposed on the ties can be quite substantial, particularly where they must resist the impact of concrete being shot from the skip into a wall form. The column reinforcement, especially in heavily reinforced columns and in columns subjected to a combination of direct load and bending, should be properly tied using longitudinal timber or large bar placed along each row of vertical bar and tied to each bar; otherwise the strength of the column will be considerably affected.

There are six types of ties that are identified below and as shown in the figure 2.3, according to the letters of the alphabet used to show individual ties [1]. But Indian standard recommends to tie reinforcement bar by using Snap tie, Saddle tie and Cross tie [32].

A. Snap tie or Simple tie. The wire is simply wrapped once around the two crossing bars in a diagonal manner with the two ends on top. These are twisted together with a pair of side cutters until they are very tight against the bars. Then the loose ends of the wire are cut off. This tie is used mostly on floor slabs.

B. Wall tie. This tie is made by going about 1 1/2 times around the vertical bar, then diagonally around the intersection, twisting the two ends together until the connection is tight, but without breaking the tie wire, then cutting off the excess. The wall tie is used on light vertical mats of steel.

C. Double-strand single tie. This tie is a variation of the simple tie. It is especially favored for heavy work

D. Saddle tie. The wires pass halfway around one of the ban on either side of the crossing bar and are brought squarely or diagonally around the crossing bar with the ends twisted together and cut off. This tie is used on special locations, such as on walls.

E. Saddle tie with twist. This tie is a variation of the saddle tie. The tie wire is carried completely around one of the bars, then squarely across and halfway around the other, either side of the crossing bars, and finally brought together and twisted either squarely or diagonally across. The saddle tie with twist is used for heavy mats that are to be lifted by a crane.

F. Cross tie or Figure-eight tie. This type of tie has the advantage of causing little or no twist in the bars.

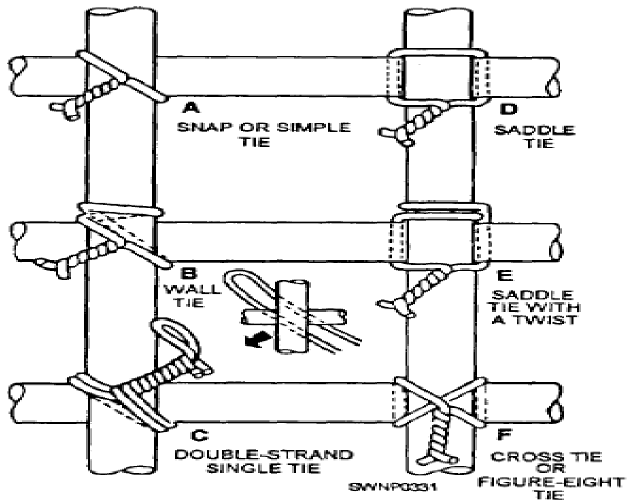

Fig 2.3: - six types of ties [17]

Reinforcement shall be placed in position as given on the detailed design drawing and shall be secured at their designed positions at all times so that considerable care should be exercised in the placement, alignment and projection, supporting, and fastening of bars. These bars should not be disturbed once they are in their correct position, especially after the concrete has been placed and vibrated around them. Any disturbance will tend to destroy their bond with the concrete and consequently the value of the bar itself.

The condition of the reinforcement bars should be rechecked immediately prior to placement to make certain that they are free of dirt, grease, oil, paint, heavy rust, or any other foreign matter which would tend to destroy the bond between the concrete and the reinforcement. If the forms have not already been treated with form oil (in the case of wood forms), this should be done before the reinforcement bars are placed. The bars should not be dragged across or laid directly on forms which have recently been treated with form oil.

The positioning and spacing of the bars should be in accordance with the plans before placement is started. In addition to this, adequate concrete cover using concrete blocks must be provided to ensure; safe transmission of bond forces, adequate fire resistance and protection of the steel against corrosion due to exposure to air, moisture, and salt action. Those blocks are prepared from cement mortar, it may be square or rectangular its thickness is equivalent to the distance between the outer surface of the reinforcement (including links and stirrups) and the nearest concrete surface as stated in the Ethiopian standard EBCS 2,1995. Excess cover should be avoided as micro cracking due to bending stress can result in the growth and development of cracks and resulting corrosion of reinforcement or member loss due to spalling.

Workers often walk on reinforcement bars which have been placed for sidewalks, curbs, and medians in order to perform their work. Because these bars are relatively small, they tend to bend rather easily and are sometimes found to have shifted from their correct position. The Contractor should be required to provide plank walkways outside of or over such reinforcement, both for the protection of the work and for the safety of the workers. Walking on reinforcement bars which are partly embedded in concrete that has started to set should not be permitted. To avoid this situation, walkways should be provided which are supported directly on the forms or on the structural members [1].

2.2. Hollow concrete block (HCB) production

Hollow concrete block is an alternative wall and floor making material in the building construction having one or more large holes with the solid material between 50 and 75 percent of the total volume of the block calculated from the overall dimensions [ES 596:2001]. Most hollow concrete blocks have one or more hollow cavity manufactured from a zero-slump mixture of Portland cement (and possibly other cementitious materials), aggregates, water and sometimes admixtures.

2.2.1.Hollow concrete filler blocks for ribbed slabs

Hollow concrete filler blocks for a ribbed slab shall be manufactured in approved vibrated machine and shall be so shaped as to give a minimum bearing of 25 mm of the filler blocks on the joist its production is done the same way as production of wall hollow concrete blocks. According to Indian standard IS 6061(Part I)-1971 hollow cement concrete filler blocks specify to conform requirements for size and shape and breaking strength. A typical section of the hollow cement concrete filler block to span between joists kept at 600 mm centers. If the hollow cement concrete filler block has to span between joists kept at 750mm centers or above, the block should be suitably reinforced.

The blocks shall be so prepared, that at any point it shall have a thickness of not less than 25 mm with maximum variation in the dimensions shall be not more than ± 1.5 mm for height and breadth and ±3.00 mm for length. In addition to this, blocks shall be prepared to have a bearing of not less than 25 mm on the joists. On the other hand Ethiopian standard CES 24- 2013 recommended maximum dimensional variation shall be ±5 mm and nominal dimension are listed in the table 2.21 below.

Table 2.21. Nominal dimensions of hollow concrete filler blocks [CES 24-2013]

Height (mm)	Breadth (mm)	Length (mm)	Face shell (mm)	Web (mm)
140	400	200	20	20
180	400	200	25	20
240	400	200	30	25

2.1.1.1. Breaking strength test on hollow cement concrete filler block

According to IS 6061(Part I)-1971 filler hollow concrete blocks shall be suitably and simply supported without any mortar at the supports and having a bearing of at least 25 mm on the supports placed at 600 mm centre to centre. A load of 300 kg shall be applied on a steel plate 20 mm wide kept centrally over the entire width of the block and parallel to the supports. The strip load of 300 kg is applicable only for blocks having width of 250 mm and for wider blocks the load should be increased in proportion to the actual width and 250 mm. The block shall not break or crack or show any type of deformation. At least two blocks from the lot manufactured in a day, or two blocks from 1000 blocks whichever is less should be tested for dimensions and breaking strength. On the other hand, Ethiopian standard CES 24- 2013 recommends class C strength (average strength of 6 hollow blocks not less than 2 Mpa and individual strength not less than 1.8 Mpa). It is done by taking six full size samples from a lot of 5000 blocks or fraction there for the compression test. If blocks are kept in batches at least three samples shall be taken from each.

2.2.2.Hollow concrete blocks for wall construction

Hollow concrete blocks used for wall construction classified as load bearing and non load bearing depends on their structural function [18]. According to ASTM C90-70 hollow load bearing concrete blocks have three weight classifications those are normal weight, medium weight and light weight blocks as listed in Table 2.22 and shall conform two grades those are grade N and grade S.

Grade N blocks are suitable for general use such as in exterior walls below and above grade level that may or may not be exposed to moisture penetration. But grade S blocks limited to use above grade level for walls not exposed to weather and for exterior walls with weather protective coating.

Both grades have two types such as moisture controlled units designed as Type I (N-I and S-I) and shall conform all requirement listed in the Table 2.23 and non moisture controlled units designed as type II (N-II and S-II) and shall conform all requirements except moisture content requirements listed in Table 2.23.

On the other hand non load bearing hollow concrete blocks are manufactured in accordance with specification ASTM C129-70. Those blocks intended for use in non load bearing partitions, but under certain conditions may be suitable for use in non load bearing walls above grade, where effectively protected from weather.

Table 2.22 weight classification of hollow concrete block [ASTM C90-70]

Classification of hollow block	kg/m^3
Light weight	Less than 1682
Medium weight	1682-2002
Normal weight	2002 or more

Table 2.23. Moisture content requirement for type I units [ASTM C90-70] & [ASTM C129-70]

Linear shrinkage percent	Moisture content requirement max percent of total absorption average of 3 units		
	Humidity condition at job site or point of use		
	Humid (Average annual relative humidity above 75%)	Intermediate (Average annual relative humidity 50 to 75%)	Arid (Average annual relative humidity less than 50%)
0.03 or less	45	40	35
From 0.03 to 0.045	40	35	30
0.045 to 0.065, max	35	30	25

According to Ethiopian standards ES 596:2001 hollow concrete block shall conform four classes depends on their strength, as Class A, B, C and D and their requirements are defined below and their minimum comprehensive strength listed in Table 2.28. On the other hand Indian standard recommended classes of hollow concrete blocks as A, B, and C but class D manufactured as solid block used for the purpose of load bearing wall having a minimum density of 1800 kg/m^3.

- **Class A** used for load bearing wall construction above or below ground level in damp proof course, in exterior walls that may or may not be treated with weather- protective coating and for interior walls and density of Class A blocks must conform between the range of 900 – 1200 kg/m^3 on the other hand Indian standard IS: 2185 (Part I) – 1979 recommended minimum density 1500 kg/m^3.

- **Class B and C** are used for load bearing wall construction above ground level in damp proof course in exterior walls that are treated with suitable weather- protective coating and their density should be between 900 – 1200 kg/m^3 on the other hand Indian standard IS: 2185 (Part I) – 1979 recommended minimum density within the range of 1000-1500 kg/m^3 but class C is recommended for non load bearing wall.

- **Class D** are used for non load bearing interior walls and exterior panels walls in steel or reinforced concrete framed construction when protected from weather by rendering or by some other efficient treatment and their density should be between 600 - 900 kg/m^3.

2.2.3.Hollow concrete blocks production process

2.2.3.1.Raw Materials

Portland cement (OPC or PPC), aggregates and water are commonly raw materials used to make concrete mixture for production of hollow concrete blocks. But concrete mixture used for blocks has a higher percentage of sand and a lower percentage of gravel and water than the concrete mixtures used for general construction purposes. This produces a very dry, stiff mixture that holds its shape when it is removed from the block mold. In addition to these, basic components various chemicals, called admixtures, can be used to alter curing time, increase compressive strength, or improve workability sometimes pigments may be added to give the blocks a uniform color throughout. Aggregates should be pass through a sieve of nominal aperture of 9.5 mm in addition to this the size of aggregate should not exceed two–third of the thickness of the thinnest part of the shell or web unit [19].

2.2.3.2.Mixing

In case of hand-molded block where compaction is done manually, concrete mix should be sufficiently consistent to enable remolding immediately after casting. The consistency of the mix should be such that it may cohere when compressed in the hand without free water being visible. Too little water causes the mix to be friable, while too much water causes difficulty in the immediate withdrawal of the mould. It shall be carried out on a water-tight platform and care shall be taken to ensure that mixing is continued until the mass is uniform in colour and consistency. Ten percent extra cement may be added if hand-mixing is an alternative according to Indian standard IS: 2185 (part I)-1979.

In case of machine-molded blocks, the web markings on the units as they come from the machine give a good indication as to whether the proper consistency of concrete has been used. In addition to the grading of the aggregate and the quantity of cement, the amount of water required for mix will depend to an extent on the type of machine on which blocks are produced. It is possible to judge the proper consistency by squeezing a handful of concrete mixture.

2.3.2.3. Compaction and placing

According to Indian standard IS: 2185 (Part I) – 1979, manual compaction, the mixture shall be placed into the mould in layers of about 50 to 75 mm and each layer thoroughly tamped with suitable tampers until the whole mould is filled up and struck off level with a trowel.

In the case of mechanical compaction, the mould shall be filled up to overflow, vibrated or mechanically tamped and struck off level. After remolding the blocks shall be protected against sun and wind by placing on the shade until they are sufficiently hardened to permit handling without damage. On the other hand, GTZ low cost housing manual Volume I specify to vibrate the mixture for 60 second before extruded as hollow concrete block and transported and remains for 24 hours on wooden pallet then it is be cured covered by plastic sheet to enhance the curing process and preventing the water from evaporation.

2.3.2.4.Curing

Indian standard IS: 2185 (Part I) – 1979 recommends for manufactured blocks on the site shall be cured in water tank or a curing yard by being kept thoroughly moist with water for a period of at least 14 days. When the blocks are cured in an immersion tank, the water of the tank shall be changed at least every 4 days. On the other hand, steam curing can be adopted for the purpose of reduction curing time. The blocks shall be stocked on a clean and level platform free from earth or other impurities during the curing process, and shall be stocked in honeycomb fashion with voids horizontal to facilitate through passage of air.

The blocks shall not be used prior to one month after production in order to complete initial shrinkage before blocks are laid in the wall. On the other hand, GTZ low cost housing manual Volume I recommends 10 days of curing time, in addition to this, date of production must be write on blocks for the purpose of identification whether it is ready or not for construction.

2.3.2.5.Surface texture and finish

Concrete masonry units can be given a variety of surface textures ranging from a very fine close texture to a coarse open texture by the proper selection, grading, and proportioning of aggregates at the time of manufacture.

Textures may also be developed by treating the face of the units while still green by wire brushing or combing, by slightly eroding the surface by playing a fine spray of water upon it, and by splitting (split block) such surface must provide adequate adhesion for plaster or other finish as stated in Ethiopian standard ES 596:2001.

Colour may be introduced by incorporating non-fading mineral pigments in the facing concrete, or by applying a coloured cement grout or paint to the face of the units soon after they are removed from the moulds. Selected coloured aggregates may also be used in the facing and exposed by washing with water or dilute hydrochloric acid.

2.2.4. Physical requirements

2.2.4.1. General

All units shall be sound and free of cracks or other defects which interfere with the proper placing of the unit or damage the strength or performance of the construction. Minor chipping resulting from the customary methods of handling during delivery, shall not be deemed grounds for rejection. Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks, or other imperfections, except that if not more than 5 percent of a batch contains slight cracks or small chippings not larger than 25 mm [ASTM C90-70] or 10mm [ES596:2001] or [IS: 2185-1979], this shall not be deemed grounds for rejection.

2.2.4.2. Dimension and Tolerance of Hollow concrete block

Hollow Concrete block, shall be referred to by its nominal dimensions. The term 'nominal' means the standard dimension which designed by manufacturer plus thickness of the mortar joint. For modular size units nominal dimension equal to standard dimension plus 9.53 mm but for non modular size units it exceeds the standard dimension by 3.18 to 6.35 mm [ASTM C90-70]. Other standards such as Indian standards [IS: 2187-1979] recommended mortar joint 10 mm for modular size and 6 mm for non modular ones.

Different standards specify their own limits on the permissible variations in the dimensions of standard hollow concrete block masonry units. These limits make easy laying of the units, assist the mason to construct the masonry within the suitable tolerances and help to offer an aesthetic finish and appearance of the constructed masonry.

According to ASTM C90-70 and ASTM C129-70 over all dimensions tolerance (length, width and height) of hollow concrete block shall not differ by more than 3.18 mm from specified standard dimension. In addition to this, face shells and webs thickness shall not less than ½ in or 12.7 mm for non load bearing hollow concrete block but load bearing shall conform the Table 2.24. In case of Indian standard IS: 2185:1979 over all dimensions shall not differ by ±5 mm for length and ±3 mm for height and breadth in addition to this face shells and webs thickness shall conform the Table 2.25.

British standard BS: 6073-part I 1981 specify the maximum dimensional deviation for masonry units by measuring at four corners of end faces for length and for height at six position using caliper it should be +3 mm or -5 mm and ±2 mm for thickness by measuring at seven position. On the other hand Ethiopian standard [ES 596:2001] specify maximum dimensional variation (length, height, breadth), it should be ± 5mm for nominal dimensions of concrete masonry blocks these are listed below in Table 2.26. In addition to this, face shells and webs thickness of hollow units shall be at least one-sixth of overall breadth of a unit or 25mm whichever is the greater.

Table 2.24 Minimum face-shell and web thickness [ASTM C90-70]

Nominal width (mm)	Face shall thickness (mm)	Web min (mm)
102	19	19
152	25	25
203	32	25

Table 2.25 Minimum face-shell and web thickness [IS: 2185-1979]

Nominal block width (mm)	Face shall thickness (mm)	Web Min (mm)
Less than 100 mm	25	25
100 to 150	25	25
150 to 200	30	25

Table 2.26 Nominal dimensions of hollow concrete blocks [ES 596:2001]

Length (l) mm	Breadth (b) mm	Height (h) mm
400	100 150 200	200
500	100 120 150 200	100 150 200 250
600	100 120 150 200	100 150 200 250

Note: 40 mm length is preferred modular size

2.2.4.3. Block Density

For hollow concrete, low density is probably the most characteristic feature. This is due to the holes. In addition, it depend primary on the aggregate density and the proportions of aggregate because the particle density of individual grading fraction can differ considerably and thus will affect the density of concrete. This property also influenced by the cement, water and air contents (ACI Committee 213, 2003).

The density of a block can only be obtained after the casting process by taking three blocks taken randomly from the selected samples and then dried to constant mass in a suitable oven heated to approximately 105°C. After cooling the blocks to room temperature, the dimensions of each block shall be measured in centimeters (to the nearest millimeter) and the overall volume computed in cubic centimeters. According to Ethiopian standard ES 596:2001 and Indian standard IS: 2185-(part 1)-1979 three blocks shall be taken for average density and it should conform to the requirements specified in Table 2.27 below. The blocks shall then be weighed in kilograms (to the nearest 10 g) and the density of each block calculated as follows:

$$Density = \frac{mass\ of\ block\ in\ kg}{Volume\ of\ specimen\ in\ cm^3} x10^6\ kg/m^3 \qquad \text{..........................2.8}$$

Table 2.27.density classification of concrete masonry units [ES 596:2001] and [IS: 2185-1979]

Class of Hollow concrete block	Ethiopian standard ES 596:2001 (kg/m^3)	Indian standard IS: 2185-1979 (kg/m^3)
A	900-1200	1500
B	900-1200	1000-1500
C	900-1200	1000-1500
D	600-900	1800

Note- According to Ethiopian standard Class A, B, C are load bearing units but class D is non load bearing unit but in case of Indian standard class A and B are load bearing units but Class C is for non load bearing units.

2.2.4.4. Compressive Strength

The strength of hollow concrete is closely related to the specimen size and shape, method of pore formation, direction of loading, age, water content, water-cement ratio, degree of compaction, and cement content characteristic of its ingredients used, method of curing, size and number of holes created. Both hollow structure of the air holes and mechanical condition of the pore shells have a great influence on the compressive strength of hollow concrete block. It is also been found that a reduction in density due to formation of holes will results in a significant drops in strength. Generally, compressive strength increases linearly with density of structural concrete (CEB/FIP Manual, 1977).

The minimum compressive strength at 28 days being the average of six units, and the minimum compressive strength at 28 days of individual units should be tested. Compressive strength of a concrete masonry unit shall be taken as the maximum load in Newton divided by the gross cross-sectional area of the unit in square millimeters finally the results of the nearest 0.1 N/mm^2, separately for each unit and as the average for the six units will be recorded [19]. On the other hand British standard BS: 6073 (part I) 1981 recommended for blocks having a thickness of 75 mm or more to test for compressive strength and their average compressive strength of 10 blocks shall not less than 2.8 MPa or individual block shall not less than 80 % of the minimum permissible average compressive strength.

The following are the minimum compressive strength requirements for blocks at the age of 28 days. The mix proportions of the material components are to be adjusted as required to obtain the required compressive strength according to Ethiopian standard, Indian standard and ASTM standards listed in the Table 2.28, 2.29 and 2.30 respectively.

Table 2.28. Comprehensive strength of hollow concrete blocks at 28 days [ES 596:2001]

Type of hollow concrete block	Class	Minimum comprehensive strength (N/mm^2)	
		Average of 6 units	Individual units
Load bearing	A	5.5	5.0
	B	4.5	4.0
	C	3.5	3.0
Non load bearing	D	2.0	1.8

Table 2.29. Comprehensive strength of hollow concrete blocks [IS: 2185-1979]

Type of hollow concrete block	Class	Density of block kg/m^3	Minimum comprehensive strength (N/mm^2)	
			Average of 8 units	Individual units
Load bearing	A	Not less than 1500	3.5	2.8
			4.5	3.6
			5.5	4.4
			7.5	5.6
	B	1000-1500	2	1.6
			3	2.4
			5	4
Non load bearing	C	1000-1500	1.5	1.2

NOTE- the density of block is specified for the guidance of manufacturers; while ordering the blocks, purchaser shall specify the grade only.

Table 2.30. Comprehensive strength of hollow concrete blocks [ASTM C90-70 & ASTM C-129-70]

Type of hollow concrete block	Grade	Minimum comprehensive strength (N/mm^2)	
		Average of 3 units	Individual units
Load bearing	Type N (type I & II)	6.9	5.5
	Type S (type I & II)	4.8	4.1
Non Load bearing	(type I & II)	Average of 5 units	Individual units
		3.5	3.0

2.2.4.5. Water Absorption

It is a measure of the voids (reachable pore volume) within the net volume of the concrete, including the voids within the aggregate itself. According to ASTM C140-70, the water absorption determined from five full-size units by completely immersed in water at room temperature for 24 hours and they shall be removed from the water and allowed to drain for one minute by placing them on a 10 mm or coarser wire mesh, visible surface water being removed with a damp cloth, and immediately weighed and then all specimens shall be dried in a ventilated oven at 100 °C to 115 °C for not less than 24 hours and until two successive weightings at intervals of 2 hours show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen and the recommended Water Absorption requirements of load bearing Hollow concrete block in the table 2.31. On the other hand Ethiopian standard [ES 596:2001] specify water absorption 290 kg/m^3 (25%) for load bearing hollow concrete block and 320 kg/m^3 (30%) for non load bearing hollow concrete block but Indian standard recommended 10 percent.

Table 2.31. Absorption requirements of load bearing Hollow concrete block [ASTM C90-70]

Grade	Water absorption max (kg/m^3)			
	Oven dry weight Classification (kg/m^3)			
	Light weight		Medium weight	Normal weight
	>1362 (kg/m^3)	1362 – 1682 (kg/m^3)	1682 -2002 (kg/m^3)	< 2002 (kg/m^3)
N-I & II	-	290	240	210
S-I & II	320	-	-	-

2.2.4.6. Drying Shrinkage

The drying shrinkage is defined as the change in linear dimension of test specimen due to drying from saturated condition to an equilibrium weight and length under specified accelerated drying condition. dimensional changes of units has a significant effect on cracking that may be takes place during the early curing and drying which leads to a reduction in volume due to loss of moisture. The amount of drying shrinkage that occurs depends on the properties of the materials used for production, for instance units produced with normal weight aggregates tend to shrink less than units produced with lightweight aggregates and high strength units, with the corresponding high cement content, will shrink more. In addition to this the weather conditions at the job site also contribute to the dimensional changes in concrete masonry. Clearly, there will be more shrinkage in hot, arid climates as the amount of moisture lost to the atmosphere is greater than in cooler, humid climates.

Units when unrestrained being the average of three units shall not exceed 0.1 percent [IS: 2185:1979]. The 'drying shrinkage' shall be calculated for each specimen as the difference between the 'original wet measurement' and the 'dry measurement' expressed as a percentage of the 'dry length [20]'.

2.2.4.7. Moisture content

Moisture content requirement of concrete block masonry units is related to their linear shrinkage characteristics. Concrete loses or absorbs moisture with changes in the moisture content or relative humidity of the surrounding air. The cement paste may gain moisture and hence "swell", or lose moisture and "shrink" before it attains an air dry equilibrium condition. It will undergo no dimensional change when the moisture content of the concrete is in equilibrium with the relative humidity of the surrounding so that masonry units are never delivered to a construction site in a saturated condition, and moreover, could not be laid in this condition. If unacceptably moist units are laid in a wall at the time of construction, and this inherent shrinkage is restrained in-service, stresses are developed within the masonry that may cause cracking. ASTM C90-70 specifies three moisture content requirements corresponding to linear shrinkage as listed in the table 2.23 above.

2.2.5.Sampling of hollow concrete blocks

The blocks required for carrying out tests in according to Ethiopian standard [ES 596: 2001] by taking a sample of 12 hollow concrete blocks shall be taken from every consignment of 10,000 blocks or part thereof of the same size and same batch of manufacture can be taken from stack in which case the required number of blocks shall be taken at random from across the top of the stacks, the sides accessible and from the interior of the stacks by opening trenches from the top and those block shall be kept under cover and protected from extreme conditions of temperature, relative humidity and wind until they are required for test. The tests shall be undertaken as soon as practicable after the sample has been taken. From these samples, the blocks shall be taken at random for conducting the tests.

All the 12 blocks shall be checked for dimensions and inspected for visual defect. Out of the 12 blocks, 3 blocks shall be subjected to the test for block density and water absorption, 6 blocks to the test for compressive strength and the remaining 3 blocks shall be reserved for retest purpose.

On the other hand, Indian standard IS 2185 (Part I) - 1979 a sample of 20 blocks shall be taken from every consignment of 5000 blocks. From these samples 20 blocks shall be checked for dimensions and inspected for visual defects Out of the 20 blocks, 3 blocks shall be subjected to the test for block density, 8 blocks to the test for compressive strength, 3 blocks to the test for water absorption and 3 blocks to the test for drying shrinkage and later to the test for moisture movement. The remaining 3 blocks shall be reserved for retest for drying shrinkage and moisture movement if a need arises.

British standard BS: 6073 (part I) 1981 recommended 10 blocks for dimensional, compressive strength and 4 blocks for drying shrinkage testing in every 1,000 blocks but ASTM C 140-70 for strength, absorption and moisture content determinations recommended 10 units shall be selected from each lot of 10,000 units of fraction thereof and 20 units from each lot of more than 10,000 and less than 100,000 units. For lots of more than 100,000 units 10 units shall be selected from each 50,000 units or fraction thereof contained in each lot.

2.2.6.Criteria for conformity of hollow concrete blocks

According to Ethiopian standard [ES 596:2001] the number of units must conform with dimensions outside the tolerance limit and/or with visual defects, among those inspected shall be not more than two, in addition to this comprehensive strength and water absorption shall confirm the limit specified in sec 2.2.4.4 & 2.2.4.5.

In addition to this, Indian standard IS 2185 (Part I) – 1 1979 specify hollow concrete blocks to conform dimensions and visual defects, block density, compressive strength, water absorption and drying shrinkage requirements as defined in section 2.2.4.2, 2.2.4.3, 2.2.4.4, 2.2.4.5 and 2.2.4.6 as defined in section.

ASTM C90-70 recommend to conform the requirements such as physical requirements (linear shrinkage and moisture content, compressive strength, water absorption), minimum face-shell and web thickness and permissible dimension in variation and visual defects as defined in table 2.23, 2.30, 2.31 and 2.24 and section 2.2.4.2 and 2.2.4.2

3. METHODOLOGY

The following methodology has been employed to achieve the objectives of the research

Stage I: Literature review

A comprehensive literature review is made to understand the previous efforts, which include the review of textbooks, standards, academic journals, and research papers.

Stage II: Main research

The methods followed to achieve the objectives are:

- Observations on site activities were made on active building construction sites.
- Designing questionnaire and distribute it to resident engineers and supervisors working on investigated construction sites. The questions are both open and closed ended having contents which mainly focus on the quality control during production of reinforced concrete and hollow concrete block.
    - ✓ There are about thirty-three questions related to reinforced concrete production and
    - ✓ Twenty six questions related to hollow concrete block production.
- Collecting compressive strength test results of structural grade concrete and hollow concrete block used in building construction from the consultant`s test data files.
- Analyzing information gathered through questionnaire, test results and observations. Then make a subjective assessment on the current reinforced concrete and hollow concrete block production practices with respect to the recommended scientific approaches of literatures and also to make a quantitative evaluation on the level of quality control in production of reinforced concrete and hollow concrete block on the investigated building construction sites.
- Based on the findings conclusions are drawn and recommendations are forwarded.

Investigation is undertaken on randomly selected sites located in Addis Ababa. The sites in which the research is conducted are Yeka Ayat II, Yeka Ayat III, Yeka Abado, Bole Arabsa, Kolfe keranyo Tulu dimtu and klento. Those sites currently extensive building construction projects has been executed by construction of hundreds of blocks for condominium building and they are owned by Addis Ababa housing Agency.

4. RESULTS AND DISCUSSIONS

To investigate effectiveness of quality control for production of reinforced concrete and hollow concrete blocks in projects administered by AAHP. Thirteen (13) questionnaires were collected from active projects for reinforced concrete production and ten (10) questionnaires were collected for hollow concrete block production. In addition to this, compressive test result for concrete and hollow concrete blocks were collected from consultant data file.

The information gathered through questionnaire, site observations and compressive strength test results are briefly discussed here. The practices of quality control in related to production of reinforced concrete and hollow concrete blocks are evaluated against the recommended scientific practices. Reinforced concrete and hollow concrete block quality are affected both by the quality of ingredients and the production processes, each ingredient and every production processes are thoroughly seen. The questionnaires are attached on the annex part of this paper. In addition to this, three hundred forty one (341) lots compressive test result are collected for the study from the sites selected for investigation. Each lot represents three cubes (15cm x 15cm x 15cm), which makes the total number of cubes investigated 1023. The construction sites included in the research are listed on table 4.4 with the analysis of compressive strength test results. In addition to this three hundred fifty four (354) compressive strength test results of hollow concrete blocks are collected.

4.1.Reinforced concrete production

Concrete in its fresh state is a plastic material, the flow characteristics of which can be simply controlled. Initially the gain in strength is rapid, measured in hours, but concrete continues to harden throughout a number of years. For convenience, concrete strength is measured using 28 days at a constant temperature (20°C in Britain) as a reference point [1].

Concrete can be used unreinforced in massive construction works such as dams and similar applications. Unreinforced concrete has considerable resistance to compressive stresses and a dense and durable concrete has much to offer in simple load bearing uses above and below ground level and in water. Where forces other than direct compression are to be sustained, it becomes desirable to reinforce the concrete with some further material which can provide much greater resistance to tensile and shear forces. Reinforcement may take the forms of bars of steel.

Reinforced concrete production involves two distinct but equally important activities one is related to concrete production and the other is related to fabrication of reinforcement, so that suitable control is maintained over selection of the constituent materials, the way in which they are batched and mixed, and as long as handling, placing, compaction and curing are properly carried out, the concrete will be capable of sustaining considerable loading in demanding situations. In addition to this, reinforcement bar requires careful controlling starting from handling and storage, cutting, bending and fixing steel because if any contaminant is present in quantity, it may be necessary to clean the bars using wire brushes-a costly and wasteful process and shifting reinforcement bars from their correct position leads reduction in resisting force coming to reinforced concrete.

4.1.1. Concrete production

Concrete is one of the oldest construction materials in the construction industry and it is widely used throughout the world. It is suitable to almost all types of constructions starting from foundations, road pavements, dams, buildings of various types etc. So that suitable care has to be taken over selection and handling of the constituent materials, the way in which they are batched and mixed, and as long as handling, placing, compaction and curing are properly carried out to produce concrete as economically as possible with appropriate workability, strength and durability. The result questionnaires related to production of concrete which is forwarded to the respondents written as follows.

4.1.1.1.Quality of concrete making materials and their handling

As it is mentioned in the literature review, concrete is produced mainly from three different construction raw materials that can be both manufactured and naturally available. Cement is one of the constituents of concrete and is a result of a factory manufacturing process. The rest constituents that are aggregates and water are naturally available and are usually used directly for construction purposes. It is usually easy to control the quality of construction materials that pass through a manufacturing process. However, it is very difficult to control the uniformity and quality of construction materials that are available naturally and used directly for construction purposes. This is usually true for concrete making materials especially for the aggregates. Hence, care should be taken starting from the selection, handling and estimation of the amounts of constituents of the concrete because poor quality of concrete can be happen from well designed mix and proper production process due to lack of attention in controlling quality of row materials.

4.1.1.1.1. Cements

Portland cement considered as generic material. Hydrated cements having different chemical composition may exhibit different properties. It should thus be possible to select mixture of raw materials for the production of cements with various desired properties [9].

Two types of cements their source from Messobo, Muger and Pakistan used for concrete production, in the construction sites selected for investigation, those are OPC and PPC. OPC has higher calcium oxide content which results in higher C_3S content so that, the rate of strength gain or the rate of hydration is accelerated in early age of concrete containing this cement.

Portland-Pozzolan cement (PPC) is manufactured by intergrinding or blending pozzolans with Portland cement clinker but puzzolana has no cementing value itself but has the property of combining with lime to produce a stable lime-puzzolana compound which has definite cementitious properties [9]. With the effect that PPC acquires greater water-resisting property than ordinary Portland cement. Portland-pozzolan cements gain strength slowly and therefore require curing over a comparatively long period, but the long-term strength is high [5].

The age of cement used for concrete production on construction sites is not exactly known. Because the date of production of cements produced in Ethiopia is not written on the packing paper. Therefore, this is considered as one of the problems that could seriously affect the quality of concrete due to improper or prolonged storage, or adulteration during transport .The test for loss on ignition must be performed before use. But in all construction sites selected for investigation there is no test conducted to check the quality of cement. In addition to this, Ethiopian standard agency (ESA) must include labeling (writing date of production on their packing papers) as criteria of quality conformity for cement factories when it issues license to them.

Minimum cement content per meter cube is specified in all construction sites selected for investigation, it is 360 kg/m^3 for production C-25 grade of concrete. However, it is excess amount as shown in the table 2.9 of literature review and 280 kg/m^3 is sufficient to produce C-25 concrete. This has an impact on the client as it has the possibility of increasing the total project cost but the need to specify minimum cement is important for the purpose of durability specially to prevent corrosion of reinforcement [5].

On the other hand, concrete quality can be affected due to improper storage of cement due to moisture and due height of stocks become lumpy. In all construction sites selected for investigation their storage is not safe for cements from moisture and their height of stocks not limited as shown in the figure 4.1 below.

Figure 4.1 storage of cement in Ayat site

There is awareness about cement handling, but the problem is in the implementation. Because the respondent's mention the following points about handling of cement.

- All cracks and openings in walls and roofs of cement storage should be closed.
- Cement bags should not be stored on damp floors. But they should be rest on pallets and stacked close together to reduce air circulation but should never be stacked against outside walls.

- Bags should be covered with tarpaulins or other waterproof covering when stored for long periods.
- Bags should be placed on raised wooden platforms (pallets) above the ground.
- Limit the height of stocking to prevent lumping up under pressure

4.1.1.1.2. Aggregates

Aggregates cover the major portion of concrete it occupy 60% to 75% of the concrete by volume (70% to 85% by mass) [4], so that careful attention for maintaining of quality of aggregates are very important because aggregate quality affects the overall concrete quality significantly as compared to cement and water due to its higher proportion and modules of elasticity [2]. In addition to this, it provides better dimensional stability and wear resistance as their use of as economical filler materials. Aggregates are unlike cements they are non factory products strongly influence the concrete's freshly mixed and hardened properties, if not properly controlled its quality starting from quarrying selection and handling in the construction site, in which an aggregate must be free from any harmful effects such as veins and adherent coating; and injurious amounts of disintegrated pieces, alkali, vegetable matter and other deleterious substances. As far as possible, flaky and elongated pieces should be avoided [5].

Various aggregate sources are observed in construction sites selected for investigation. All sites used coarse aggregate which is distributed by Addis Ababa housing project which is obtained from quarry sites near to Addis Ababa on the other hand fine aggregate bought by the contractors from different sources such as Lafesa, Minjar, Sodere, Meki, Langano, Mermersa and Koka. When aggregates are bought from different quarry sites or river deposits mineralogical contents of aggregate are not tested. Mineralogical contents such as reactive constituent's in the form of opals, charts, chalcedony etc…which results in disruption of concrete with the spreading of pattern cracks and eventual failure of concrete structures and presence of other deleterious substance like salts and sulphates that are likely to cause corrosion of reinforcement.

There are a number of tests for fine and coarse aggregates which is stated in different standard but during observation on the construction sites which is selected for investigation no test is conduct for coarse aggregate but for fine aggregate 15.38 % (two of them) of respondents uses fine aggregate for concrete production without any test as shown in the table 4.1 and figure 4.2 in pie chart, but the remaining respondents asses silt content by using jar test, visual observation or both. According to the response 30.77 % (four of them) of respondents uses visual observation and jar test to asses quality of fine aggregate, 38.46% (five of them) of respondents uses jar test to determine silt content, and the remaining of 15.38 % (two of them) of the respondents uses visual observation only.

Determination of silt content is important because excessive amount of dust and silt increases the water consumption, thereby reducing the strength in which interferes with the processes of hydration of cement, coatings preventing the development of good bond between aggregate and cement paste, and durability of concrete. This is an indication that sufficient tests don't carried out on the aggregates supplied for concrete production.

Table 4.1 Test conduct for fine aggregate

R.No	Type of test	Construction sites In percent
1	No test	15.38
2	Silt content using Visual observation and jar test	30.77
2	Silt content using jar test	38.46
4	Silt content using Visual observation only	15.38

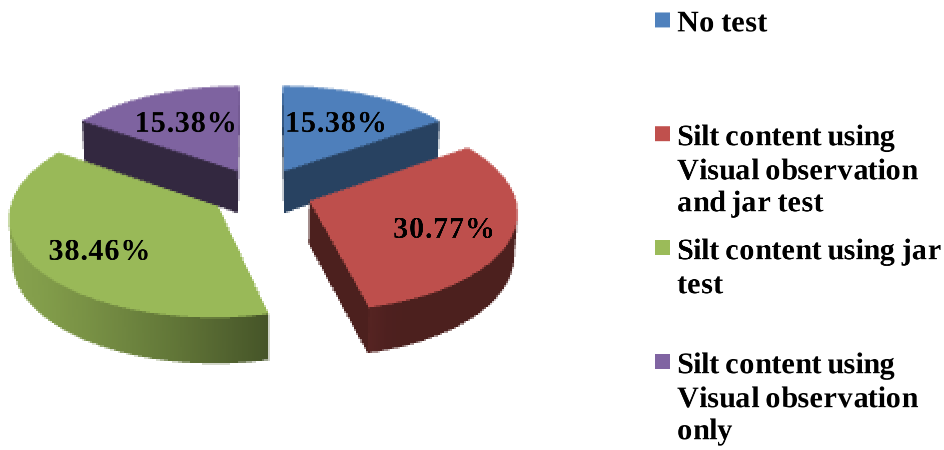

Fig. 4.2 Percent of Tests for fine aggregates used on Investigated construction sites

Besides to testing of aggregates, frequency of testing also important in order assure the quality, because when aggregate stacked in the open and unused for long time may contain moss and mud in the lower level of the stack, or it may be degraded as a result low quality of aggregate may be occur. Tests for aggregate discussed in the preceding parts are carried out either once or more than once for a source. The percent of the respondents which take a sample of fine aggregate to be tested once are 84.62 % (eleven of them) but the remaining 15.38 % (two of them) of respondents not take a sample for testing. On the other hand 100 % (thirteen of them) of the respondents not conduct tests more than once depending on condition as shown in table 4.2 below.

Table 4.2 frequency of testing for fine aggregates on construction sites

R.No	Testing frequencies	Projects in percent
1	No samples taken for testing	15.38
2	Only once when it comes from the source	84.62
3	More than once depending on condition	0.00

It was observed on some sites that aggregates aren't stored properly till the time of usage. They are placed where they easily get dust, due to the work on site by moving dump trucks and growing of grass on the stock piles as shown in the pictures in fig 4.3 & 4.4 below, and this can increase the amount fines due degradation and organic content of aggregates after decay. Such negligence in aggregate handling affects or degrades the quality of aggregate. There is a thought among respondents 15.38% (two of them) not care for defective aggregates, 38.46 % (five of them) of respondents defective aggregates should automatically be rejected. However; 46.15 % (six of them) of the respondents reply mechanisms before rejecting the aggregates these are:

- Washing
- Blending, and
- Changing quarry site and defective aggregate uses for non structural parts such as lean concreting work.

Fig 4.3 dump truck moving on the coarse aggregate in Ayat site and Yeka Abado

Fig 4.4. Handling of fine aggregate in Ayat III site

There is awareness about good quality of aggregate, but the problem is in the implementation. Because the respondent's mention the following points in order to get good quality of aggregates

a. Select good quality providing source
b. Sources of good aggregates has to be used consistently
c. Stock fine aggregate and coarse aggregate separately on hard dry and level pitch of ground
d. Prevent aggregates from intermixing of clay, dust and vegetables matter.
e. Fine aggregates must stocks in a place where loss due to the effect of wind is minimum.
f. The location of the deposit of river sand along the river course has to be inspected and tested
g. It must be made sure by frequent inspection that the supplying source doesn't show significant variation of quality.

4.1.1.1.3.Water for concrete mixing

Drinking or potable water is the commonly used mixing water in all construction sites. In all construction sites under investigation, there is no test conducted for water of coarse drinking water could be used for mixing purpose without any test; however, when the water is brought from other sources like river and drilled well of the ground, it should be tested. Substances in water which, if present in large amounts, may be harmful are: salt, oil, industrial wastes, alkalis, sulphates, organic matter, silt, sewage etc…could have a negative impact on both fresh and hardened concrete quality.

During observation in construction sites selected for investigation. they used drinking water coming from the water tap and stored in the contractor water tank constructed on the ground as shown in the figure 4.5 & 4.6 but lack of fences around water tank, could bring accident especially for children's and security persons during night time, in addition to this, those water tanks are not protected from wasting through dusts and other deleterious particles unless they are washed and cleaned regularly. Among the respondents 15.38% (two of them) of them cleaned the water tank once in every six months, 23.08 % (three of them) of them cleaned the water tank once in every three months but the remaining 61.54 % (eight of them) percent of the respondents haven't a regular time for cleaning of the water tank but it is conducted depends on accumulation of dusts. Those dusts in water can have negative impact on fresh concrete because dusts can affect the bond between cement and aggregate and retard hydration of cement process [5].

Figure 4.5 water tanks in Bole Arabsa site

Figure 4.6 water tank in Kolfe keranyo site

4.1.1.2. Concrete Production Process

The production of concrete involves two distinct but equally important activities. One it has been discussed above, which is related to 'materials' required for concrete production such as cement, aggregate and water and the other, related to 'processes' involved in production such as batching, mixing, transportation, placement, compaction and curing [2]. Lack of sufficient attention for production process result poor concrete from well designed mix [2]. Therefore, if we are able to control the process, we can obtain good quality concrete which satisfy strength and durability. The results of questionnaires related to production of concrete which is forwarded to the respondents written as follows.

4.1.1.2.1. Concrete specification

There are three specifications of concrete as mentioned in the literature review, but all construction sites which is selected for investigation follows nominal mix procedure. Nominal mix is used unimportant or simpler works because it is assumed that by adhering to such perspective specifications satisfactory performance may be achieved. EBCS 2, 1995 recommended for concrete with rich cement to produce without verification of comprehensive strength by testing, in addition to this maximum size of aggregate, level of workability, slump, total aggregate, percentage of fine aggregate and volume of finished concrete must specified.

There is only one type of structural concrete grade observed on the investigated construction sites, it is C-25.

On the observation, design and prescribed method of specifying concrete mix are not shown. This practice couldn't help to client to get good quality of concrete with lower amount of cement because mix ratio is prepared based on the property of ingredients.

4.1.1.2.2. Batching of ingredients

Batching is the process of measuring concrete mix ingredients by either mass or volume, to introducing them into the mixer. To produce concrete of uniform quality, the ingredients must be measured accurately for each batch [5]. Most specifications recommended weight batching rather than volume batching because it allows rapid and convenient adjustment of aggregates and water when a change in aggregates moisture content has occurred. In addition to this there is no adjustment required for bulking of sand, but water and liquid admixtures can be measured accurately by either volume or mass [2].

As a response from the respondents, aggregates (fine and coarse) are batched using volume batching using box size of 40 cm x 50 cm x 18 cm per 50 kg of OPC and 40 cm x 50 cm x 16 cm per 50 kg of PPC in all construction sites selected for investigation. But under investigation, some sites were observed batching was not done properly. They used excess aggregate during batching as shown in the figure 4.7 below. This practice could affect quality concrete because uniform quality of concrete achieved as a result of accurately measured ingredients.

Fig 4.7 batching of fine aggregate in bole Arabsa site

In order to accurately meet the water requirement of the mix design, the amount of water added at the concrete batch plant must be adjusted for the moisture conditions of the aggregates, because if the water content of the concrete mixture is not kept constant, the water-cement ratio will vary from batch to batch causing other properties, such as the compressive strength and workability to vary from batch to batch. The water in aggregate, if not adjusted, affects the water cement ratio with the subsequent impact on the properties of fresh concrete and the ultimate compressive strength. The increase in the amount of water in the mix increases the w/c ratio. However; it is known that compressive strength is inversely related with the w/c ratio [5].

During observation there is a negligence observed on adjusting the quantities of ingredients on construction sites, especially on aggregates. In addition to adjusting the amount of water because of free surface moisture, bulking of sand should also be considered. It is found out from the respondent in all construction sites don't make any adjustment. If there is significant bulking and allowance is not given to compensate for it, the concrete will deficient in sand and prone to segregation and honey combing. In addition, sand deficient mix lacks sufficient mortar to fill the void system as a resulting a harsh mix will be occur. This concrete requires a greater effort to compact.

4.1.1.2.3. Mixing of concrete ingredients

Thorough mixing is essential for complete blending of materials that are required for production of homogenous and uniform concrete [6]. It is observed that in all construction sites selected for investigation, their mixing is carried out by using mixers (reversing type) having a capacity of 360 liter as shown in the figure 4.8. Careful controlling for mixing time, slump and discharging of fresh concrete are important to get concrete with desired property.

During mixing careful attention for mixing time is important, because complete blending of materials depends on mixing time whether mixing time is less or more than specified in the standard, many specifications require a minimum mixing time of one minute plus 15 seconds for every cubic meter of concrete. But it is observed in the same sites, 15.38 % (two of them) of respondents mixing time is less than one minute, 7.7 % (one of them) of respondents mixing time is less than two minute, 46.15 % (six of them) of respondents use excess mixing time it was minimum of 5 to 10 minutes and the remaining of 30.77 % (four of them) of respondents do not care for mixing time. As a result from discussion only 7.7 % (one of the respondents) only follow correct mixing times. If mixing is done over a long period, evaporation causes decrease in workability and breaking of aggregate and leads decreasing of air content in addition to this, short mixing time causes improper blending of ingredients, excessive of air voids in fresh concrete.

Workability of fresh concrete assessed by its slump value during investigation, it was observed in all construction sites selected for investigation that the adjusting slump of fresh concrete when it is higher or lower than the required limits carried out by simply adding or reducing water. But the difficulty of attaining the specified slump may not be corrected always with water. The problem may be attached with the grain size distribution of aggregates or may be with the amount of either or both fine and/or coarse aggregate in the mixed concrete [2]. In order to correct the slump value, adding water may have a negative impact on the compressive strength of concretes. Increasing the amount of water increases the water-cement ratio which in turn decreases the compressive strength and durability [5]. Therefore, always before starting concrete mixing it has to be properly checked and supervised to make sure that materials are in conformity with standards.

Freshly mixed concrete should be transported immediately to casting place after discharging from the mixer but during observation, it is shown a fresh concrete discharged directly on the ground as shown in the figure 4.8, this practice can affect the quality of concrete due to evaporation, drawing too much water by the ground and intermixing with dirt or loose particles which affect hydration process.

Fig 4.8 discharged fresh concrete on the site in Bole Arabsa site

4.1.1.2.4. Transporting, Placing, Compaction and Curing

There are many ways of handling fresh concrete, and the choice will depend mostly on amount of concrete involved, size and type of construction, the topography of the job, location of batch plant and relative cost. From material point of view, any method of transportation should protect a concrete from the effects of the weather (heat, cold, or moisture). It should not also cause segregation by excessive jarring or shaking. In short, the methods used should be selected to maintain concrete quality [5].

Proper handling of concrete during placing in the forms can prevent the formation of honey combing, which is causes due to segregation and cold joint if there is delay in placing of concrete forms a joint between hardened and newly placed fresh concrete which is commonly called construction or cold joints. Hence those weak joints have to be avoided during concrete construction. During observation, the site workers had good awareness on haw to eliminate and reduce those cold joints. The work procedure followed to reduce or eliminate cold joint formation is listed below.

- ✓ casting of concrete has to be stopped on non critical portion about one-third from the column
- ✓ by cleaning the surface from foreign mater before pouring concrete
- ✓ by making surface rough using chiseling, sprinkling water, add rich mortar and finally pour the fresh concrete on the wet surface

Concrete needs careful attention during compaction because it is very important part of what concrete production helps to obtain good quality of concrete by eliminate voids of entrapped air and to ensure intimate complete contact of the concrete with the surfaces of the forms and the reinforcement. During observation in the sites under investigation used immersion vibrators for compaction.

Proper use of immersion vibrators in terms insertion time, center to center spacing of vibrators poker immersion and depth of compaction are important for best result [5]. But if there is carelessness, bad concrete may be obtained from well designed mix so that to access compaction practices, queries related to compaction process are forwarded to the respondents.

According to the response, 38.46 % (five of them) of respondents don't not pay attention both for the insertion time and center to center spacing of vibrators poker immersion during compaction, 38.46 % (five of them) of respondents attention is given for the time insertion and spacing of vibrators, 15.38 % (two of them) of the respondents attention is given for the spacing of vibrators poker immersion only but insertion time of vibrators carried by guessing and Again also 7.7 % (one of them) of respondents have mentioned attention is given only for insertion time as shown in the table 4.3 & figure 4.9 in the pie chart.

Table 4.3. Response of respondents for time and spacing of poker immersion vibrator

R.no	Access insertion time and spacing of poker immersion vibrator	% of respondents
1	Respondents don't show attention for both insertion time & spacing of vibrators	38.46
2	Respondents given attention for insertion time & spacing of vibrators	38.46
3	Respondents care insertion time of vibrators	7.7
4	Respondents care spacing of vibrators	15.38

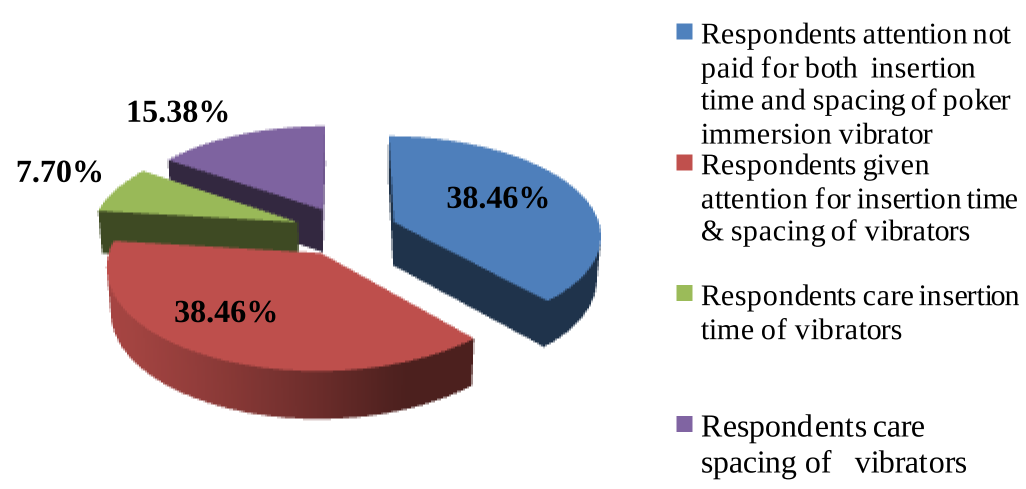

Fig 4.9. - Response of respondents for insertion time and spacing of poker immersion vibrators

Among the respondents, given attention for the insertion time of vibrators, all respondents recommended less than one minute. But vibrator should be held stationary until adequate consolidation is attained and then slowly withdrawn. An insertion time of 5 to 15 seconds will usually provide adequate consolidation [2]. And among the respondents giving attention for spacing of poker immersion vibrators, 23.07% (three of them) only provided 30 to 50 cm spacing, 30.77 % (four of them) of respondents provided one meter of spacing but the remaining 46.15 % (six of them) of the respondents do not care for spacing of the vibrator. During vibration, limit on spacing of poker immersion is important because the effective radius of action of a vibrator increases with increasing diameter [5]. The distance between insertions should be about 1½ times the radius of action [5].

On the other hand, the responses about depth of compaction, it is observed that 46.15 % (six of them) of respondents given 20 cm depth for compaction, 15.38 % (two of them) of respondents provided 30 cm and the remaining 38.46 % (5 of them) of respondents provided 50 to 60 cm maximum depth of compaction. However; to efficiently utilize the compaction effort obtained from vibrators, it is recommended that the height of each layer or lift should be about the length of the vibrator head or generally a maximum of 50 cm in regular formwork [5].

On the above results, more than half of the respondents 53.85 % (seven of them) didn't give any response is given to insertion time. This indicates the concreting work on the site is under question because if the compaction effort of vibrator is not appropriately used, it might result either to over vibration or under vibration. Over vibration enhances bleeding and segregation and under vibration leaves excessive voids in concrete which contains entrapped air.

When the curing practice on the investigated construction sites are observed, all respondents have given equal curing period for both OPC and PPC. It is done for 7 days by sprinkling water without providing of burlap or other moisture retention materials as shown in fig 4.10 below. As a result curing time is not sufficient for concrete made with PPC cement because PPC cement requires more curing time, some literatures recommended two to three times of OPC due its property of slow hardening. Curing has a strong influence on the properties of hardened concrete; proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicers [5].

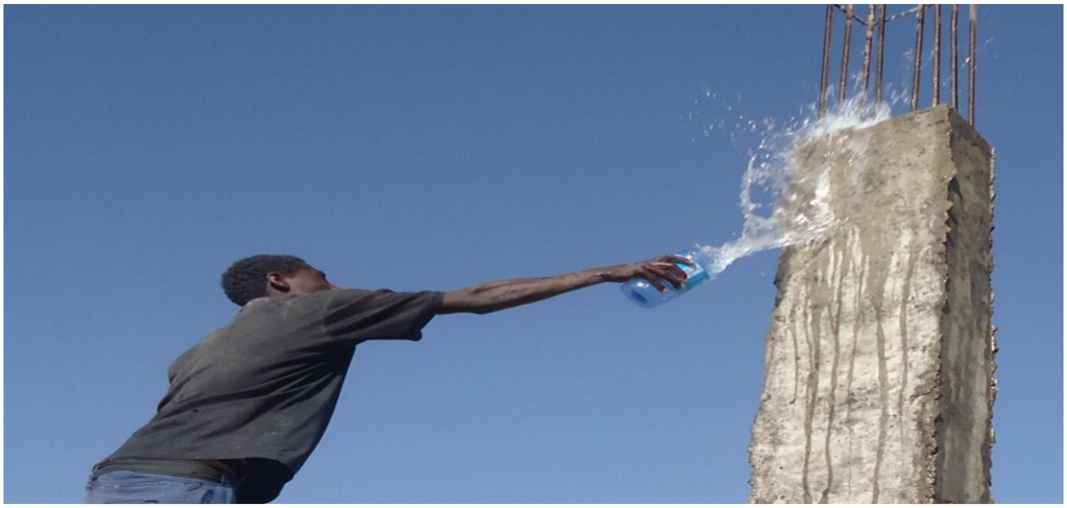

Fig 4.10 curing of concrete in Bole Arabsa site

4.1.1.3. Compliance of 28th day compressive strength test results

Concrete is assured its quality by taking representative samples when concrete poured from mixer and analyze whether the results are satisfactory or not, but the results represent the potential strength of the concrete rather than the actual strength of the concrete in the structure [9]. The magnitude of variations in the strength of concrete test specimens is a direct result of the degree of control exerted over the constituent materials, the concrete production and transportation process, and the sampling, specimen preparation, curing and testing procedures. Variability in strength can be traced to two fundamentally different sources: variability in strength-producing properties of the concrete mixture and ingredients, including batching and production, and variability in the measured strength caused by variations inherent in the testing process [9].

In addition to taking representative samples, frequency of sampling have also significant factor in the effectiveness of quality control. Different standards specify their own frequencies of sampling for acceptance as mentioned in the literature review, but as observed during the investigation; the respondents take a sampled concrete cubes for testing for five times from one block of G+4 building during construction. The components of building selected for taking samples are footing foundation, first floor column, first floor slab, third floor slab and top tie beam to test 7-day, 14-day and 28-day strength. But Ethiopian standard EBCS 2, 1995 recommends at least one sample every week from each grade of concrete.

Since the design of reinforced concrete structures of buildings or other concrete elements are based on the strength of concretes. The testing of sampled concrete cubes should be given a special emphasis. Therefore, the sample should be representative of the mass; the testing should follow the right procedures specified by codes and standards starting from casting concretes to molds up to testing it. Otherwise, the results obtained will be misleading and unreliable [2]. The main objectives of making quality tests for concrete ingredients and carefully undertaking the production processes is at the end to obtain good quality concrete that satisfies both the strength and durability.

Three hundred forty one (341) lots of compressive strength test results are collected from construction sites selected for investigation for assessing the level of quality control and their compliance is checked with Ethiopian standard (EBCS 2, 1995), the British standard (5328: 1990) and the American standard (ACI 318) and the result of standard deviation and variance after performing statistical analysis on sample of test results are evaluated based on ACI 214. The level of quality control is also quantitatively assessed with the use of statistical parameters measuring variability after undertaking statistical analysis as shown on table 4.4.

To perform the analysis shown on table 4.4, the following points are considered.

- A lot having three samples or cubes are used to carry out the statistical analysis, for determination of the mean, the standard deviation and the coefficient of variation using eq. (2.1), eq. (2.2) and eq. (2.3) respectively. In addition to this, for the purpose of least acceptance criterion in the Ethiopian building codes of standards, the values of K_1 and K_2 shown in table 2.14 are variable for various lots. But for analysis of test results in this thesis paper, 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.

- In order to assess quality control based on standard deviation and coefficient of variation as per the ACI 214. The cube strengths which are collected require conversion to cylindrical strengths, this is achieved by using conversion factor of 0.8 [i.e. cylindrical strength =0.8*cubic strength] [11].

Table 4.4 compressive strength test results on investigated projects and their analysis

No.	Name of construction sites & grade of concrete (C-25)	Total mean compressive strength(MPa)	Standard deviation in Mpa	Sample Standard Deviation in Mpa (cylindrical strength)	Coefficient of variation Variation	Ethiopian Standard (EBCS 2,1995)			American Standard (ACI 318)			British Standard (BS5328:1990)		
						No. of defective lots	No. of non defective lots	% of defective lots	No. of defective lots	No. of non defective lots	% of defective lots	No. of defective lots	No. of non defective lots	% of defective lots
1	Project 13, C-25	42.61	3.23	2.58	7.57	0	2	0	0	2	0	0	2	0
2	Project 15 A, C-25	27.28	1.73	1.38	6.34	1	0	100	0	1	0	0	1	0
3	Project 15 B, C-25	25.64	4.77	3.81	18.59	5	1	83.33	1	5	16.67	3	3	50
4	Bole Arabasa A, C-25	31.35	6.13	4.90	19.55	2	6	25	1	7	12.5	1	7	12.5
5	Bole Arabasa B, C-25	40.59	2.41	1.93	5.94	0	1	0	0	1	0	0	1	0
6	Yeka Ayat II A, C-25	38.72	8.33	6.66	21.51	1	7	14.29	1	7	16.67	1	7	16.67
7	Yeka Ayat II B, C-25	23.05	5.12	4.09	22.19	6	2	75	5	3	62.5	6	2	75
8	Bole Ayat III, C-25	36.46	7.87	6.29	21.58	1	4	20	0	5	0	0	5	0
9	Kolfe keranyo 15, C-25	29.32	3.35	2.68	11.42	3	5	37.5	1	7	12.5	1	7	12.5
10	Tulu dimtu project 11 A,	33.90	4.55	3.64	13.41	0	3	0	0	3	0	0	3	0
11	Tulu dimtu project 11 B,	32.34	8.99	7.19	27.78	3	3	50	0	6	0	1	5	16.67
12	Tulu dimtu project 12 A,	32.39	7.53	6.02	23.24	1	4	20	0	5	0	1	4	20
13	Tulu dimtu project 12 B,	29.72	6.18	4.95	20.81	3	10	23.08	2	11	15.38	2	11	15.38

As per the result obtained from table 4.4, to asses compliance 35.14 % of the construction sites contain defective or non complying lots for tests made on samples taken for compressive strength test results in accordance with the requirement set on the EBCS 2, 1995. However; as per the American standard ACI, 318 and British standard BS 5328: 1990 only 14.86 % and 21.62 % of lots have got defective lots.

As the response of respondents, Schmidt hammer test is ordered for those tests having defective lots, for the structural part of the building in which unsatisfactory test results are obtained. However; result of Schmidt hammer test are affected by direction of impact and condition of concrete in terms of its surface condition, moisture content, temperature, rigidity and degree carbonation [2].

As a result obtained from table 4.4, to asses level of quality control according to ACI 214, statistical tools such as standard deviation and coefficient of variation are used to evaluate the variability of compressive strength of concrete and determine compliance with a given standard. According to the result 46.15 % and 76.92 % of lots as determined from the observed variability of test results using standard deviation and using coefficient of variation fall under poor and fair range as shown in shown in Table 4.5 a and Table 4.5 b and as shown in pie chart in Fig 4.11 & 4.12 below.

Table 4.5 assessment of the level of quality control

a) Classification of the level of quality control using standard deviations

Standard deviation	No, of construction Sites	Percentage of construction sites	Control standards
< 2.8	4	30.77	Excellent
2.8 - 3.4	0	0	Very good
3.4 - 4.1	3	23.08	Good
4.1 - 4.8	0	0	Fair
> 4.8	6	46.15	Poor

b). Classification of the level of quality control using Coefficient of variations

Coefficient of variations	No of construction sites	Percentage of construction sites	Control standards
< 7.0	2	15.38	Excellent
7.0 – 9.0	1	7.69	Very Good
9.0 – 11.0	0	0.00	Good
11.0 -14.0	2	15.38	Fair
<14.0	8	61.54	Poor

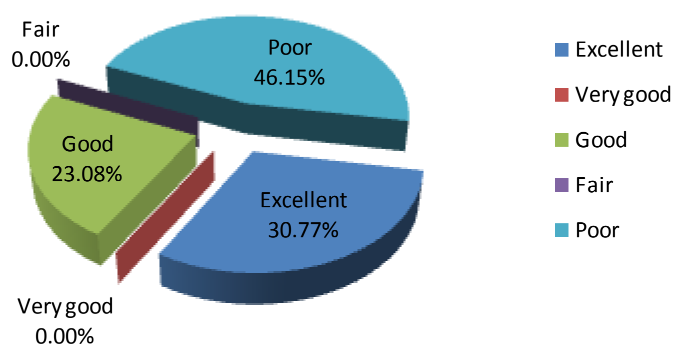

Fig. 4.11 level of quality control of construction sites based on standard deviation

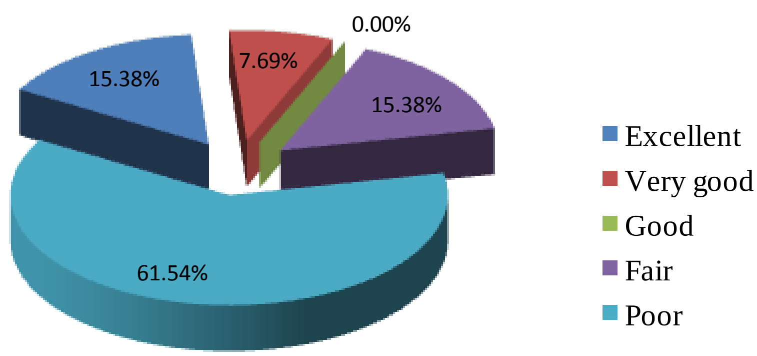

Fig. 4.12 level of quality control of construction sites based on Coefficient of variations

Again as a result obtained from Table 4.4, same construction sites, for instance Project 13 and Bole Arabasa B, produce a concrete having higher mean compressive strength, they uses compressive strength of 42.61 and 40.59 to produce C-25, with lower variability and their standard deviations are 2.58 and 1.93, this shows standard of quality control work is excellent. On the other construction sites such as Yeka Ayat II A and Tulu dimtu project 11 B produce a concrete having higher mean compressive strength they use compressive strength of 38.72 and 32.34 to produce C-25, with higher variability and their standard deviations are 6.66 and 7.19 this shows standard of quality control work is poor.

Quality concrete doesn't only mean a concrete with higher compressive strength. Higher mean strength which results due to larger variability consumes much cement that makes the production uneconomical, because the mix design of concrete is prepared by considering the expected variation during concrete production in which a concrete with higher variability is designed to attain higher required mean strength than a concrete with lower variability for the same concrete grade so that durability is also important to determine quality [2]. In addition to this, Due to the higher cement content of concrete; cracking due to drying shrinkage in thin section or thermal stress in thick sections can be occur [11]. Hence, there should be a strict follow up of the production process to assure the overall quality of concrete.

Concrete should be tested on time to assure its compliance, because concretes having longer age showed higher strength. One of the observations made during investigating 45th days compressive test samples tests are observed, especially for concretes produce with PPC cements in all construction sites selected for investigation. But design of concrete structure is based on the 28th day strength that concrete attains [1]. Hence, concrete strength test result should be taken on time to assure its compliance because of the removal of such a poor quality concrete may have a possibility of damaging the erected superstructure over it. As a result; this has an impact on the quality of the overall structure and lead to additional maintenance cost. Therefore, It should have to be taken the 3rd , 7th and 14th day compressive strength test result to forecast the 28th day strength and take on time measures so that to proceed with the subsequent work without incurring any delay.

Testing of concrete, from which the quality of concrete is assessed quantitatively, need to be seriously considered on construction sites. Representative samples should be taken and tests have to be conducted on time and measures have to be taken to rectify defects at the earliest possible time to assure both quality and economy.

4.1.2. Reinforcement bar

Steel is the most suitable building material among metallic materials. This is due to a wide range and combination of physical and mechanical properties that steels can have. Steel for reinforcing bars can be classified according to its use. for instance for impacts and suddenly applied loads mild steel reinforcement may prove to be a better choice since high yield steels are more brittle and may fail under such conditions.

In many instances, the contract includes site fixing of the reinforcement bar, although the steel may sometimes simply be delivered precut and bent for fixing by the contractor. It is essential that the quality controller has an understanding of the physical properties of steel reinforcement, the reasons for its particular location and factors regarding concrete cover. On the job site the quality controller will be concerned with planning and controlling the sequence of operations and he must, therefore, be familiar with the activities and skills of cutting, bending and fixing steel.

Methods of site handling and storage of steel are also extremely important. Failure to maintain stocks in good order may result in installation of steel in a substandard condition due to contamination, or worse consequences, such as the separation of the steel from the concrete, with resultant failure of the structure. As a result, the steel in lengths or in bundles should be stacked in such a way to be free of contamination, such as splashes of mud from an adjacent roadway. In addition to this, reinforcement must be free of grease, oil, loose mill scale and excessive rust at the time of installation. Where any of these contaminants is present in quantity, it may be necessary to clean the bars using wire brushes-a costly and wasteful process [16].

4.1.2.1. Requirements of reinforcement bars

Reinforcing steel is required to be fixed in a construction and must satisfy a defined set of criteria; it must be bent in to the shape, passes minimum strength, ductility, bond property, weldablity and good fatigue properties [16]. Therefore, different specification set their own requirements, for instance Ethiopian building and transport construction design authority (BaTCODA) technical specification recommended a test to verify the properties of reinforcement bars for their ultimate tensile stress, yield point stress, elongation and cold bend test.

During observation, 100 % of the respondents didn't care about grade of reinforcement bar, but they focus on the cross sectional area of the reinforcement and surface condition (plain and ribbed bar) only. Care on the grade of reinforcement is important because reinforced concrete designs are based on yield strength of reinforcement bar. Insufficient grade of reinforcement bar may lead to failure, for instance due to load carrying capacity.

There are different tests conducted for reinforcement bar, which are specified in the literature review. But during visiting in the construction site, 100 % of the respondents didn't conduct any test for reinforcement bar; they use the reinforcement bars without any test.

Tests for reinforcement bar on its tensile strength, yield strength, especially on cross sectional area is very important, because a lot of reinforcement bar on the site are not stored on proper place, they exposed for rusting. Rusting can subsequently create reduction bond between reinforcement and concrete, and reduction in cross section of the steel causing reduction load carrying capacity of reinforcement as a result. Some standards recommend rejection, when weight loss of reinforcement bar is less than 95 % of the required weight after brushing with wire brush.

During visiting of sites, on request of how frequent do you take samples when testing reinforcement; all respondents replied no sample is taken for testing because they use reinforcement without testing.

4.1.2.2. Handling of Reinforcement bar

Care on handling of reinforcement bar is also important, because reinforcement bar can be easily deteriorated due to improper handling, especially when it contacts with moisture. When it contaminates by dust, it reduce bond with concrete. During observation reinforcement bars are stored near to roadway directly on the ground in the main store (storages of kifle ketemas), it is exposed to contact with moisture and dusts as shown in the figure below 4.13. Where dust present in quantity, it may be necessary to clean the bars using wire brushes, it is costly and wasteful process

Figure 4.13 Kifle ketema rebar storage in yeka abado site

Those reinforcements are bought to site without bending (in straight form) but for the purpose of storage those straight bar are bent as shown in the figure 4.14 below, and finally contractors use these bars after re-bending, this process makes the reinforcement to reduce the strength on the bending and re-bending area. The bending and re-bending procedure is not also carried out properly on the sites as recommended in the literature review.

Fig 4.14 bending of reinforcement bar in Yeka Abado site

On the other hand, 100 % of the respondents recommended reinforcement bar to store above the ground by laying on the timber sleepers in the contractors' stocking area, but the timber sleepers are not laid in sufficient space to prevent deflection of rebar as well as height of sleeper are not safe as shown on the figure 4.15. But some standards such as Indian standard [IS 2502-1963] recommend to stock reinforcement bars 150 cm above the ground to prevent from moisture. In addition to this, sufficient spacing of the timber support is recommended to prevent deflection of reinforcement bar.

During observation, the respondents on the request of what do you do to prevent the reinforcement from moisture or dampness; 100 % respondents prevent it by raising the rebars above the ground only. But in rainy season reinforcements can easily contact with moisture as a result it can be deteriorated. But some standards such as Indian standard recommend [IS 2502-1963] to stock reinforcement bars under the shelter when the reinforcement is likely to get corroded.

Fig 4.15 stacking of rebar in construction site in Ayat site

4.1.2.3. Onsite fabrication of reinforcement bar

Fabrication of reinforcing steels into shapes suitable for fixing in to the concrete formwork is normally performed on site as seen during observation. Accurate cutting and bending operation is vital to insure proper fit on site and to maintain required lap lengths, anchorage lengths and cover.

Therefore, the bar bending on the site should be well equipped to do so in constantly manner and by working with in defined set of quality criteria as provided in the standards.

Reinforcement bar is manufactured in stock lengths as straight bars to a length of 12 m for sizes above 8 mm diameter it is deformed bar, or in coils for size 6 mm diameter it is plain bar as seen during observation. These lengths of bars are cut to the required length using handsaw, but plain bar requires de-coiling. But handsaw cutting is time consuming process especially for larger sized bars.

It is important with reinforcing steel to get the bends correct. Site-bending requires different sized mandrels for bending different sized bar to different radii, because deformed and plain bars are bent to differing radii, and as the sizes increase, so does the required radius [11, 25].

During observation, all sized reinforcement bars are bent manually in all sites selected for investigation as shown in the figure 4.17 below. This process can causes of excessive bending, and can change the metallurgical structure of the steel and can also crush the deformations, thus initiating a zone of weakness [16]. In addition to this, they didn't care about the size of mandrel. The diameter of a bend should not be so large that the hook cannot fit inside the concrete or that it will pull out rather than act as a hook. Nor should it be so small that the pressure between the bend and the concrete will crush the concrete. Besides this, bending is not carried out slowly and under constantly applied force.

Some standards such as Australian standards (AS 3600) don't recommend pipes for bending, because it generate extremely small effective bend diameter, resulting in extremely high localized stresses in bend zone. This may lead to crushing of the ribs and cracking of the bar in the bend area, or fracture of the bar if subsequent re-bending is performed.

Figure 4.16.Site bending of reinforcement bar in Bole Arabsa site

4.1.2.4. Onsite supervision of reinforcement bar

Reinforcement bars after cutting and bending requires tying or fixing on appropriate spacing and placing on form work by providing suitable cover block before concreting. This process requires suitable controlling to assure that the bars are placed based on detailed drawing and specification.

During observation concreting starts, after evaluating the rebar condition by quality controller for its diameter (size), spacing, anchorages & lap lengths, cover, rebar condition, whether it is properly tied in place and free from deleterious substances as response by respondents. But during observation, reinforcement bars having dried mortar on their surface are placed on improperly braced and not cleaned formwork without cover blocks and ready for concreting, as shown in the picture in Figure 4.17. This practice can affect the strength and durability of reinforced concrete.

Improperly braced formwork can't prevent loss of grout or mortar from the concrete. In addition to this, appropriate method of placing and compacting can't occur. The surface condition of the reinforcement bar and form work shall be examined prior to use, to ensure that it is free from deleterious substances which may adversely affect the steel or concrete or the bond between them. For durability reasons, minimum cover shall be provided to ensure; safe transmission of bond forces, adequate fire resistance and protection of the steel against corrosion.

Figure 4.17. Reinforcement bar ready for concreting in Bole Arabsa site

4.2. Hollow concrete block & hollow concrete filler blocks production

Hollow concrete block is an alternative wall and floor making material, it is used for construction of walls using hollow concrete block and for construction of ribbed slab using filler blocks. Those blocks are used for construction of walls and ribbed slabs and follow the same procedure of production [22].

The manufacture of hollow concrete blocks requires constant monitoring to produce blocks that have the required properties such as shape, appearance, texture and color and apparent density, water absorption and compressive strength [19]. In general all units shall be free of cracks or other defects which interfere with the proper placing of the unit or impair the strength or the performance of construction [23]. In order to achieve those properties; care should be taken in material mix proportion, method of manufacturing and handling to ensure the compliance with the requirements stated in different standards those are mention in the literature review [23].

Hollow concrete block production starts from selection and proportioning of raw materials such as aggregates, cement and water. Next, production process will be continued; it composed of batching, mixing, compaction (vibration), curing and drying. Finally, those hollow concrete blocks must complied with the requirements stated in the recommended standards in terms of dimension, density, water absorption, linear shrinkage and compressive strength by testing on sample of blocks. And the number of sampled blocks and selection procedures should follow right procedure which is stated in the recommended standard [19, 23, 24].

This research is done to assess effectiveness of quality control during production of hollow concrete blocks, which comprises production control (includes selection and proportioning of raw materials and production process) and compliance control (includes testing of sampled units). This was achieved by distributing questionnaires and site observation for assessment quality of raw materials and production process. And for assessing compliance criteria; test results are collected and evaluated through different standards such as Ethiopian standard, Indian standard, American society for testing and materials (ASTM).

During observation, in construction sites selected for investigation, hollow concrete blocks having two holes for masonry work, and three holes for ribbed slabs are produced to meet Ethiopian standard class C category and their dimensions are listed in the table 4.6 below.

Table 4.6 Dimensions of hollow block produced in the production area

R.No.	Type of hollow blocks	Dimensions of hollow blocks
1	Hollow concrete block (l x h x t)	40 x 20 x 20
		40 x 20 x 10
2	Filler hollow concrete block (l x w x d)	52 x 20 x 22
		52 x 20 x 16

Note: l :- stands for length

h :- stands for height

t :- stands for thickness

w :- width

d :- stands for depth

4.2.1. Quality and handling of ingredients

For production of hollow concrete blocks, those ingredients such as cement, crashed aggregate, sand; pumice and red ash (scoria) are used with the ratios of 1:1:1:1:2 in all production areas selected for investigation. But the crashed aggregates are a combination of 00 and 01 size. It is understood from those ingredients those blocks must be medium weight blocks, because weight classification of hollow blocks are classified based on aggregates used for production such as light weight blocks are produced by using light weight aggregates, normal weight blocks are produced by using normal weight aggregate such as natural sand and crashed aggregate and medium weight blocks are produced by using a combination of light and normal weight aggregates.

On the observation, the ratios of ingredients are the same in all production areas selected for investigation. Thus, it is clear they have fixed proportion for production of hollow concrete blocks, but the mix ratio must be prepared based on the property of ingredients.

Aggregates such as crashed aggregates having sizes of 00 and 01, supplied to the site by the Addis Ababa housing agency from crasher plants located near Addis Ababa. But sand, pumice and red ash (scoria) are bought by the enterprises involved in production of hollow concrete blocks from different places near to Addis Ababa. For instance, sand is imported from Lafesa, Minjar, Sodere, Meki, Langano, Mermersa and Koka, and pumice and red ash (scoria) are bought from Debrezeit. When aggregates are bought from different quarry sites or river deposits mineralogical contents of aggregate and presence of other deleterious substance like salts and sulphates are not tested.

During observation, the respondents reply on the request of what are the tests made for aggregates; crashed aggregate, pumice and red ash (scoria) used without any test for production. But test for a dry loose bulk density of the light weight aggregate (pumice and scoria) is important in order to prevent reduction in density of HCB which leads reduction in compressive strength.

In the case of sand 80 % (eight of them) of the respondents reply was no test is conducted, but the remaining 20 % (two of them) of the respondents conduct test once when the sand arrives in the site by observation and jar test for its silt content. In case of failing to meet the specified requirement the respondents decided rejection.

As seen on the site during observation, aggregate handling was poor, because coarse and fine aggregates are not placed separately and rest on the ground directly without cleaning from dust as shown in the figure 4.18 below. This may increase silt content of aggregate. In addition to this, leaves and grass grow on aggregates are shown in the sites; especially on the top of sand this can increase organic content of aggregates. As a result, compressive strength and setting time of hollow concrete block can be affected.

Fig 4.18. Handling of aggregate in Yeka Abado production area

On the request of what do you propose to maintain the quality of aggregates? There is awareness about good quality of aggregate, but the problem is in the implementation. Because the respondent's mentionthe following points in order to get good quality of aggregates

- Checking the quality of aggregate before damping to the site.
- Blending of aggregates.
- Sieving to avoid larger size aggregate especially for red ash (scoria) and pumice.
- Placing of aggregates separately having different sizes on proper place.
- Consistently used for quarry sites having good quality aggregates.

On the request about the type of cement used for production of Hollow concrete block, the respondents uses OPC and PPC cement from Muger, Messebo and Pakistan. During observation, the respondents produce the amount of hollow concrete block and filler blocks for ribbed slab using one bag of cement (per 50 kg) are listed in the table 4.7 below:

Table 4.7. Amount of concrete blocks produced per 50 kg of cement

R.No.	Type of hollow blocks	Dimensions of hollow blocks	Amount of block produced per 50 kg of cement
1	Hollow block	10 x 20 x 40	33
		20 x 20 x 40	22
2	Ribbed slab	54.5 x 20 x 22	16
		54.5 x 20 x 16	22

On the request about the test for cement used for production, all respondents used cements without any test. Besides this, the date of production of cements produced in Ethiopia is not specified and written on the packing paper; hence the age of cement to be used for production is not exactly known. But when cements are stored even under good conditions, bagged cements may lose its 20 percent strength after two months and forty percent after six months of storage and cement which is four months old has to be classified as aged and be retested for use. On the other hand the bags of cement is not stored properly as stated in the literature review, bags laid directly on the dumpy floor are shown during observation.

In all production areas drinking or potable water is used for production of hollow concrete blocks as shown during observation. All standards specified drinking water to be used for production without any test, but the water tanks in all production areas are constructed leveled with ground due to lack of fences and cover, the water was wasted by dust as shown in the figure 4.19 below. In addition to this all production areas haven't a regular time for cleaning their tanks, this may increase dust content of water and can affect on the property of hollow block such as reduction of compressive strength.

Fig 4.19 water tank in Bole Arabsa site

4.2.2. Production process

Hollow concrete blocks are passed through different steps of production. These are batching, mixing, molding (vibration), curing and drying. Each and every production process requires control to maintain quality of production.

In case of batching of ingredients used for production of hollow concrete blocks, all respondents use volume batching. It is done without any adjustments, but it is supported by observation. Adding and reducing amount of water by observation is not sufficient because excess water in the mix causes of difficulty in molding, due to this wastage may be increase.

During observation all the respondents used hand mixing, and it is done on the ground directly as shown in the figure 4.20. But some standards recommend, when hand mixing is permitted by the engineer-in-charge, it shall be carried out on a water-tight platform, and care shall be taken to ensure that mixing is continued until the mass is uniform in color and consistency. Ten percent extra cement may be added when hand-mixing is resorted to. On the request of the corrective method, when the slumps aren't able to attain the required slump, the respondents correct the slump by adding and reduction amount of water.

Fig 4.20 mixing of ingredients in yeka abado site

Very dry cohesive concrete is used in masonry production, in conjunction with power full mould vibration in order to compact the concrete sufficiently to achieve the required strength; it is done for about 60 seconds before extruded as hollow concrete block [22]. But as seen during observation, the respondents did not care for the time of vibration; they compact the concrete by guessing. This practice may affect hollow concrete blocks due to over or under vibration.

On the curing of finished concrete blocks, 70 % (seven of them) of the respondents cured for 7 days for block produced with OPC cement and 14 days for block produced with PPC cements. And the remaining 30 % (3 of them) of the respondents, cured for 3 days for both OPC and PPC as shown in the figure 4.21.

Curing must be done under the shade to prevent evaporation, In addition to this, hollow blocks shall be stocked with voids (honey comb fashion) horizontal to facilitate through passage of air.

Based on observation the curing is not sufficient especially for OPC because it is done for 7 days but blocks on the site shall be cured in water tank or a curing yard by being kept thoroughly moist with water for a period of at least 14 days. Insufficient curing leads reduction in compressive strength.

Figure 4.21 Curing of hollow concrete block in Bole Arabsa site site

The finished hollow concrete blocks, on observation, after three days of production stored outside the shade for minimum of 4 weeks up to 10 courses, the time of stocking on the shade is not sufficient. In addition to this, the amount of the course is to excess because the blocks are laid when they are fresh; even curing is done on stocking area located outside of the shade as shown in the figure above 4.21. Blocks in the interior part of stocking do not get sufficient curing. Besides this, the blocks are not stocked properly in honeycomb fashion as mentioned in some standard in the literature review. On top of that, as seen in the observation on the construction sites, the method of transportation used to transport hollow concrete blocks is not safe as shown in the figure 4.22. This method can't be effective and can increase wastage. In addition this, way of transportation is not safe for workers and may lead to accidents.

Fig 4.22 Transportation of HCB from ground to 4th floor in Yeka Ayat II site

4.2.3.Compliance of hollow concrete block

On observation about the test conduct for hollow concrete blocks, in the case of 40 % (four of them) of the respondents, no laboratory test is conducted for hollow concrete block. Actually they conduct field test by dropping hollow concrete from 1m height, but the remaining 60 % (six of them) of respondents replied that they conduct compressive strength test only. A quality hollow concrete block is not only with higher compressive strength, but durability is also important to determine quality. For instance, due to linear shrinkage, cracks may form. Hence, there should be a strict follow up of the production process to assure the overall quality of concrete. As a result, 40% of hollow concrete blocks produced are directly used for construction without test for compressive strength.

When we see sampling, it is done by taking 6 sample blocks but these samples are not taken regularly, but some standards, for instance Ethiopian standard recommends 12 blocks for testing such as compressive strength, water absorption and unit density testing in every 10,000 blocks. In addition to this, Indian standard recommends the sample of blocks to be taken during loading on vehicles or unloading off vehicles, depending on whether sample is to be taken before delivery or after delivery. When this is not practicable, the sample shall be taken from the stock in which case the required number of blocks shall be taken at random from across the top of the stocks, the sides accessible and from the interior of the stocks by opening trenches from the top regularly. But from observation, sample of blocks are not taken from produced blocks as procedures mentioned above, the sample of blocks for testing are prepared independently by taking concrete from the mix, this procedure may affect the blocks produced from the subsequent mixes because the producers may not care for quality of mixes after taking the concrete mix by quality controller.

As replied by respondents in the production areas, the blocks are tested for comprehensive strength only; even it is not conducted regularly as it is mentioned in the literature review of this thesis. Thus compliance testing for hollow concrete blocks is insufficient, because, for instance Ethiopian standard recommends testing dimension, visual defects, and water absorption. In addition to testing for compressive strength, average compressive strength of 6 hollow concrete blocks at 28 days expected to achieve 2 Mpa as response of the respondents on the site. But according to Ethiopian standard EC 596 : 2001, average compressive strength of 6 hollow concrete blocks required to attain 3.5 Mpa and individual compressive strength 3 Mpa are recommended for class C, as a result, hollow concrete blocks produced in production areas are substandard.

5. CONCLUSIONS AND RECOMMENDATIONS

The research carried out has shown some of the problems associated with quality control practice on projects administered by Addis Ababa housing project on investigated construction sites and attempt is made to show the impact of improper quality control practice on the quality of reinforced concrete and hollow concrete block productions. The following conclusions and recommendations are drawn out from the investigation undertaken on the building construction projects.

5.1.Conclusions

1. Selection, testing and handlings of construction materials are important element to ensure the quality of products. Materials such as aggregates, cement, water and reinforcement bar are observed on the sites selected for investigation. But those materials are not passed through sufficient tests. In addition to this, their handling (stocking) at construction sites is very poor.

2. During observation, RC and HCB producers follows nominal mix procedure for proportioning of ingredients. There is only one type of structural concrete grades observed on the investigated construction sites, it is C-25 which is produced by using 360 kg/m^3 cements it is excess amount. On the other hand hollow concrete blocks having two hollows for masonry wall and three holes for ribbed slabs construction are produced to meet class C category but those blocks not conform Ethiopian standard EC 596 : 2001 class C category

3. Control during production process is important because the expenditure incurred on materials goes waste if the process is not taken care of. During observation, RC producers and HCB producers used volume batching. But it is carried without adjustments for moisture content and bulking of sand. On the other hand, HCB producers follow hand mixing method.

   RC producers used mixers having a capacity of 360 litters and time for mixing, as it is observed in the sites, 15.38 % of respondents mixing time is less than one minute, 7.7 %

of respondents mixing time is two minute, 46.15 % of respondents found to use excess mixing time in the construction sites selected for investigation. It was minimum of 5 to 10 minutes and the remaining of 30.77 % of respondents do not care for mixing time. As a result from discussion, only 7.7 % (one of the respondents) only follow correct mixing times.

4. Concrete needs careful attention during poker compaction on its time, spacing and depth of compaction as a result 38.46 % of respondents attention not paid for both time and the spacing, 38.46 % of respondents care for the time and spacing of compaction & 15.38 % of the respondents attention care for the spacing only but the time of vibration is carried out by guessing and Again also 7.7 % (one of them) of respondents have mentioned attention is given only for time of compaction. On the other hand 20 cm, 30cm and 50 to 60 cm depth of compaction is provided by respondents 46.15 %, 15.38 % & 38.46 % respectively. On the other hand HCB producers do not care for time of vibration during production.

5. When the curing observed, all RC producer respondents have given equal curing period for both OPC and PPC. It is done for 7 days by sprinkling water without providing of burlap or other moisture retention materials. On the other hand HCB producers, 70 % (seven of them) of the respondents cured for 7 days for block produced with OPC cement and 14 days for block produced with PPC cements and the remaining 30 % (3 of them) of the respondents cured for blocks 3 days for both OPC and PPC. In addition to this the most of the curing time (more than 78 %) is done outside of the shade, the time of stocking on the shade is not sufficient. In addition to this, the amount of the course is to excess because the blocks are laid when they are fresh even blocks in the interior of the stacks do not get sufficient curing. Besides this the blocks are not stocked properly in honeycomb fashion as mentioned in same standard in the literature review.

6. In the case of fabrication reinforcement bars, cutting, bending, tying done on the site but all sized reinforcement bars are cut and bent manually. But this process can cause excessive bending because they didn’t care about the size of mandrel. The diameter of a

bend should not be so large that the hook cannot fit inside the concrete or that it will pull out rather than act as a hook. Nor should it be so small that the pressure between the bend and the concrete will crush the concrete. Besides this, bending is not carried out under slowly and under constant applied force.

7. Compliance control is a check made to ensure the compliance of the product with the specification. As on a result of statistical analysis made on compressive strength test results indicated that the quality control on significant portion of the projects is not good. As per the classification of ACI 214, the standard deviation of 46.15 % of the compressive strength has shown that the quality control is not good from which none fall in the "fair" classification range and 46.15 % in the "poor" range; and the coefficient of variation of 76.92 % of the compressive strength has shown that the quality control is not good from which 15.38 % fall in the "fair" classification range and 61.54 % in the "poor" range. In the case of analysis of compressive strength test result, 32.89%, 19.74% and 21.05% of the projects has shown defective lots as per the Ethiopian, the American and the British codes compliance requirement respectively.

8. 60 % of the respondents conduct compressive test of hollow concrete blocks by taking a sample of 6 blocks, those samples of blocks are prepared by taking concrete from the mix independently and also taken not regularly. But the remaining 40 % of respondents test a block on field by dropping from 1 m height.

9. Compliance testing for hollow concrete block is insufficient because Ethiopian standard recommended testing dimension, visual defects, and water absorption in addition to testing for compressive strength. In addition to this average compressive strength of 6 hollow concrete blocks at 28 days expected to achieve 2 Mpa as response from respondents on the site but according to Ethiopian standard EC 596: 2001 average compressive strength 3.5 and individual compressive strength 3 Mpa are recommended for class C. But as a result hollow concrete blocks produced in production area substandard or hollow blocks produced on the site conformed Class D rather than Class C.

5.2.Recommendations

1. Construction materials such as aggregates, cements and reinforcement bars should be passed through necessary tests; all specified tests have to be done in accordance with standard procedures before use and handled (stocked) properly in the site to prevent from any harm full effects, in addition to this aggregate source have to be identified and studied on its mineralogical contents and cement producing factories should specify the date of production of cement so that concrete producers know whether the cement is aged or not easily. Consultants on the site must pay attention for construction of water reservoirs by providing the fence and cover in order to ensure safety for human and protect from dust and other foreign matter which affect quality of concrete.

2. Production process for reinforced concrete and hollow concrete blocks must be carried out under careful controlling, starting from batching to curing. For instance concrete for reinforced concrete and hollow concrete block should be produced by proportioning of ingredients based on their property and by providing appropriate mixing time and slump, but failing slumps shouldn't be corrected by adding or reducing amount of water and then compaction should be done on appropriate time, spacing and depth. Finally curing time must depend on the type of cement used whether (whether it is PPC or OPC) and must be cured sufficiently by considering necessary prevention mechanism from evaporation of water from the surface.

3. On the other hand reinforcement fabrication on the site for reinforced concrete should follow correct procedure specially for bending, it should be performed by using machines such as simple bar bending machine, geared bending machines or power operated benders for obtaining accurate bending fit with radius of bending specified in the recommended standard and it can replace time consuming practice especially for larger sized bars. In addition to this supervision during fixing specially for cover blocks and condition of form work must be identified before concreting.

4. By giving emphasis to concrete quality control system, which reduces variation in concretes, it is possible to minimize cement consumption and make concrete production economical. Hence quality control is important to maintain both quality and economy simultaneously.

5. Hollow concrete blocks must be passed through sufficient tests in appropriate way starting from sampling to testing; all specified tests have to be done in accordance with standard procedures particularly for sampling, it should be selected from already produced blocks, those are ready for loading/unloading.

6. There must be well-experienced professionals both on the contractor and the consultant staff to improve quality. In addition to this, consultants must have enough man power for controlling purpose as observation some consultants assign one site inspector for one production area, and one site is observed which is visited once a week by supervisors.

7. It is very important that production guideline, manuals are prepared in simple language and it should be applicable. Because during observation in construction sites selected for investigation, any manuals and guide lines were not available on consultant side or in the producers. It is necessary that all concerned bodies work hand in hand to enhance the quality.

    - Educational institute should work on improving the skill and awareness of construction workers related to handling of materials and their production process.

    - Consultants must assess the quality of contractors engaged in construction especially for their skilled man power. In addition to this, they must adopt controlling mechanism for contractors whether they are working based on the criteria stated in contractor's registration in terms of skilled man power, equipment…

    - The housing agency must secure safety of workers involved in construction activities. In addition to this, the shades prepared for hollow concrete block producers should have enough size to accommodate every production process specially for curing purpose. Because during observation most of the curing is done outside the shade. In addition to this, the housing agency must have enough man power for controlling purpose whether the consultants assigns enough man power and accomplish their responsibilities properly.

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ANNEX I

Questionnaire for reinforced concrete producer

Please give response to the following questions either by putting an `x` mark at your choice on the rectangles shown for questions having choices or by writing your answers in the space provided.

1. What is the structural grade of concrete that is used for this project (cubic strength in MPa)?

   ________ , _________

2. Where is the source(s) of your coarse and fine aggregate?

   Coarse aggregate: ____________ , ____________ , ____________

   Fine aggregate: ____________ , ____________ , ____________

3. What are the tests made for aggregates? Please write down the corresponding values obtained.

   Coarse aggregate: ____________ , ____________ , ____________

   Fine aggregate: ____________ , ____________ , ____________

4. How frequent do you take samples when testing aggregates?

   ☐ Only once for one source

   ☐ Once when it came from the source and then after depending on conditions (That is when the aggregate seems defective, test may be ordered.)

If any other sampling procedure to be followed, please specify

   ____

   ____

   ____

5. Are you satisfied with the quality of aggregate? What would you do if test result fails? Or if it doesn't satisfy the requirement stated on the specification?

   ____

   ____

   ____

6. What do you propose to maintain the quality of aggregate?

   _________________ _________________

   _________________ _________________

7. What type of cement do you use for the concrete production?

   ☐ OPC

   ☐ PPC

8. Where is the source of cement used in concrete production?

   ____

   ____

   ____

9. What is the minimum cement content specified in the specification of the contract document of this specific contract?

   ____

10. Is there any test made for the cement that you are using? If any, please specify.

    __________________ __________________

    __________________ __________________

11. How old is the age of the cement until casting date? (Starting from the time of its production)

    ____

12. What quality of water do you use for concrete mixing?

    ☐ Drinking water

    ☐ If non-drinking water;

    - ☐ From river
    - ☐ Round water from drilled well

13. Is there any test that was made for the water? If any, please specify

    __________________ __________________

    __________________ __________________

14. Do you use admixture in concrete production? If it is used, please specify the type and dosage the admixture.

☐ Yes ☐ No

If your answer is yes, please specify the type and dosage the admixture.

a. ________________
b. ________________
c. ________________

15. What kind of concrete mixing procedures do you follow?

☐ Designed mixes
☐ Prescribed mixes
☐ Standard (or nominal) mixes

16. Which batching techniques do you use?

☐ By weight
☐ By volume

17. What are the adjustments that you make to ingredients when using;

a) Weight batching:

__________________ __________________

__________________ __________________

b) Volume batching:

__________________ __________________

__________________ __________________

18. How do you mix your concrete?

☐ Manually
☐ Using mixing plant
☐ Both of them (both manually and using mixing plant).

19. What is the capacity of your mixing plant?

____

20. For how long do you mix the ingredients?

____

21. What is the corrective measure that you take in case when you aren't able to attain the required slump?

____

____

____

22. How do you compact concrete?

☐ Using hand compaction (rodding)

☐ Using mechanical vibration

If any other, please specify

____

____

____

23. If you use mechanical compaction (i.e. compaction using vibrators)

a. For how long do you compact at an immersion place?

____

b. What is the center to center spacing of vibrators tube on the fresh concrete surface being compacted?

____

c. In case of compacting thicker concrete sections, what is the maximum compaction depth that you use?

____

24. During concrete placing what are the measures that you take to prevent formation of cold joint?

    ____

    ____

25. After casting your concrete, for how long do you cure it if

    OPC__________ PPC ____________

26. Please specify grade of reinforcement used for reinforced concrete.

    Plain bar ________ Deformed bar ________

27. Where do you store your reinforcement?

    - ☐ Under the shade
    - ☐ Outside the shade
    - ☐ Above the ground
    - ☐ Directly on the ground

28. What do you do to prevent the reinforcement from moisture or dampness?

    ____

    ____

    ____

29. What do you propose to prevent reinforcement from corrosion?

    ____

    ____

    ____

30. What are the tests made for Reinforcement? Please write down the corresponding values obtained.

    ____

    ____

    ____

31. How frequent do you take samples when testing Reinforcement?

____

____

____

32. Are you satisfied with the quality of Reinforcement? What would you do if test result fails? Or if it doesn't satisfy the requirement stated on the specification?

____

____

____

33. What do check for reinforcement bar before pouring for concreting?

- ☐ Diameter (size) of bar
- ☐ Spacing of the bar
- ☐ Anchorages & lap lengths
- ☐ Rebar Condition
  - ☐ Rebars must be securely and properly tied in place
  - ☐ Rebars must be freed from concrete dropping, corrosion etc

Thank you for your cooperation!

Questioners for hollow concrete block producers

Please give response to the following questions either by putting an `x` mark at your choice on the rectangles shown for questions having choices or by writing your answers in the space provided.

1. Please specify the types of HCB produced in your site?
   - ☐ HCB for masonry wall
   - ☐ HCB for ribbed slab

2. Please specify class of HCB produced in this site?

   HCB for masonry wall

   ☐ A ☐ B ☐ C ☐ D

   HCB for precast slab__________

3. What is the size of HCB used in this project?

Hollow Concrete Block (L x W x T)	Filler blocks (L x W x D)
☐ 40 x 20 x 20	☐ 52 x 20 x 20
☐ 40 x 20 x 15	
☐ 40 x 20 x 10	☐ 52 x 20 x 16

4. Where is the source(s) of your Ingredients?

   Coarse aggregate: ______________ ______________ ______________

   Fine aggregate: ______________ ______________ ______________

5. What type of Aggregate used for production?
   - ☐ Light weight Aggregate
   - ☐ Normal weight Aggregate
   - ☐ Combined Aggregate

6. What are the tests made for aggregates? Please write down the corresponding values obtained.

   __________________ __________________ __________________

   __________________ __________________ __________________

7. How frequent do you take samples when testing aggregates?

☐ Only once for one source

☐ Once when it came from the source and then after depending on conditions (That is when the aggregate seems defective, test may be ordered.)

If any other sampling procedure to be followed, please specify

________________ ________________

8. Are you satisfied with the quality of aggregate? What would you do if test result fails? Or if it doesn't satisfy the requirement stated on the specification?

____

____

9. What do you propose to maintain the quality of aggregates?

____

____

____

10. What type of cement do you use for the Hollow concrete block production?

☐ OPC

☐ PPC

11. Where is the source of cement used in Hollow concrete block production?

____

____

____

12. How much HCB produced per 100 kg of cement? (LxHxW)

Hollow Concrete Block		Precast hollow concrete block	
40 x 20 x 20	__________	52 x 20 x 20	__________
40 x 20 x 15	__________	52 x 20 x 16	__________
40 x 20 x 10	__________		

13. Is there any test made for the cement that you are using? If any, please specify.

_______________ _______________

_______________ _______________

14. How old is the age of the cement until casting date? (Starting from the time of its production)

____

15. What quality of water do you use for mixing?

- [ ] Drinking water
- [ ] If non-drinking water;
    - [ ] From river
    - [ ] Round water from drilled well

16. Is there any test that was made for the water? If any, please specify

_______________ _______________

17. Which batching techniques do you use?

- [ ] By weight
- [ ] By volume

18. What are the adjustments that you make to ingredients when using;

a) Weight batching: _______________

b) Volume batching: _______________

19. How do you mix your ingredients?

- [ ] Manually
- [ ] Using mixing plant
- [ ] Both of them (both manually and using mixing plant).

21. What is the capacity of your mixing plant?

____

22. For how long do you mix the ingredients?

____

20. What is the corrective measure that you take in case when you aren't able to attain the required slump?

____

____

21. For how long do you vibrate your hollow concrete block?

____

22. After molding your HCB, for how long do you cure it?

____

23. Where do you cure your finished Hollow concrete block?

- ☐ Under the shade
- ☐ Outside the shade

24. For haw long your HCB store on the site after manufacturing?

____

25. Haw many sample of hollow concrete block used for testing?

____

26. What are the tests made for Hollow concrete block please specify?

- ☐ Dimension
- ☐ Density
- ☐ Water absorption
- ☐ Linear shrinkage
- ☐ Compressive strength

Thank you for your cooperation!

ANNEX II

Project number & concrete grade	Compressive Strength MPa	mean compressive strength each lot	Total mean strength of all cubes	Standard deviation	coefficient of variation	compliance of compressive strength to the various standards for each lots		
						Ethiopian standard	**American standard**	**British Standard**
Project 13 C-25	40.576	40.113	42.61	3.23	7.5	Complied	Complied	Complied
	38.932							
	40.83							
	43.392	45.109				Complied	Complied	Complied
	47.978							
	43.956							
Project 15 A C-25	29.107	27.279	27.23	1.73	6.3	Failed	Complied	Complied
	25.669							
	27.062							
Project 15 B C-25	22.739	25.23	25.52	4.84	17.77	Failed	failed	failed
	26.029							
	26.923							
	28.284	27.354				Failed	failed	Complied
	24.728							
	29.050							
	26.041	27.697				Failed	Complied	Complied
	27.261							
	29.788							
	26.3	30.67				Complied	Complied	Complied
	32.6							
	33.1							
	29.185	25.443				Failed	failed	failed
	25.015							
	22.128							
	15.4	17.47				Failed	failed	failed
	18.6							
	18.4							
BOLE ARABSA A C-25	44	42.3	31.48	6.35	20.17	Complied	Complied	Complied
	39.4							
	39.4							
	28.62	29.18				Complied	Complied	Complied

	30.61							
	28.31							
	29.43	27.49				Failed	Complied	Complied
	28.02							
	25.01							
	26.59	28.55				Complied	Complied	Complied
	30.65							
	28.4							
	28.50	28.53				Complied	Complied	Complied
	27.99							
	29.12							
	19	22.67				Failed	failed	failed
	25							
	24							
	37.77	38.02				Complied	Complied	Complied
	35.33							
	40.97							
	35.47	35.39				Complied	Complied	Complied
	35.38							
	35.34							
YEKA AYAT II A C-25	31.87	31.87			21.51	Complied	Complied	Complied
	32.62							
	31.23							
	44	43.34				Complied	Complied	Complied
	43.83							
	42.3							
	47.41	45.31				Complied	Complied	Complied
	44.79							
	43.72							
	15.83	28.78				Complied	failed	Failed
	34.22							
	36.22							
	42.2	40.13				Complied	Complied	Complied
	40							
	38.2							
	23.87	28.37	38.72	8.33		Complied	failed	Complied

	33.08							
	28.15							
	46.89	46.70				Complied	Complied	Complied
	45.49							
	47.72							
	45.84	45.22				Complied	Complied	Complied
	45.82							
	44							
AYAT II B C-25	18.7	18.67	23.05	5.12	22.21	Failed	failed	Failed
	17.5							
	19.8							
	15.5	16.43				Failed	failed	Failed
	17.5							
	16.3							
	30.69	29.99				Complied	Complied	Complied
	29.1							
	30.17							
	17.1	19.73				Failed	failed	Failed
	19.9							
	22.2							
	20.9	23.4				Failed	failed	Failed
	24.8							
	24.5							
	26.39	26.43				Failed	Complied	Failed
	26.41							
	26.5							
	19	19.9				Failed	failed	Failed
	19.8							
	20.9							
	29.86	29.87				Complied	Complied	Complied
	30.72							
	29.03							
AYAT III C-25	34.45	35.37	36.33	7.89	21.72	Complied	Complied	Complied
	35.95							
	37.71							
	28.56	27.66				Failed	Complied	Complied

	26.94							
	27.48							
	46	44.33				Complied	Complied	Complied
	39							
	48							
	49.22	44.94				Complied	Complied	Complied
	43.16							
	42.43							
	29.26	29.33				Complied	Complied	Complied
	29.16							
	29.56							
KOLFE KERANIO SITE C-25	27	27.2	29.34	3.37	11.49	Failed	Complied	Complied
	28.1							
	26.5							
	25.5	28.49				Complied	Complied	Complied
	31.7							
	28.28							
	27.23	27.41				Failed	Complied	Complied
	27.04							
	27.96							
	31.87	32.29				Complied	Complied	Complied
	31.22							
	33.37							
	21.42	24.26				Failed	Failed	Failed
	26.05							
	25.31							
	33.76	34.03				Complied	Complied	Complied
	35.01							
	33.32							
	32.97	30.48				Complied	Complied	Complied
	28.54							
	29.92							
	31.34	30.52				Complied	Complied	Complied
	31.96							
	28.27							
BOLE ARABSA B C-25	38.31	40.59	40.59	2.41	1.93	Complied	Complied	Complied
	40.34							
	43.11							

Tulu dimtu project 11 A	29.74	29.36	33.9	4.55	13.41	Complied	Complied	Complied
	28.93							
	29.42							
	33.00	35.40				Complied	Complied	Complied
	36.64							
	36.55							
	30.63	36.93				Complied	Complied	Complied
	39.44							
	40.72							
Tulu dimtu project 11 B	28.8	30.01	32.36	8.99	27.77	Complied	Complied	Complied
	30.77							
	31.32							
	60.16	49.97				Complied	Complied	Complied
	41.68							
	48.07							
	25.46	27.76				Failed	Complied	Complied
	29.09							
	28.74							
	33.43	31.96				Complied	Complied	Complied
	32.15							
	30.30							
	28.09	27.98				Failed	Complied	Complied
	27.40							
	27.29							
	26.07	26.48				Failed	Complied	Failed
	26.32							
	27.03							
Tulu dimtu project 12 A	34.36	32.44	33.38	7.53	22.56	Complied	Complied	Complied
	27.04							
	35.93							
	25.63	25.22				Failed	Complied	Failed
	25.57							
	24.47							
	37.28	31.18				Complied	Complied	Complied
	26.39							
	29.86							
	40.7	44.68				Complied	Complied	Complied

	47.75							
	45.58							
	29.33	28.46				Complied	Complied	Complied
	27.83							
	28.14							
Tulu dimtu project 12 B	18.1	18.1	29.80	6.18	20.75	Failed	Failed	Failed
	17.2							
	19							
	22.4	22.8				Failed	Failed	Failed
	24							
	22							
	27.72	31.84				Complied	Complied	Complied
	34.21							
	33.60							
	48.93	33.19				Complied	Complied	Complied
	24.51							
	26.13							
	28.2	27.9				Failed	Complied	Complied
	25.4							
	30.1							
	36.35	35.46				Complied	Complied	Complied
	34.44							
	35.61							
	29.09	28.62				Complied	Complied	Complied
	29.44							
	27.34							
	36.62	35.5				Complied	Complied	Complied
	31.62							
	35.22							
	25.82	28.45				Complied	Complied	Complied
	28.73							
	30.80							
	31	31.33				Complied	Complied	Complied
	29.9							
	33.1							
	41.4	36.03				Complied	Complied	Complied
	28.8							
	37.9							

	27.8	28.53				Complied	Complied	Complied
	28.8							
	29							
	28.2	29.63				Complied	Complied	Complied
	30.1							
	30.6							

ANNEX III

Kolfe Keranyo

R.No	Compressive strength Individual blocks (MPa)						Compressive strength Average of 6 blocks (MPa)
1	2.3	2	2.4	2.1	1.8	2.5	2.18
2	2.3	2	2.4	2.1	1.8	2.5	2.18
3	2.4	3.6	3.7	2.6	2.5	2.5	2.88
4	2.5	2.2	2.9	2.7	2.3	2.1	2.45
5	2.5	2.6	2.9	2.43	2.4	2.3	2.52
6	2.4	3.6	3.2	2.9	2.9	1.7	2.78
7	3	2	1.3	2.3	3.3	1.6	2.25
8	1.9	2.4	2.4	2	1.8	2.4	2.15
9	2.3	2.5	1.6	2.7	3.4	2.6	2.52
10	2.1	2.8	2.9	2.9	2.3	2.1	2.52
11	2.3	2.4	2.8	2.8	2.5	2.4	2.53

Project 15 A

R.No	Compressive strength Individual blocks (MPa)						Compressive strength Average of 6 blocks (MPa)
1	1.9	2	1.9	2.3	2	2.3	2.07
2	2.4	1.9	2.5	2.4	2.5	2.9	2.43
3	2.3	2.1	1.9	2.1	1.9	2.1	2.07
4	2.1	2.4	2.4	2.1	2.4	1.8	2.20
5	2	1.8	2.3	2.1	2.2	2.4	2.13
6	2.9	2.1	1.9	2	1.8	1.9	2.10
7	1.9	2.3	1.9	1.9	2	1.9	1.98
8	2.2	1.9	1.9	2	2.2	1.9	2.02
9	2	1.8	1.9	1.8	2.1	2.5	2.02
10	1.9	2.4	2.03	2.2	2.3	2.3	2.19
11	2.2	2	2.3	2	2.13	1.9	2.09
12	2.01	2.35	1.91	2.28	2.1	2.15	2.13
13	1.89	2.5	2.19	1.85	2.31	2.01	2.13
14	1.87	2.35	2.18	1.96	2.15	2.51	2.17
15	2.22	2.01	1.97	2.3	2.2	1.9	2.10
16	2.8	2.7	1.9	2.4	2.6	2.8	2.53
17	2.01	2.13	1.81	1.94	2.15	2.28	2.05
18	2.35	2.21	1.99	2.25	2.78	2.15	2.29
19	1.9	2.16	2.45	2.01	1.93	2.28	2.12
20	2.15	2.21	1.97	1.87	1.99	2.31	2.08
21	2.01	2.34	1.9	2.29	2.01	21.51	5.34
22	2.96	2.34	2.17	2.33	2.01	2.2	2.34

23	2.1	2	2	2.1	2	1.8	2.00
24	2.3	1.9	1.96	2.89	2.76	1.9	2.29

Project 13 A

R.No	Compressive strength Individual blocks (MPa)						Compressive strength Average of 6 blocks (MPa)
1	1.9	2.01	1.94	2.28	2	1.93	2.01
2	1.94	1.79	2.49	1.96	2.1	2.23	2.09
3	2.44	2.28	1.96	2.15	2.31	2.06	2.20
4	2.275	2.13	2.44	2.33	2.07	2.22	2.24
5	3.14	3.044	2.31	2.23	2.64	2.63	2.67
6	2.14	2.48	2.67	2.52	2.25	2.42	2.41
7	2.97	2.6	2.5	2.87	2.401	2.79	2.69

Project 14

R.No	Compressive strength Individual blocks (MPa)						Compressive strength Average of 6 blocks (MPa)
1	1.986	1.92	2.7	1.68	1.99	2.87	2.19
2	1.368	1.25	2.86	2.76	2.44	2.02	2.12
3	2.16	2.07	2.29	2.79	2.45	1.95	2.29
4	1.99	2.47	1.68	2.38	2.1	1.8	2.07
5	1.8	1.95	2.05	2.55	1.92	1.9	2.03
6	1.8	2.35	2.13	2.3	2.83	2.2	2.27

Ayat II

R.No	Compressive strength Individual blocks (MPa)						Compressive strength Average of 6 blocks (MPa)
1	2.1	2.15	2.1	1.82	1.94	2.315	2.07
2	1.901	2.41	2.2	1.922	2.12	2.15	2.12
3	2.2	2.11	1.95	2.23	2.53	2.28	2.22
4	2.301	2.21	2.201	2.13	2.23	1.8	2.15
5	2.32	1.92	1.967	2.422	2.132	1.96	2.12

Ayat III

R.No	Compressive strength Individual blocks (MPa)						Compressive strength Average of 6 blocks (MPa)
1	2.2	2.22	1.967	1.87	1.89	2.68	2.14
2	1.96	2.14	2.01	2.28	2.01	2.16	2.09
3	2.2	1.95	2.23	2.31	2.13	1.99	2.14
4	20.23	1.82	2.17	2.1	1.82	2.13	5.05
5	2.25	1.95	1.96	2.186	2.46	1.94	2.12
6	1.93	1.95	1.89	1.93	2.45	2.24	2.07