JIMMA UNIVERSITY

JIMMA UNIVERSITY INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

(Construction Engineering and Management Stream)

ASSESSMENT OF HOLLOW CONCRETE BLOCKS PRODUCTION IN MICRO AND SMALL SCALE ENTERPRISES: A CASE STUDY IN AKSUM TOWN.

By

SIMRET MEZGEBU

A thesis submitted to the school of graduate studies of Jimma University Institute of Technology, School of Civil and Environmental Engineering in partial fulfillment of the requirement for the degree of Master of Science in Construction Engineering and Management.

OCTOBER, / 2016

JIMMA, ETHIOPIA

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MAIN ADVISOR: -Dr. Ing. Esayas Alemayehu (PhD)

CO- ADVISOR: -Eng. Getachewu Kebede

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DECLARATION

I, the undersigned, declare that this thesis entitled "**Assessment of Hollow Concrete Blocks Production in Micro and Small Scale Enterprises in Aksum**" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for theses have been dually acknowledged.

Candidate:

Mis. Simret Mezgebu wibneh

Signature________________________

As Master research Advisors, we hereby certify that we have read and evaluate this Msc research prepared under our guidance, by Mis. Simret Mezgebu wibneh entitled**: ASSESSMENT OF HOLLOW CONCRETE BLOCKS PRODUCTION IN MICRO AND SMALL SCALE ENTERPRISES IN AKSUM.** We recommend that it can be submitted as fulfilling the MSc Thesis requirements**.**

Dr. Ing. Esayas Alemayehu (PhD)	___________________	____/_____/____
Advisor	Signature	Date
Eng. Getachewu Kebede	____________________	_____/_____/____
Co-Advisor	Signature	Date

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ABSTRACT

The Ethiopian government has given priority to micro and small scale enterprises which have a significant contribution in the infrastructure development of the country. These enterprises include different sectors like manufacturing, service and construction industry etc. This study focuses on the construction industry, production of prefabricated building elements, particularly hollow concrete block products. In order to produce 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.

The laboratory tests on the compressive strength of hollow concrete blocks were conducted on 18 blocks sample with different size from each enterprise. The sampling technique was random sampling method that taken particularly from newly or fresh produced concrete blocks. The ratio was 1:12 and mold sizes were 10x20x40 cm, 15x20x40 cm and 20x20x40 cm. The samples were tested for compressive strength at the ages of 28 days.

The research was carried out by conducting laboratory test on randomly selected 18 blocks samples and collecting primary and secondary data through questionnaires interview and observation. Questionnaires interview and observation were employed to assess the qualities of ingredients and method of production. Compressive test were conducted to evaluate the compression strength of the hollow concrete blocks. The compressive test results of the sampled hollow concrete blocks were evaluated 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 producers, sufficient tests are not conducted for all ingredients used for production of hollow concrete blocks, In addition to this, handling of those ingredients was poor, intermixing of sand and aggregate was observed, and production process was also not conducted properly as specified in the recommended standards.

According to Ethiopian standard (ES 596:2001) the results were not affected in case of material quality but the final outputs of HCB were poor, these because of lack of mixing ratio the result were decreases. All producers attain Class D, and this was based on compressive strength result and its density.

These were an indication that the test results among a significant portion of the investigated projects have shown large variability implying the quality control is unsatisfactory.

Keywords: - Batching, mixing, molding, compacting, placing, transporting and compressive strength.

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ACRONYM

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
Cm	Centimeter
CMU	concrete masonry unite
EBCS	Ethiopian Building Code of Standard
ES	Ethiopian Standard
HCB	Hollow Concrete Block
MSSE	Micro and Small Scale Enterprises
Mm	Millimeter
MSc.	Master of Science
IS	Indian Standard
Kg	Kilo Gram
NO.	Number
PPC	Portland Pozzolana Cement
U.K.	United Kingdom

CHAPTER ONE

1. INTRODUCTION

1.1 Background

There are quite many types of wall making materials in use today ever since the earliest history of man who has been building various types of masonry structures that includes stone, mud brick and clay brick, and concrete blocks. Concrete blocks are one of the most widely used wall making materials that have become very popular in the modern times with the development of hydraulic cements after the English stonemason Joseph Aspidin developed Portland cement in 1824, and with advancement of the various concrete block making machines. like foundations, piers, columns and other structural members, and also non-load-bearing walls, for fire protection of steel, for sidewalks etc. (William, 2006).

Concrete blocks are manufactured in a wide range of standard sizes and custom designed architectural units. Concrete blocks could be of solid units or hollow units. Hollow concrete block, which is the Concrete blocks are those blocks that are made of cement, aggregates, water, and in some cases admixtures and pigments for use in structural and non-structural applications focus of this research, refers to concrete block which is hollow in the middle. It can be used for wall partitioning or as load bearing unit. These units can be manufactured having various sizes, shapes, texture and color. They can be light weight, medium weight or normal weight depending on the raw materials used. The weight of the blocks depends on whether the aggregates used are normal weight like sand and gravel, or light weight that include pumice, scoria, expanded shale, clay and slate, air cooled slag, limestone etc. They can be produced having various strength levels.

The quality of hollow concrete blocks depends on the type of materials selected, their proportion and the process of manufacturing (William, 2006). The production process starts from the selection of materials. The materials, aggregates and cement, are selected based on the type of block we want to produce, its availability, and cost. Then the process of proportioning, mixing, molding, and curing comes. There exist various technologies and methods to undertake these all processes. The handling process during storage and dispatch is also one criterion that affects the quality of the hollow concrete blocks. Therefore in order to produce good quality hollow concrete blocks, one has to have a clear understanding of the right way of doing all these parts of the process.

Hollow concrete blocks are one of the wall making materials used in the urban parts of Ethiopia. It is dominantly used in the low cost housing projects of the government, in the real estate development, in private residential and commercial buildings, in the construction of schools and health centers etc. there is some micro and small scale as well as large scale production centers in Aksum and in the whole town.

In the construction process, the amount of wasted materials for formwork can be reduced as well the time for building and dismantling formwork. Re-usage of metal formwork, which can be adapted to every kind of house, helps to economize on the construction costs. A concrete block is primarily used as a building material in the construction of walls. It is sometimes called a concrete masonry unit (CMU). A concrete block is one of the several precast concrete products used in construction industry. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. Most concrete blocks have one or more hollow cavities, and their sides may be cast smooth or with a design.

By introducing a modular architectural system the number of different building parts is reduced, leading to a further reduction of different types of formwork. Moreover the usage of local materials, whenever cost efficient, has a positive effect on the environment, because of less pollution through reduced transport (Schierhom, 1996).

1.2. Statement of the problem

Micro and small scale industry sector occupies a place of strategic importance in any economic structure. Micro and small scale industries play a key role in the industrialization and development of a country. This is because, they provide immediate large scale employment, compared to higher capital intensive industry they need lower investment, offer a method of ensuring a more equitable distribution of national income and facilitate an effective mobilization of resources, capital and skill. Even though this was good, to create job opportunity on the other hand, the quality of prefabricated elements especially in the constriction focus areas (Hollow Concrete block) was very **controversial** in the construction industry of the country.

It is generally known that quality control is the most significant step in producing good quality of products. In case of HCB productions there are two distinct but equally important activities, one is related to material type and quality 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 factors.

a. If care is not taken for materials on their quality and handling mechanism, poor quality of products are 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, it can result in less strength. As a result, poor quality blocks will be occurring (Richardson, 2005).
- Manifestation of soft particles in sand and aggregate may weaken the bond

b. If care is 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 (Tesfaalem, 2014).

- Under or over vibration.
- Insufficient curing.
- Improperly store raw materials.

To this end, the Ethiopian government has given priority to micro and small-scale industries which have important contribution to the development of the country.

1.3. Research questions

- What are the major factors that influence of HCB production?
- What is the quality of HCB produced by micro and small scale enterprise?
- Is there any cost comparison between standard and micro and small scale enterprise in the production of HCB?

1.4. Objectives

1.4.1. General objective

The general objective of this study is basically to assess the production quality of Hollow Concrete Block in micro and small scale enterprise in Aksum.

1.4.2. Specific objectives

- ❖ To identify the major factors that influence hollow concrete block production in Aksum.
- ❖ To examine the quality of hollow concrete block production in micro and small scale enterprises in Aksum.
- ❖ To make comparative analysis of cost in HCB production by micro and small scale enterprise in Aksum.

1.5. Significance of the study

This research was mainly important to the experts involved in the construction of private and public buildings using such blocks and to these who have a concern about the quality of hollow concrete blocks. Considering the increase of construction industry in the country and the importance of the concrete blocks, it is paramount to work or research on improving the quality of hollow concrete blocks. Unfortunately there is no as such well-studied, comprehensive guideline as to how manufacturers could make material selection, proportion them and also the overall process of manufacturing. The use of guideline as to how to proportion materials to produce the intended quality of hollow concrete blocks, the output of the research will have a significant importance in that. It will serve as a starting point for producers to prepare selection, proportion them and also the overall process of manufacturing of hollow concrete blocks of varying qualities using normal weight aggregates only.

1.6. Scope and Limitation of the study

The research reports the objectives and attempts to investigate the quality control on production of hollow concrete block in building projects administered by Aksum Housing Project based on the existing theories and principles. Investigation was undertaken on randomly selected sites located in Aksum. The sites in which the research was conducted are named as Project 1, Project 2, Project 3, Project 4 and Project 5. Those enterprises currently produce allot of blocks in different sizes and provide to customers, private and public enterprises and they are owned by Aksum MSSE Agency.

Due to lack of willingness by producer, the research hasn't been done in all enterprise. Therefore the effectiveness of quality control was assessed only for specific enterprises listed above.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Background

Hollow concrete block refers to concrete block which is hollow in the middle. It can be used for wall partitioning or as load bearing unit. Hollow concrete masonry blocks can be manufactured manually or with a mechanized machine. They can have various sizes, shapes, texture and color. They can be light weight, medium weight or normal weight depending on the raw materials used. They can be produced having various strength levels (William, 2006).

Concrete blocks are believed to have been used thousands of years back in the Roman Empire during the reign of the Roman emperor Caligula, in 37-41 A.D., small blocks of precast concrete were used as a construction material in the region around present-day Naples, Italy. Much of the concrete technology developed by the Romans was lost after the fall of the Roman Empire in the fifth century. It was not until 1824 that the English stonemason Joseph Aspdin developed Portland cement, which became one of the key components of modern concrete. The development of concrete blocks began in the United States, where large heavy solid blocks were made of a molded mixture of quicklime and moist sand cured by steam. This soon spread to the UK (Yeaple, 1991).

The first hollow concrete block was designed in 1890 by Harmon S. Palmer in the United States. After 10 years of experimenting, Palmer patented the design in 1900. Palmer's blocks were 8 in (20.3 cm) by 10 in (25.4 cm) by 30 in (76.2 cm), and they were so heavy they had to be lifted into place with a small crane. By 1905, an estimated 1,500 companies were manufacturing concrete blocks in the United States. These early blocks were usually cast by hand, and the average output was about 10 blocks per person per hour. Today, concrete block manufacturing is a highly automated process and can be produced in thousands per hour (BMTPC).

Hollow concrete blocks are substitutes for conventional bricks and stones in building construction. They are lighter than bricks, easier to place and also confer economics in foundation cost and consumption of cement. In comparison to conventional bricks, they offer the advantages of uniform quality, faster speed of construction, lower labor involvement and longer durability. In view of these advantages, hollow concrete blocks are being increasingly used in construction activities (John, 1992).

Currently, concrete blocks are the most commonly used construction materials in Ethiopia. Some of the producers of hollow concrete block in Aksum use the similar types of ingredients. The common types of ingredients are sand, cement, gravel, pumice, scoria (red ash) and water. The quality of ingredients will determine the quality of the produced blocks.

Hollow concrete blocks are used in Aksum with standard dimensions of (10x20x40) cm, (15x20x40) cm, and (20x20x40) cm. the blocks with smaller sizes are used for internal walls whereas larger sizes are used for external walls. There is no common standard mix proportion in the country for the production of hollow concrete blocks in Ethiopia. Due to immense variations in the properties of raw materials and non-scientific methods of hollow and solid concrete block productions (Ethiopian standard, 2001).

2.2. Types of Hollow Concrete Blocks

Hollow concrete blocks used for wall construction classified as load bearing and non-load bearing depends on their structural function. Concrete blocks can be manufactured in a wide variety of types, many designed for a special use. They are produced in main groups namely: various countries in the world have developed their own specifications and standards for the type and performance of hollow concrete blocks. To understand and compare the concrete block technology of Ethiopia with respect to the world practice, the specifications of concrete blocks in India have been provided below.

2.2.1. The Indian Specification

The Indian Standard Specification for Concrete Masonry Units, IS 2185 (Part I)-1979 R 2003, classifies hollow concrete blocks in to four grades namely Grade A, Grade B, Grade C and Grade D. Each is then further classified in to sub groups based on the 28 days compressive strength values (IS 2185 (Part I) – 1979 (Reaffirmed 2003)).

Grade A. These are used as load bearing units. They have a minimum block density of 1500kg/m^3. The minimum 28 days compressive strength values for all the sub groups are 3.5MPa, 4.5MPa, 5.5MPa and 7MPa.

Grade B. These also are used as load bearing units but with block density between 1000kg/m^3 and 1500kg/m^3. The minimum 28 days compressive strength values for all the sub groups are 2MPa, 3MPa and 5MPa.

Grade C. These are used as non-load bearing units but with block density between 1000kg/m^3 and 1500kg/m^3.The minimum 28 days average compressive strength value for this particular grade type hollow concrete block 1.5MPa.

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.

Table 2.1 the nominal dimensions for concrete block [IS: 2185-1979]

Length(l)	Height	width (mm)	Face shall thickness (mm)	Web Min (mm)
400	200 or 100	Less than 100 mm	25	25
500	200 or 100	100 to 150	25	25
600	200 or 100	150 to 200	30	25

In addition, blocks are manufactured in half lengths of 200, 250 or 300mm to correspond the full lengths. Other block sizes can also be manufactured as per the mutual agreement between the supplier and purchaser.

2.2.2. The Ethiopian Standards

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 2.3. In the Ethiopian Standards the specification for hollow concrete blocks and beam tiles is given in ES.C.D3.301. This standard classifies the hollow concrete blocks in to four groups namely classes A, B, C, and D (Dinku, 2002).

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.

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.

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.

Ethiopian standard specify maximum dimensional variation (length, height, breadth, Face shell, Web), it should be + 5mm for nominal dimensions of concrete masonry blocks these are listed below.

Table 2.2 Nominal dimensions of hollow concrete blocks [ES 596:2001]

Length(l)	Height(h)	Breadth(b)	Face shell(d)	Web€
400	200	100	20	20
400	200	150	25	25
400	200	200	30	25

Note: 40 mm length is preferred modular size

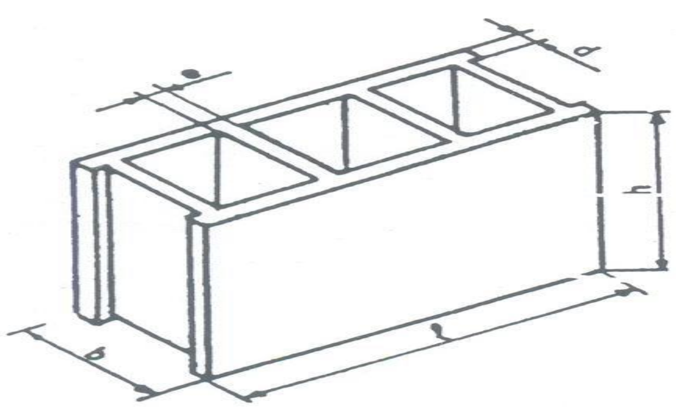

Figure 2.1: - Hollow concrete block form

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 listed below.

Table2.3. 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

2.3. Hollow Concrete Block Making Materials

2.3.1. Cement

Cement is the key component of concrete in general and hollow concrete blocks in particular. Cement mixed with water forms a paste that binds the aggregates in to a rock like mass as the past hardens because of hydration (Steven H., 2003). These days there are various cement types widely used throughout the world. The present day cement has passed through various developments through time. Portland cement is essentially calcium silicate cement, which is produced by firing to partial fusion, a well-homogenized and finely ground mixture of limestone or chalk (calcium carbonate) and an appropriate quantity of clay or shale (ASTM C 140–70).

2.3.2. Aggregates

Aggregates are the filler materials held together by cement past. It constitutes 70 to 80% of the volume of a normal concrete. The commonly used aggregates are natural sand, gravel and crushed rock, but recycled crushed concrete and manufactured materials such as furnace slags and expanded clay, shale or slate pellets are also used to a more limited extent. To get the satisfactory performance of concrete, the aggregate as a material must be strong, durable and inert and the sizes of the constituent particles must be appropriate for the intended application. Aggregates are classified based on whether they are normal weight, heavy weight, or light

Weight. They are also classified based on their size and gradation, or based on their source rock (ASTM C 140–70).

2.3.2.1. Aggregate Classification

Classification of aggregates beyond the broad categories of crushed rock, sand and gravel must be appropriate to its use in the construction industry and have both a scientific and a commercial viability (ASTM C 140–70).

Aggregates are classified in to size groups based on the results of sieve analysis namely;

- Coarse aggregate, with size greater than 4.75mm, and
- Fine aggregate, with size less than 4.75mm.

2.3.2.2. Natural and Manufactured Aggregates

Aggregate can be classified based on whether it is natural or manufactured as described below;

2.3.2.2.1 Natural sands and gravels: - are those obtained or formed in riverbeds or sea beds and usually dug from a pit, river, lake, or seabed; sands are fine aggregates; gravels are coarser particles. Weathering and erosion of rocks produce particles of stone, gravel, sand, silt, and clay. Gravel (including sand) is natural material that has broken off from bedrock and has been transported by water or ice. During transport, gravel is rubbed smooth and graded to various sizes. Gravel and sand are often a mixture of several minerals or rocks. The quality (or soundness) of sand and gravel depends on the bedrock from which the particles were derived and the mechanism by which they were transported. Sand and gravel derived from sound rocks, like many igneous and metamorphic rocks.

2.3.2.2.2. Manufactured aggregate: - is often used where natural gravels and sands are either not available in sufficient quantities or are of unsuitable quality. It is produced by crushing sound parent rock at stone crushing plants. Manufactured aggregates differ from gravel and sand in their grading, shape, and texture. Because of the crushing operation, they have a rough surface texture, are very angular in nature,

2.3.3. Water

The very principle that makes cement a binding agent is its ability to form a past under water that hardens with time. This is because of the chemical reaction of water with cement called hydration.

Thus the water quality has a greater effect on the hydration process and of course the quality of the paste. In general, suitable mixing water for making concrete includes Potable water, Non potable water, and Recycled water from concrete production operations.

Both Non potable water and recycled water must be tested to ensure they do not contain impurities that negatively affect concrete strength, set time, or other properties.

2.3.4. **Admixtures and Pigments**

Various types of admixtures and coloring pigments are added to the mix so as to produce variety of hollow concrete blocks with different types of architectural requirements.

2.4. Manufacturing Process of hollow concrete blocks

The manufacturing of hollow concrete blocks starts with the selection of the appropriate type of raw materials. The raw materials used are cement, aggregates, water, and some other additives and coloring agents when necessary. The aggregates could be of light weight, medium weight or normal weight. The mix and proportion of materials could vary depending on the required performance of the product. The quality of blocks generally depends on the raw materials used, manufacturing process and handling of the product. The sequence of the manufacturing process of hollow concrete masonry blocks can be summarized in the following main stages.

2.4.1. Raw Materials Selection Process

The first step in the manufacturing of hollow concrete blocks is the selection and preparation of raw materials. The basic raw materials that need to be stocked in bulk before manufacturing starts are aggregates, cement, water in addition sometimes additives and coloring pigments when necessary. The aggregates could be of light weight, normal weight, or a combination of both light and normal weight. The choice mainly depends on whether we want light weight, medium weight, or normal weight blocks.

Normal weight aggregates mainly include natural or manufactured sand and natural gravel or crushed aggregate with the maximum size being 10mm (William, 2006). Light weight aggregates, however, include a wide variety of materials like fired-expanded shale, fire-expanded-clay, natural lightweight material such as pumice, tuff and volcanic scoria, some natural slates, expanded blast furnace slag, sintered fly ash, some ground and screened sulfur-free coal cinders. In the case of Ethiopia, it is clearly seen that the aggregates used are natural sand, crushed aggregates, scoria and pumice.

The bonding or cementing ingredients normally used are various types of cements, fly-ash and other pozolanic materials that have cement-like properties. Sometimes more expensive "high strength or early-strength" cements are used to reduce overall costs or to provide a faster product delivery to the end-user/customer. Fly-ash and some pozolanic materials are cheaper than cement and are also used to improve the properties of the concrete mix when wet (Firesenay, 2011). In the case of Ethiopia, only Portland Pozolana Cement, and Ordinary Portland Cement are available.

Generally speaking, the choice of raw materials is done based on the performance requirements of the product, the availability and cost of raw materials.

2.4.2. Proportioning

The determination of suitable amounts of raw materials needed to produce concrete of desired quality under given conditions of mixing, placing and curing is known as proportioning. As per Indian Standard specifications, the combined aggregate content in the concrete mix used for making hollow blocks should not be more than 6 parts to 1 part by volume of Portland cement. If this ratio is taken in terms of weight basis this may average approximately at 1:7 (cement: aggregate). However, there have been instances of employing a lean mix of as high as 1:9 by manufacturers where hollow blocks are compacted by power operated vibrating machines.

The water cement ratio of 0.62 by weight basis can be used for hollow concrete blocks. Water content is critical. The mixture must be wet enough to bind together when compacted, but it should not be so wet that the blocks slump (sag) when the mold is removed. A common mistake is the use of mixes that are too dry, resulting in incomplete compaction. The moisture content should be as high as possible as this allows better compaction and thus gives the best strength. Moisture content is approximately right when ripple marks form on a steel rod or the back of a shovel when it is rubbed against some of the mixture. The water content is just over optimum when ripple marks start appearing on blocks when they are remolded (Indian standard 1983).

2.4.3. Mixing

The objective of thorough mixing of aggregates, cement and water is to ensure that the cement-water paste completely covers the surface of the aggregates. All the raw materials including water are collected in a concrete mixer, which is rotated for about 1 ½ minutes. The prepared mix is discharged from the mixer and consumed within 30 minutes.

For machine mixing, first mix aggregate and cement then add water gradually while mixing until water content is correct.

For Hand mixing with the use of shovels should be done on a level concrete slab or steel plate. First spread the sand out 50 to 100 mm thick. Then distribute the cement, and stone if any, evenly over the sand. Mix aggregate and cement until the color is uniform. Spread the mixture out, sprinkle water over the surface and mix. Continue with this process until the right amount of water has been mixed in (Firesenay, 2011).

2.4.4. Molding

Once the materials are mixed and blended, the next step is to put the mix in to the mould in the block making machine. In manual production, the mix after it is discharged from the mixer is carried and fed in to the moulds. In automatic plants, however, the mix is directly discharged in to the moulds. There exist various types of block making/molding machines. These could be manual or automatic, stationary or mobile. Some produce one block at a time, others many blocks at a time. The output varies from a few blocks an hour up to thousands of blocks an hour. The form/mold determines the size, shape, or type of product being made. The concrete is compacted by a combination of hydraulic and mechanical (weight) pressure and controlled vibration. The equipment vibrates the forms/molds in many different ways to maximize compaction, product homogeneity/uniformity and strength. Depending on the size and type of machine, there are machines that can produce more than 5,000 products per hour; and, in such cases, the form/mold is filled with fresh semi-dry concrete, vibrocompacted and the newly made high quality concrete masonry product can be de-molded from 4 to 9.5 times per minute (MPA, 2013).

2.4.5. Compacting

The purpose of compacting is to fill all air pockets with concrete as a whole without movement of free water through the concrete. Excessive compaction would result in formation of water pockets or layers with higher water content and poor quality of the product.

Compacted, formed/molded products are extracted out of the form/mold onto a steel pallet (a hard-wood pallet is used for very small manual machines) and transported to a curing area using forklifts, or other mechanized systems in case of big plants, but in case of small scale manufacturing, labors lift the pallets one by one and then put them in a shade for curing. In case of mobile machines (egg-layer machines), the blocks are laid down on a smooth surface and left there to cure. At this point, the concrete products are referred to as "green" or uncured. Different mechanisms of curing are then used to cure these blocks.

Remolding or removal of the mould should be done carefully so that the fresh blocks are not damaged. Fresh blocks should be protected from rain (with plastic sheets or any suitable covering) and from the drying effects of the sun and wind until curing starts (Ethiopian, 2006).

2.4.6. Curing

Curing is the process of maintaining satisfactory moisture content and a favorable temperature in the blocks to ensure hydration of the cement and development of optimum strength.

Hollow blocks removed from the mould are protected until they are sufficiently hardened to permit handling without damage. This may take about 24 hours in a shelter away from sun and winds.

The hollow blocks thus hardened are cured in a curing yard to permit complete miniaturization for at least 21 days. When the hollow blocks are cured by immersing them in a water tank, water should be changed at least every four days.

The greatest strength benefits occur during the first three days and valuable effects are secured up to 10 or 14 days. The longer the curing time permitted the better the product (Hornbostel, 1991).

2.4.7. Drying

Concrete shrinks slightly with loss of moisture. It is therefore essential that after curing is over, the blocks should be allowed to dry out gradually in shade so that the initial drying shrinkage of the blocks is completed before they are used in the construction work. Hollow blocks are stacked with their cavities horizontal to facilitate thorough passage of air. Generally a period of 7 to 15 days of drying will bring the blocks to the desired degree of dryness to complete their initial shrinkage. After this the blocks are ready for use in construction work (Hornbostel, 1991).

2.4.8. Storage and Dispatch

Cured concrete masonry products are removed from the kilns by handling equipment or semi manually and are moved to a processing area where optional operations may or may not occur depending on the needs of the producers and the requirements of the market, Various equipment's are available for a great variety of these procedures (Splitters, turnovers, delivery stations, etc.) and manipulations of the end product prior to delivery to the cubing and packaging equipment stations. The masonry units are then normally "cubed" and are made ready for loading on to trucks using one by one by hand or forklifts, cranes (CMAA, 2000).

2.5. Physical requirements

The physical properties of concrete masonry 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 10mm [ES596:2001] or [IS: 2185-1979], this shall not be deemed grounds for rejection (Tesfaalem, 2014).

2.5.1. 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 2.4 below. The blocks shall then be weighed in kilograms (to the nearest 10 g) and the density of each block calculated as follows:

$$Density = \frac{Mass of block}{Volume of specimen}$$

Table 2.4 Density classification of concrete masonry units [ES 596:2001] and [IS: 2185-1979]

Class of Hollow concrete block	Ethiopian standard ES 596:2001 (kg/m3)	Indian standard IS: 2185-1979 (kg/m3)
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.

2.5.2. 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 (Ethiopian standard (ES 596:2001)).

2.5.3. Weight

The weight of hollow concrete masonry blocks varies with the design of the hollow concrete block and the mix used to make it. It is necessary to know weights so it is better to help density of the HCB.

2.5.4. Modular Sizes

Hollow concrete masonry blocks are produced in different types of modular or nominal sizes. The modular or nominal size is the theoretical size without allowance for a mortar joint. The actual size is 10mm mortar joint less than the nominal size, so the actual unit plus a 10mm mortar joint gives the modular size. The true metric modular concrete blocks modular size is 200 x 200 x 400mm. Actual modular size is 190 x 190 x 390 mm.

Hollow concrete masonry blocks can be produced in wide variety of dimensions, textures, colors and profiles as the basis of wall design. In the civilized world, Innovations in the manufacturing process have added greatly to the palette of possible colors with the introduction of multi-blend as distinct from one-color units (William, 2006).

2.5.5. Texture

Hollow concrete masonry blocks are manufactured in such a way that they can give various textures. They can be plain face units or they can be split face units. Split face units are popularly used as facing units in masonry construction. The size and color of the coarse aggregate particles in the concrete mix have a marked effect on the appearance of the finished face. Where the color of the coarse aggregate contrasts with that of the matrix the aggregate particles will be seen quite clearly in the finished face. Split face units come in the full range of sizes and in various colors (William, 2006).

2.5.6. Profiles

Concrete masonry can be made to have a strongly profiled surface effect. Split-fluted block is a type of popular block in many parts of the world. The forms of fluting which can be incorporated are almost limitless, from the provision of minor grooves in the face to the use of substantial protruding ribs. A wide variety of profiles has been used, the main variations being the width of the split rib relative to the smooth-faced channel.

2.5.7. Color

All masonry units can be produced in a rich variety of colors. The prime determinants of color are the color of the cement, the color of the aggregates, the curing system. These can be varied to produce a limited range of subdued colors. A much bigger range, including strong colors, can be obtained by the introduction of metallic oxide pigments.

2.5.8. Other properties

Other properties that are a result of those just discussed include insulation value, coefficient of heat transmission, sound-absorbing properties, and fire resistance (William, 2006). The insulation value of units made with porous, light weight aggregate is better than those using denser material. The units with lightweight aggregate also have a lower coefficient of heat transmission. Concrete masonry walls are poor insulators and good heat transmitters.

Concrete masonry units resist the transmission of sound. Hollow block made with lightweight aggregate is recommended. The addition of a plaster interior or exterior finish increases this property. Concrete masonry units that have an open, porous surface absorb sound better than denser units with smooth surfaces. Painting the surface fills these pores and reduces sound absorbing properties. Fire resistance is the measure of hours a concrete masonry unit can be exposed to a fire before it fails. The fire resistance rating varies depending on the aggregate. Plaster on the concrete unit is an effective way of increasing its fire resistance (William, 2006).

2.6. Typical Masonry Units

In many countries of the world, there are various types of hollow concrete blocks used for different types of performance requirements. Various hollow concrete blocks are produced to satisfy structural requirements. If we take the case of Ethiopian as an example, to suit a particular purpose, specific units such as Full HCB ,Half HCB, U-shaped HCB, column HCB, lintel and ring beams made out of U-shaped HCBs, Slab HCB and methods of hollow concrete blocks production of in Ethiopian (Ethiopian Ministry of Federal affairs (2006)).

2.6.1 Full HCB

The full hollow block has a size of L=32cmxW=16cmXH=19cm. this size of the HCB is reduced in comparison to the usual sizes used in Ethiopian. The new size of the hollow block reduces the production material and makes the HCB easier to handle, this reduces labor and material costs.

During the wall construction the hollow block is placed up with the closed bottom facing upwards. Therefore the loss of mortar during construction is reduced and the bond between HCBs is increased.

One mason can build 170Pcs of HCB per day on an average, after wall construction, it has to be watered for at least 7 days.

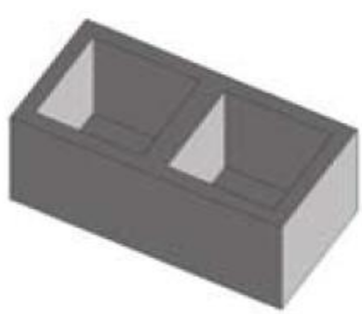

Figure 2.2: - full hollow concrete block

2.6.2. Half HCB

The half hollow block has a size of L=16cmXW=16cmXH=19cm and represents exactly half of one full HCB, usage is similar to the full HCB.

Figure 2.3: - half hollow concrete block

2.6.3. Column HCB

The half hollow block has a size of L=32cm x W=16cm x H=19cm. it is used as a formwork for columns and at the same time as a part of the wall.

After constructing the column out of column HCBs one side of the HCB at the bottom of the column has to be opened to remove the mortar that has fallen down during walling up. This has to be done to ensure a reliable connection between the cast in concrete and the slab foundation. After walling up, the column is cast with concrete.

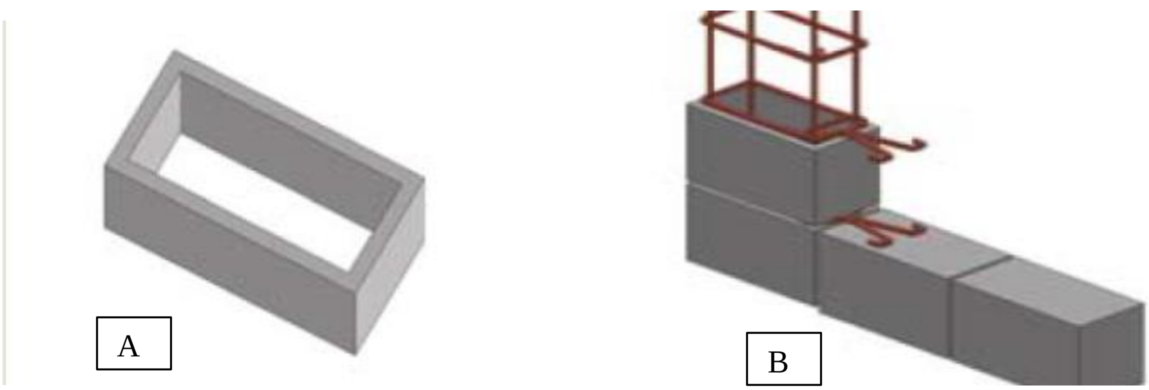

Figure 2.4: - A) Columns Block and B) Connection in between column and wall

2.6.4. U-shaped HCB

The U-shaped HCB has the same size as the full HCB; L=32cmxW=16cmxH=19cm. it is used as a form work for ring beams &lintels and at the same time as a part of the wall.

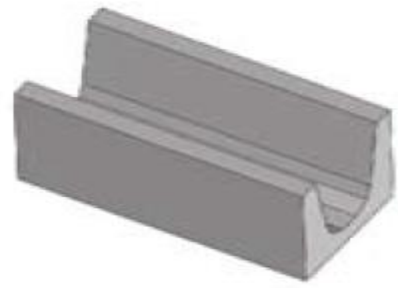

Figure 2.5: -U-shaped blocks

2.6.5. Lintels and Ring beams Made Out Of U-Shaped HCBs

After the wall is properly erected the U- shaped HCBs are placed in at the height of the ring beam; the reinforcement bars and the concrete will be the structural design.

Lintels will be prefabricated on a flat ground area in the same way as the ring beams. This technique avoids extra material for formwork. The use of wooden formwork has negative effects on the environment. Moreover it requires skilled manpower and time to mantle and dismantle the form work.

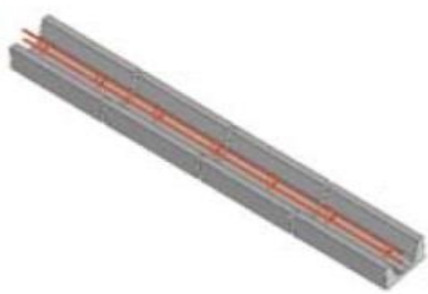

Figure 2.6: -U-shaped blocks joined together as a lintel with the reinforcement

2.6.6. Slab HCB

This slab construction system, introduced by the Low-cost housing project, avoids form work, reduces requirements' of skilled manpower and time. The system has two major components: the pre-cast beam and the slab HCB.

The production of the slab HCB is done in the same way as production of wall HCB.

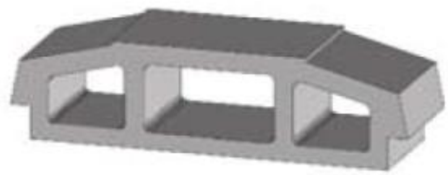

Figure 2.7: - Slab blocks

2.7. Hollow Concrete Blocks Production

The machines used to produce HCBs are electrical vibrating machines which have 1.5 HP motor to make sure, that the vibration is strong enough to compact the concrete sufficiently in the moulds and to achieve the required strength. Before starting production the different materials used to produce the HCB will be dry-mixed thoroughly on a clean and dry ground by hand. Then the mixture will be put in the mixer with appropriate amount of water required (water to cement ratio of 0.49-0.55). The mixture is inserted into the mould and vibrated for about 60 seconds before extruded as HCBs.

Except for the slab-HCB, the machines can produce three pieces at a time. The HCB is transported by two people on a wooden pallet. The HCB remains on the wooden pallet for 24 hrs. Then it is to be cured covered by a plastic sheet to enhance the curing process and preventing the water from evaporation.

Curing-time is at least 10days before using the HCBs for construction. It is important to write the date of production on the HCB so that the mason can easily identify the HCBs, ready for construction. The material required for the production of HCBs and their mixing ratio differs from site to site depending on the availability of the building materials and the ratio that fulfills the required strength. This holds true for all types of HCBs production. The overall production is 1200 HCBs per day machine.

CHAPTER THREE

3. METHODOLOGY

3.1. Introduction

The experimental design method was employed to accomplish this study. The overall flow of the study is outlined below:-

3.2. Study area

Aksum is ancient city and located in Northern part of Ethiopia in Tigray National Regional State, Tigray Central Zone at a distance of 1004 km from Addis Ababa and 248 km from Mekele the regional capital. Its geographical coordinates are 14° 7' 47" North, 38° 42' 57" East.

Figure 3.8 Map of Aksum Town (Google Map, 2016)

3.3. Study design

The research was designed in a way that can be conducted using laboratory based compressive strength test, collection of primary data and field observation. The design or procedures followed in this research were briefly discussed here

Stage – 1 Selection of enterprise that produce HCB

To assess the performance of these producers, five enterprises were selected. Several producers have been visited and some of them were not willing to tell and to help or give information about the enterprise and the number of the enterprises was mainly limited because of this reason.

Stage –2 Checking availability of material or all ingredients used for HCB production.

- Aggregates: - were used crashed aggregates from around Dura, Adikarni and Derqa
- Sand: - The enterprises were usingNatural sand from Medebay welela and chila
- Water: - some of the producers/enterprises were usingdrinking or potable water and also some of them were using from river and groundwater (from drilled well).
- Cement: - was used PPC Messebo type II.

Stage –3 Selection of machine

During the enterprise visit to these producers all producers' use a machine that can produce one block at a time and they are stationary machines. Mixing is done by hand.

Stage – 4 checking the mix proportioning

They were using the same mixing ratio and changing the mould size 10 cm x 20 cm x 40 cm, 15 cm x 20 cm x 40 cm and 20 cm x 20 cm x 40 cm.

Stage – 5 cost comparisons in the production of HCB.

The costs between standards mix ratio and enterprise mix ratio in HCB production.

Stage – 6 Compressive strength tests

Compressive strength test of hollow concrete blocks were conducted at Aksum University by taking samples from selected enterprises. These samples of blocks were selected randomly from the produced stoke of concrete blocks, for compressive strength test independently.

3.4. Population

The sample frame or target populations of this research were the HCB.

3.5. Study variables

3.5.1. Dependent variables

The dependent variable was the production of HCB.

3.5.2. Independent variables

The independent variables were

- Material:-crashed aggregates around Dura, Adikarni and Derqa and Natural sand from Medebay welela and chila
- Equipment: - they used stationary machines and tools.
- Time:-These samples were prepared by making variations in the size for 28 days.
- Cost: - comparison with standards and enterprise mix ratio.

3.6. Data collection process

Primary Data

Designing questionnaire and distribute it to working on the enterprise. The questions are contents which mainly focus on the quality control during production of hollow concrete block from micro and small scale enterprise sites in Aksum.

Secondary Data

Thorough review of literatures related to the research from different sources like: text books, research papers, journals, magazine, internet, etc.

3.7. Sources of Data

The study was used both field site investigation and laboratory tests for the assessment of hollow concrete production in micro and small scale enterprise (MSSE).

3.8. Data analysis

All data were collected, organized and relevant answers were adopted in order to ensure a meaningful presentation and also analysis were done based on the information gathered through questionnaire, site observations and compressive strength test results. Analysis and discussion were done by using Excel tables, bars, charts and graphs, Based on the findings conclusions are drawn and recommendations are forwarded.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Concrete Block Production in Aksum

To investigate effectiveness of quality control for production of hollow concrete blocks in the enterprise. Some questionnaires were collected for hollow concrete block production. In addition to this, compressive test results of hollow concrete blocks were obtained from laboratory test result.

The information gathered through questionnaire, interview, site observations and compressive strength test results are briefly discussed here, and there are many hollow concrete block producers in Aksum. To assess the performance of these producers the following selected producers have been visited;

A. Project 1 hollow concrete block production enterprise (MSSE)
B. Project 2 hollow blocks production company (MSSE)
C. Project 3 hollow concrete block production (MSSE)
D. Project 4 hollow concrete blocks production (MSSE)
E. Project 5 hollow concrete blocks production (MSSE)

During the enterprise visit to these producers was able to assess their overall manufacturing process starting from the raw materials used up to the storage and dispatch of the products.

Based on this, these all producers use a machine that can produce one block at a time and it is stationary as shown on the figure 4.1

Figure:-4.1Stationary machine

Such machines are mostly owned by the micro and small scale enterprises like the ones around Project 1 hollow blocks production (MSSE), Project 2 concrete block production enterprise (MSSE), Project 3 Block Production (MSSE), Project 4 blocks production company (MSSE) and Project 5 hollow blocks production (MSSE). These machines can produce 100 - 120 blocks in an hour by the same mixing ratio and changing the mould size 10 cm x 20 cm x 40 cm, 15 cm x 20 cm x 40 cm and 20 cm x 20 cm x 40 cm but Project 3 block production (MSSE), Project 2 blocks production company and Project 5 hollow blocks production were used stationary machine.

During interview, they used mobile machines if the customer's need a lot of blocks. They rent some mobile machines that can mold four up to seven blocks at a time by the same mixing ratio and changing the mold size. 10 cm x 20 cm x 40 cm, 15 cm x 20 cm x 40 cm and 20 cm x 20 cm x 40 cm. These machines need smooth surface to move on and lay the blocks. Such machines can produce up to an average of 250 - 350 blocks of size 20 cm x 20 cm x 40 cm per hour but this mobile machines on this enterprise is rental from another town and not available in Aksum.

The raw materials used in all the enterprises visited are aggregate, cement and water. The mix proportion used is the same mixing ratio and not clear as most producers are not willing to tell and to help or give information about the enterprise and to help anybody about their mix proportions. To my understanding, the mix proportion they use is fixed. It does not vary with the material type. This is, however, a wrong practice as the quality of blocks depends on the type of raw materials used and Mixing is done by hand.

Almost all the producers use water for curing. That is, they sprinkle water two times a day as the concrete blocks should be produced and cured under shade. However, all other producers do not fully produce and cure the blocks under shade. The curing practice is, in my opinion, poor.

The practices of quality control related to production of hollow concrete blocks are evaluated against the recommended scientific practices. 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 as Annex A.

4.2. MAJOR FACTORS THAT INFLUENCE OF HCB PRODUCTION IN AKSUM

On the observation, 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 study their storage is not safe for cements from moisture and their height of stocks not good.

They stored cement near to the place used for concrete mixes and stacked against outside walls but cement bags should be placed on raised wooden platforms (pallets) above the ground as shown on the figure 4.2

Figure 4.2 Storage of cement near concrete mixing area

They done mixing was over a long period, excessive time mixing causes 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. And they used excessive compaction in this result in formation of water pockets or layers with higher water content and poor quality of the product.

As seen on the site during observation, coarse aggregates and fine aggregates are placed separately and especially the coarse aggregates placed improper.

Figure 4.3 Improper placing of coarse aggregates

The finished hollow concrete blocks, on observation, after three days of production stored outside the shade the time of stocking on the shade is not sufficient. In addition to this, the curing is done on stocking area located outside of the shade and amount of the course is to excess because the blocks are laid when they are fresh.

4.3. Hollow concrete block production

Hollow concrete block is wall making material, it is used for construction of walls using hollow concrete block. Those blocks are used for construction of walls following the procedure of production (Ethiopian Ministry of Federal affairs (2006)).

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, 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 (Indian standard (IS 2185(part I)-1979).

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 is composed of proportioning, mixing, compaction (vibration), curing, drying and storage and dispatch. Finally, those hollow concrete blocks must comply with the requirements stated in the recommended standards in terms of 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 ((ES 596:2001), (IS 2185(part I)-1979), (IS 2185(part II)-1983)).

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). This was achieved by distributing questionnaires and site observation for assessment quality of raw materials and production process, and for assessing and evaluating through different standards such as Indian and Ethiopian standards.

During observation and questioners, in construction sites selected for investigation, hollow concrete blocks having only two holes for masonry work produced to meet Ethiopian standard and their dimensions are listed in the table below.

Table 4.1 Dimensions of hollow concrete block produced in the production area

R.No	Type of hollow blocks	Dimensions of hollow blocks
1	Hollow concrete block (t x h x l) t:- stands for thickness h:- stands for height l:- stands for length	10 x 20 x40
		15 x 20 x40
		20 x 20 x40

4.4. Handling and Quality of Ingredients

For production of hollow concrete blocks, those ingredients such as cement, crashed aggregate, sand are used with the ratios of 1:10:2 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.

During site observation and interview, the ratios of ingredients are the same in all production areas selected for investigation. Thus, it is clearly known that all enterprises have fixed proportion for production of hollow concrete blocks, but the mix ratio must be prepared based on the property of ingredients. And during collection of questioner The sources of crashed aggregates having sizes of 00 and 01 are supplied to the site by the Aksum housing agency from crasher plants located around Dura, Adikarni and Derqa near to Aksum.

Figure 4.4:- Crashed aggregates around Dura, Adikarni and Derqa

But sand is bought by the enterprises involved in production of hollow concrete blocks from different places near to Aksum. For instance, sand is imported from Medebay welela and chila.

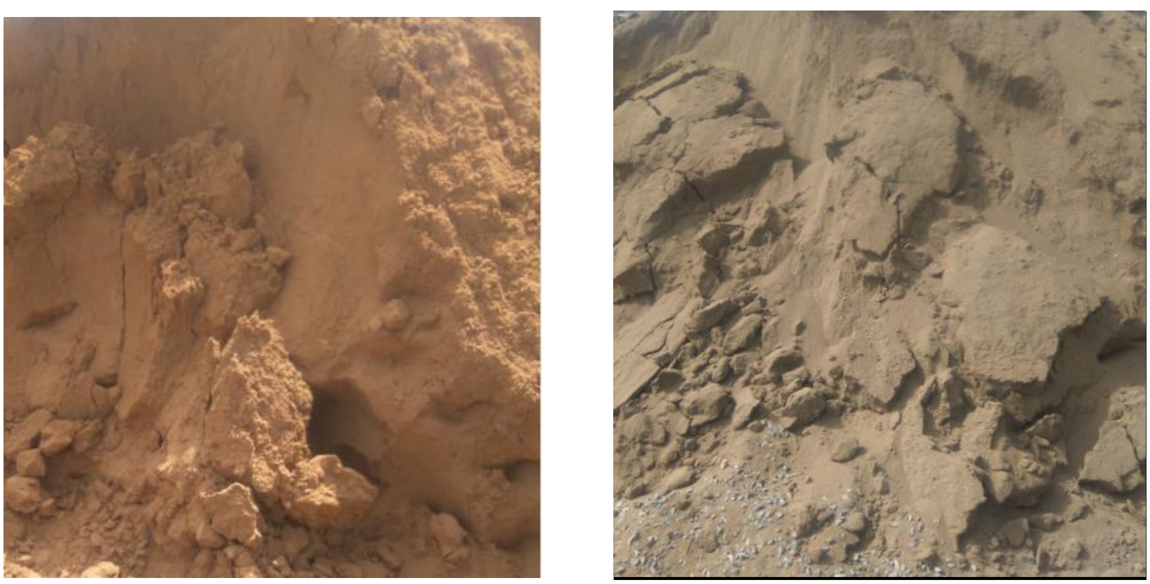

Figure 4.5:-Natural sand from Medebay welela and chila

As seen on the site during observation, aggregate handling was poor, because coarse and fine aggregates or sand and crushed aggregate are not placed separately and they put directly as shown in Figure 4.6

Figure 4.6:- Aggregate and Sand

On the request about the type of cement used for production of Hollow concrete block, the respondents use PPC cement from Messebo type II.

During observation and questionnaire, the amount of hollow concrete blocks produced using one bag of cement (per 50 kg) are listed in the Table 4.2 below:

Table 4.2:- Amount of HCB produced by 50 kg of cement

Type of hollow Blocks	Dimensions of hollow blocks	Amount of block produced per 50 kg of cement
Hollow Blocks	10 x 20 x 40	90-120
	15 x 20 x 40	90-110
	20 x 20 x 40	80-110

In some production areas drinking or potable water is used and also some of them are used from river and groundwater from drilled well for production of hollow concrete blocks as shown during observation and questioner. The water from the river has a lot of impurities and can have an effect on the property of hollow block such as reduction of compressive strength.

4.5. Production process

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

In case of proportioning of ingredients used for production of hollow concrete blocks, all respondents use volume batching by the box size of 18cm x40cm x50cm were used as shown in the figure 4.7.

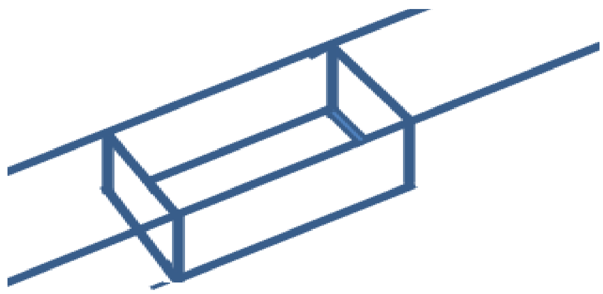

Figure 4.7 volume batching box

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 difficulty in molding, due to this wastage may be increase.

During observation and questioner, all the respondents used hand mixing, and it is done on the ground directly as shown in the figure 4.8.

Figure 4.8:- HCB production by Hand mix

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. It is done for about 60 seconds before extruded as hollow concrete block (Ethiopian Ministry of Federal affairs (2006)). 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.

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. Insufficient curing leads to reduction in compressive strength. The finished hollow concrete blocks, on observation, after three days of production stored outside the shade, the time of stocking on the shade is not sufficient. In addition to this, the amount of the course is too 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 4.9.

Figure 4.9: - Curing

Blocks in the interior part of stocking do not get sufficient curing. Besides, the blocks are not stocked properly as seen in the observation on the construction sites, the method of transportation used to transport hollow concrete blocks is safe as shown in the figure 4.10

Figure 4.10: - Loading transport hollow concrete blocks

This method can be effective and can increase wastage. In addition, this way of transportation is safe for workers and may lead to accidents.

4.6. Compliance of hollow concrete block

On observation about the test some of hollow concrete blocks produced are directly used for construction without any test for compressive strength, but they conduct field test by dropping hollow concrete from 1m height

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.

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.

At time of sampling the concrete block from the site; the sampling techniques was random sampling method that taken particularly from newly or fresh produced concrete blocks for compressive strength test however, I observed that the producers do not care about the quality of concrete mixes even if there were a quality controller.

4.7. Compressive strength and specimen Density

The compressive strength of hollow concrete blocks is measured by pressing the block placed in a compression machine such that the load is applied in the same direction as in service and dividing the load at failure by the gross area of the surface in contact with the machine as shown in the figure 4.11

Figure: - 4.11 compressive strength test machine

A. Project 1 hollow concrete block production Enterprise (MSSE)

When the compressive strength test result of the samples are evaluated with respect to the Indian Standard IS 2185-1979, the analysis result shows that all size blocks were out of the standard. However, according to Ethiopian standard both blocks 40x15x20 cm and 40x10x20 cm size have attained load bearing unit but blocks 40x20x20cm size was non-load bearing unit. The result was not satisfactory according to Ethiopian standard for hollow blocks ES 596:2001. The quality of hollow concrete block depends in its compressive strength and density; the test results of the samples are presented in Table 4.3 and Table 4.4 respectively. The average results of the compressive strength of 20 cm, 15 cm and 10 cm hollow concrete block samples are 2.0 Mpa, 2.31Mpa and 2.85 Mpa respectively. In addition the density of 20 cm, 15 cm and 10 cm hollow concrete blocks are 838.5 kg/m^3, 906.9 kg/m^3 and 1247.9 kg/m^{3}respectively. From the compressive test result, we can conclude that as the size of the hollow concrete block increases, the comprehensive strength decreases, this could be a result of bigger surface area in the large size blocks (20 cm HCB). Similarly as the size of the hollow concrete increase its density decreases, the reason could be because bigger void are in big size hollow concrete blocks.

Table 4.3: - Compressive Strength of HCB Block from Project 1 MSSE

Age of concrete	sample No.	Compressive strength (Mpa)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	2.04	2.24	2.88
	2	2.01	2.47	2.77
	3	2.0	2.23	2.9
	4	1.98	2.17	2.76
	5	1.98	2.42	2.89
	6	1.96	2.32	2.88
Average		2.0	2.31	2.85

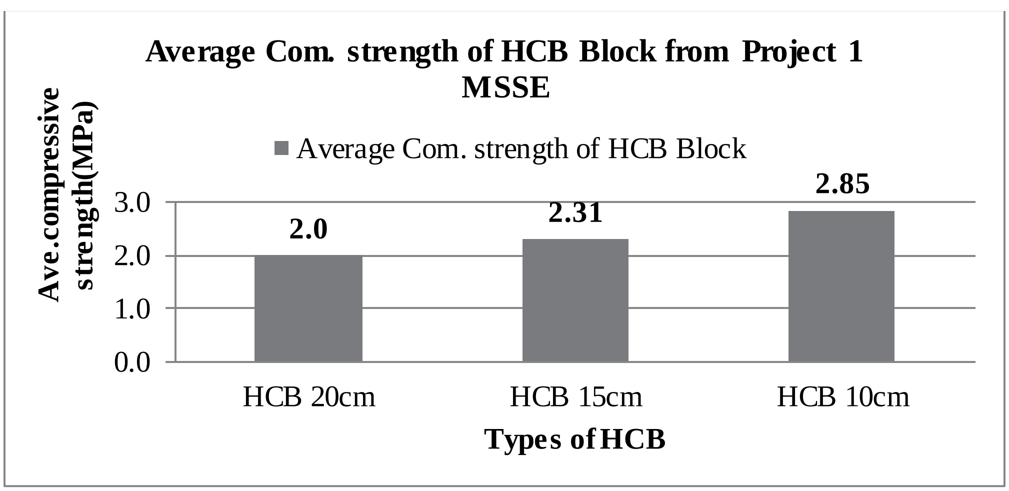

Figure 4.12: - Average Com. Strength of HCB Block from Project 1 MSSE

Table 4.4: - Specimen Density of HCB Block from Project 1 MSSE

Age of concrete	Sample No.	Specimen Density (Kg/m3)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	843.75	875	1225
	2	812.5	891.67	1325
	3	825	900	1300
	4	831.25	916.67	1200
	5	862.5	916.67	1187.5
	6	856.25	941.67	1250
Average		838.542	906.944	1247.917

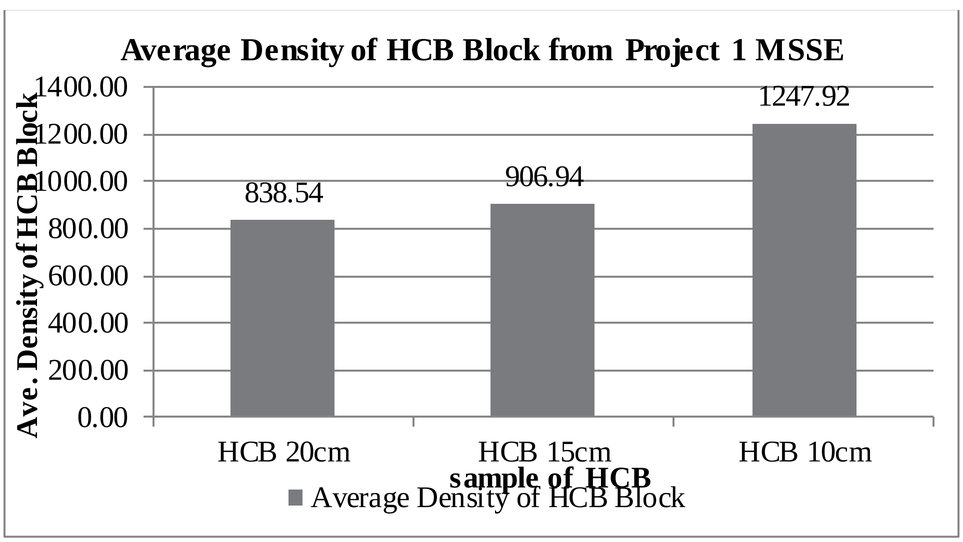

Figure 4.13: - Average Density of HCB Block from Project 1 MSSE

B. Project 2 hollow concrete block production Company (MSSE)

When the compressive strength test result of the samples are evaluated with respect to the Indian Standard IS 2185-1979, the analysis result shows that all size blocks were out of the standard. However, according to Ethiopian standard both blocks 40x15x20cm and 40x10x20cm size have attained load bearing unit but blocks 40x20x20cm size was non-load bearing unit. The result was not satisfactory according to Ethiopian standard for hollow blocks ES 596:2001.The quality of hollow concrete block depends in its compressive strength and density; the test results of the samples are presented in Table 4.5 and Table 4.6 respectively. The average results of the compressive strength of 20 cm, 15 cm and 10 cm hollow concrete block samples are 2.16 Mpa, 2.0Mpa and 2.59 Mpa respectively. In addition the density of 20 cm, 15 cm and 10 cm hollow concrete blocks are 803.125 kg/m^3, 931.944 kg/m^3 and 1079.167 kg/m^3respectively. From the compressive test result, we can conclude that as the size of the hollow concrete block increases, the comprehensive strength decreases, this could be a result of bigger surface area in the large size blocks (20 cm HCB). Similarly as the size of the hollow concrete increase its density decreases, the reason could be because bigger void are in big size hollow concrete blocks.

Table 4.5: - Compressive Strength of HCB Block from Project 2 MSSE

Age of concrete	sample No.	Compressive strength (Mpa)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	2.13	2.01	2.5
	2	2.20	2.04	2.59
	3	2.16	2.00	2.53
	4	2.25	1.93	2.77
	5	2.12	2.00	2.50
	6	2.13	2.05	2.67
Average		2.16 Mpa	2.00Mpa	2.59Mpa

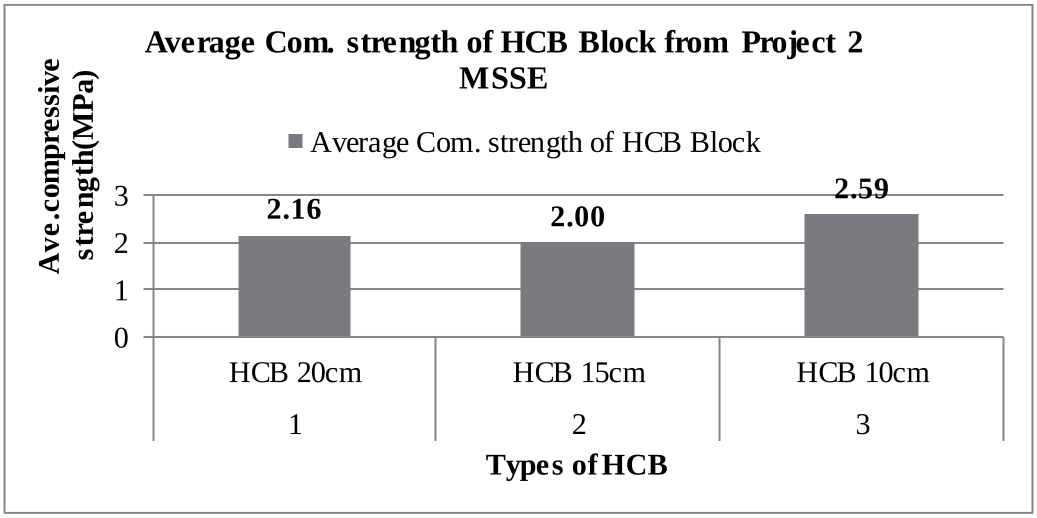

Figure 4.14: - Average Compressive Strength of HCB Block from Project 2 MSSE

Table 4.6: - Specimen Density of HCB Block from Project 2 MSSE

Age of concrete	Sample No.	Specimen Density (Kg/m3)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	800	966.66667	1100
	2	812.5	883.33	1062.5
	3	787.5	933.33333	1037.5
	4	793.75	950.00	1075
	5	806.25	908.33	1112.5
	6	818.75	950.00	1087.5
Average		803.125	931.944	1079.167

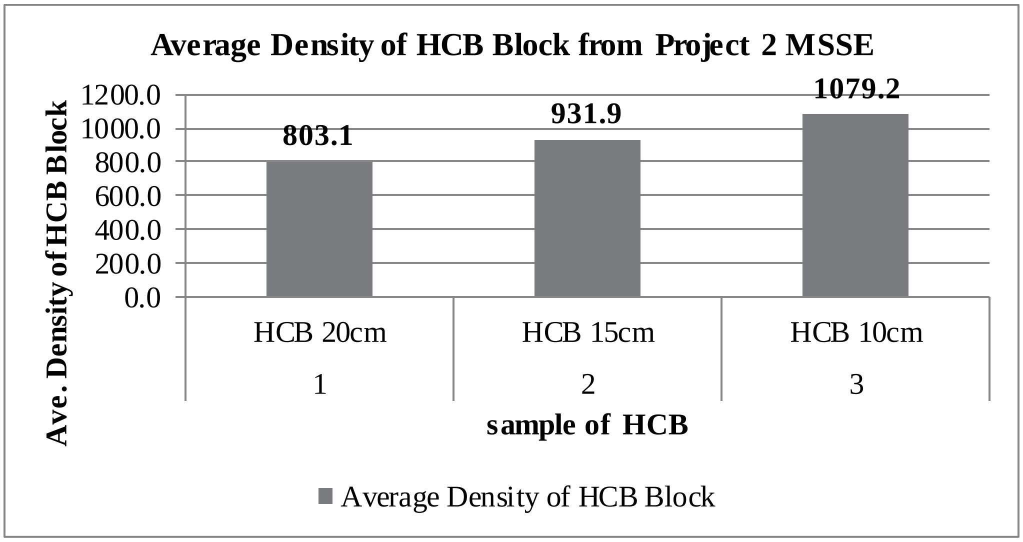

Figure 4.15: - Average Density of HCB Block from Project 2 MSSE

C. Project 3 hollow concrete block production (MSSE)

When the compressive strength test result of the samples are evaluated with respect to the Indian Standard IS 2185-1979, the analysis result shows that all size blocks were out of the standard. However, according to Ethiopian standard 40x10x20cm size have attained load bearing unit but both blocks 40x15x20cm and 40x20x20cm size was non-load bearing unit. The result was not satisfactory according to Ethiopian standard for hollow blocks ES 596:2001.The quality of hollow concrete block depends in its compressive strength and density; the test results of the samples are presented in Table 4.7 and Table 4.8 respectively. The average results of the compressive strength of 20 cm, 15 cm and 10 cm hollow concrete block samples are 2.00 Mpa, 2.10Mpa and 2.73 Mpa respectively. In addition the density of 20 cm, 15 cm and 10 cm hollow concrete blocks are 847.917 kg/m^3, 848.611 kg/m^3 and 1141.667 kg/m^3respectively. From the compressive test result, we can conclude that as the size of the hollow concrete block increases, the comprehensive strength decreases, this could be a result of bigger surface area in the large size blocks (20 cm HCB). Similarly as the size of the hollow concrete increase its density decreases, the reason could be because bigger void are in big size hollow concrete blocks.

Table 4.7: - Compressive strength of HCB Block from Project 3 MSSE

Age of concrete	sample No.	Compressive strength (Mpa)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	2.01	2.05	2.5
	2	1.99	2.15	2.76
	3	1.99	2.17	2.81
	4	2.01	2.03	2.77
	5	2.00	2.09	2.78
	6	1.98	2.11	2.74
Average		2.00Mpa	2.10Mpa	2.73Mpa

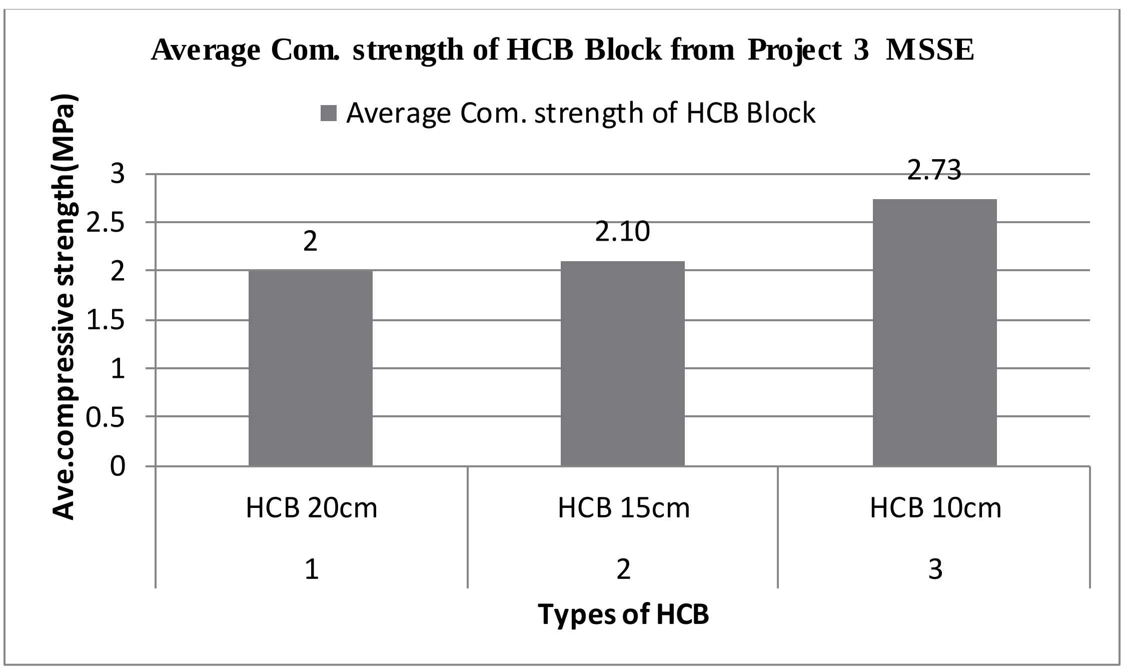

Figure4.16: - Average Compressive Strength of HCB Block from Project 3 MSSE

Table 4.8: - Specimen Density of HCB Block from Project 3 MSSE

Age of concrete	Sample No.	Specimen Density (Kg/m3)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	875	833.3333	1125
	2	812.5	833.33	1237.5
	3	825	858.3333	1112.5
	4	831.25	833.33	1125
	5	862.5	891.67	1125
	6	881.25	841.67	1125
Average		847.917	848.611	1141.667

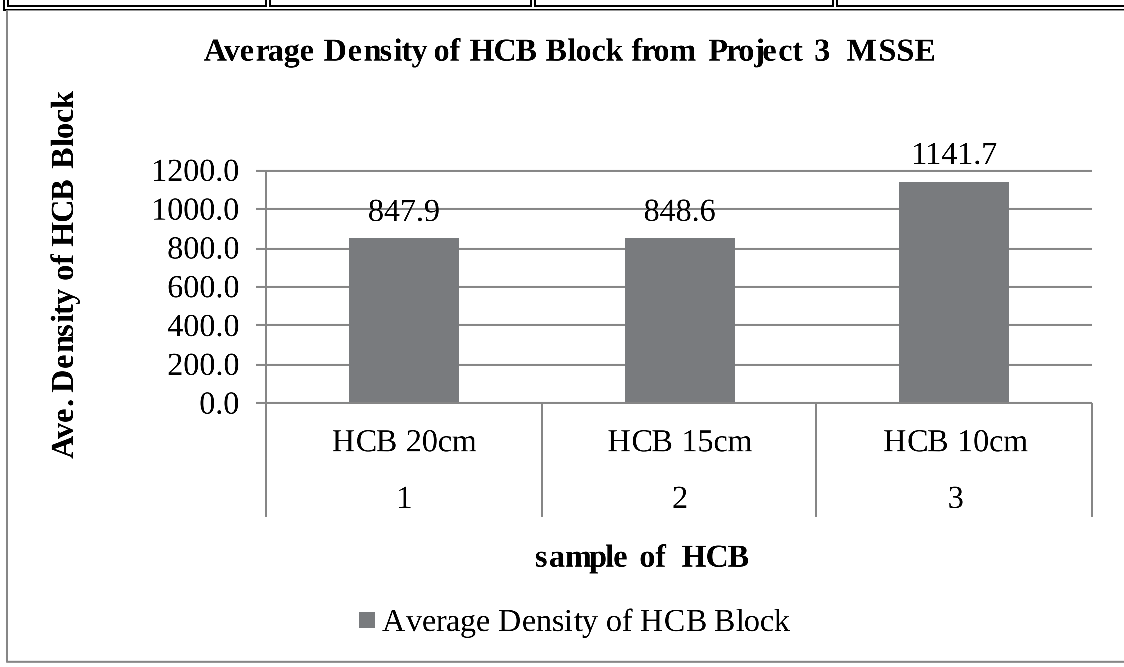

Figure 4.17: - Average Density of HCB Block from Project 3 MSSE

D. Project 4 hollow concrete block production (MSSE)

When the compressive strength test result of the samples are evaluated with respect to the Indian Standard IS 2185-1979, the analysis result shows that all size blocks were out of the standard. However, according to Ethiopian standard 40x20x20cm, 40x15x20cm and 40x10x20cm size have attained load bearing unit and this project differ with those three projects P1,P2 and P3 because all size of blocks was with standard and it was satisfactory according to Ethiopian standard for hollow blocks ES 596:2001.The quality of hollow concrete block depends in its compressive strength and density; the test results of the samples are presented in Table 4.9 and Table 4.10 respectively. The average results of the compressive strength of 20 cm, 15 cm and 10 cm hollow concrete block samples are 2.10 Mpa, 2.36Mpa and 2.88 Mpa respectively. In addition the density of 20 cm, 15 cm and 10 cm hollow concrete blocks are 951.04 kg/m^3, 938.89 kg/m^3 and 993.75 kg/m^{3}respectively. From the compressive test result, we can conclude that as the size of the hollow concrete block increases, the comprehensive strength decreases, this could be a result of bigger surface area in the large size blocks (20 cm HCB). Similarly as the size of the hollow concrete increase its density decreases, the reason could be because bigger void are in big size hollow concrete blocks.

Table 4.9: - Compressive strength of HCB Block from Project 4 MSSE

Age of concrete	sample No.	Compressive strength (Mpa)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	2.13	2.33	2.95
	2	2.12	2.38	2.90
	3	2.07	2.37	2.75
	4	2.13	2.34	2.75
	5	2.05	2.42	2.99
	6	2.13	2.34	2.95
Average		2.10Mpa	2.36Mpa	2.88Mpa

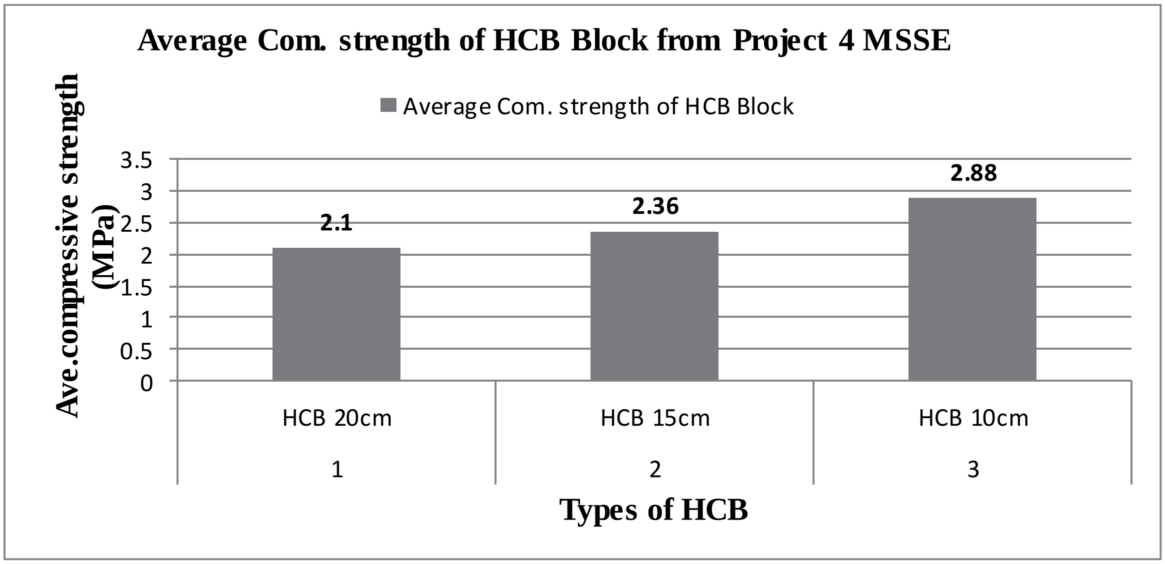

Figure 4.18: - Average Compressive Strength of HCB Block from Project 4 MSSE

Table 4.10: - Specimen Density of HCB Block from Project 4 MSSE

Age of concrete	Sample No.	Specimen Density (Kg/m3)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	937.5	875	900
	2	962.5	916.67	937.5
	3	975	900	1000
	4	937.5	1000.00	1012.5
	5	956.25	1000.00	1112.5
	6	937.5	941.67	1000
Average		951.04	938.89	993.75

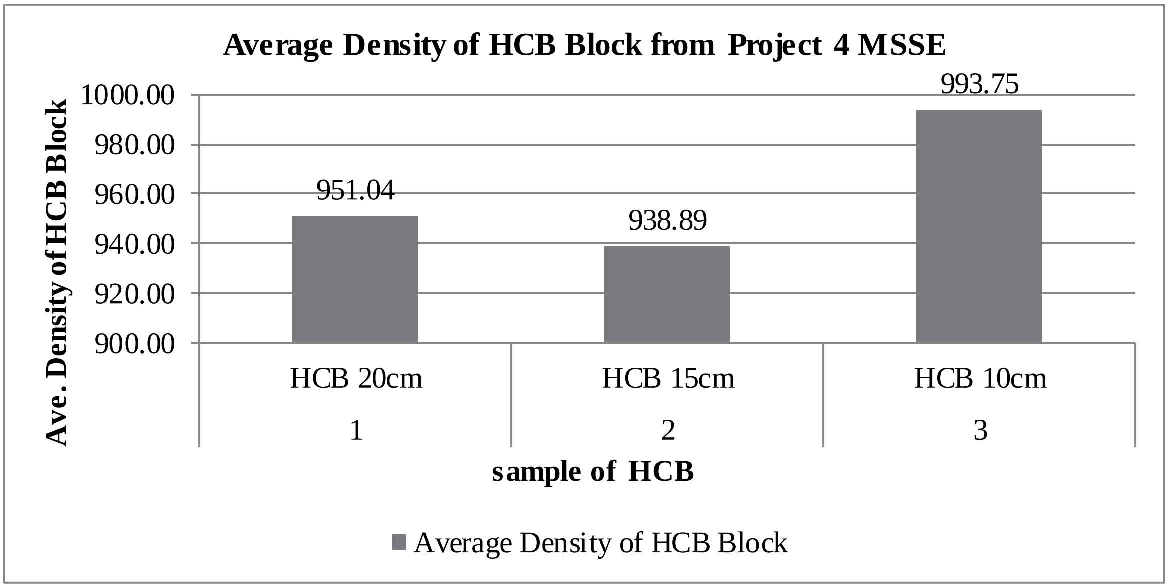

Figure 4.19: - Average Density of HCB Block from Project 4 MSSE

E. Project 5 hollow concrete block production (MSSE)

When the compressive strength test result of the samples are evaluated with respect to the Indian Standard IS 2185-1979, the analysis result shows that all size blocks were out of the standard. However, according to Ethiopian standard both blocks 40x20x20cm and 40x10x20cm size have attained load bearing unit but blocks 40x15x20cm size was non-load bearing unit. The result was not satisfactory according to Ethiopian standard for hollow blocks ES 596:2001.The quality of hollow concrete block depends in its compressive strength and density; the test results of the samples are presented in Table 4.11 and Table 4.12 respectively. The average results of the compressive strength of 20 cm, 15 cm and 10 cm hollow concrete block samples are 2.24 Mpa, 2.17Mpa and 2.81 Mpa respectively. In addition the density of 20 cm, 15 cm and 10 cm hollow concrete blocks are 898.96 kg/m^3, 883.33 kg/m^3 and 1156.25 kg/m^{3}respectively. From the compressive test result, we can conclude that as the size of the hollow concrete block increases, the comprehensive strength decreases, this could be a result of bigger surface area in the large size blocks (20 cm HCB). Similarly as the size of the hollow concrete increase its density decreases, the reason could be because bigger void are in big size hollow concrete blocks.

Table 4.11: - Compressive strength of HCB Block from Project 5 MSSE

Age of concrete	sample No.	Compressive strength (Mpa)		
		HCB Block 20cm	HCB Block15cm	HCBBlock10cm
+28 days	1	2.36	2.15	2.86
	2	2.23	2.11	2.75
	3	2.10	2.24	2.75
	4	2.18	2.17	2.77
	5	2.26	2.23	2.78
	6	2.32	2.12	2.94
Average		2.24Mpa	2.17Mpa	2.81Mpa

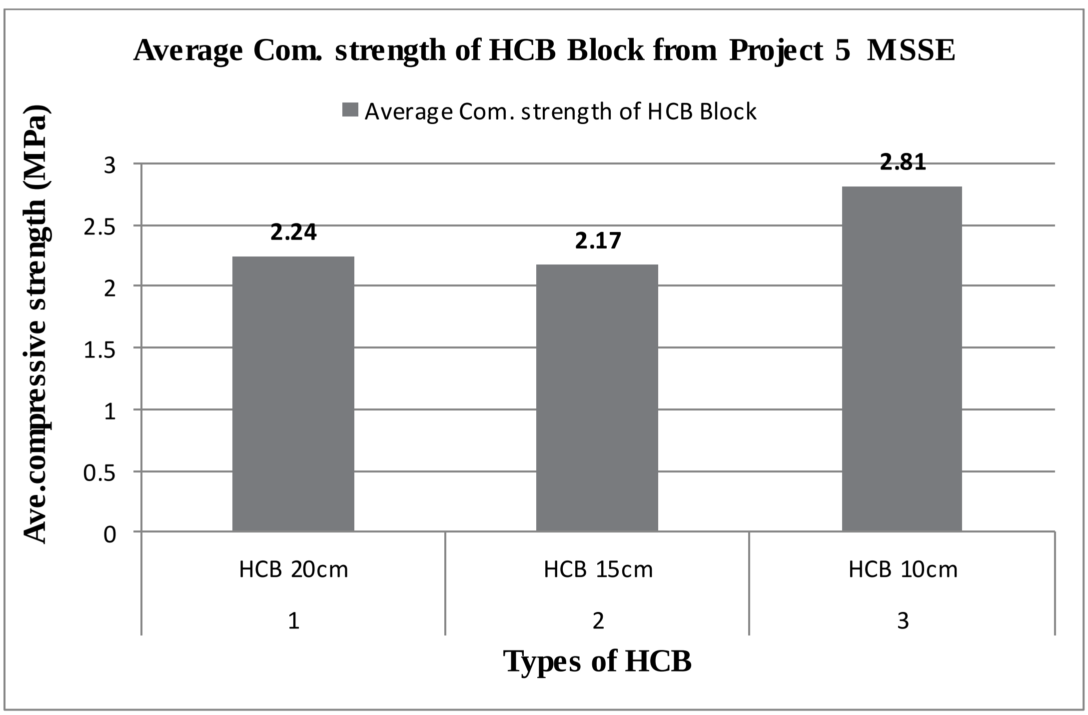

Figure 4.20: - Average Compressive Strength of HCB Block from Project 5 MSSE

Table 4.12: - Specimen Density of HCB Block from Project 5 MSSE

Age of concrete	Sample No.	Specimen Density (Kg/m3)		
		HCB Block 20cm	HCB Block 15cm	HCB Block 10cm
+28 days	1	906.25	875	1125
	2	875	891.67	1087.5
	3	900	875	1187.5
	4	887.5	841.67	1200
	5	931.25	875.00	1187.5
	6	893.75	941.67	1150
Average		898.96	883.33	1156.25

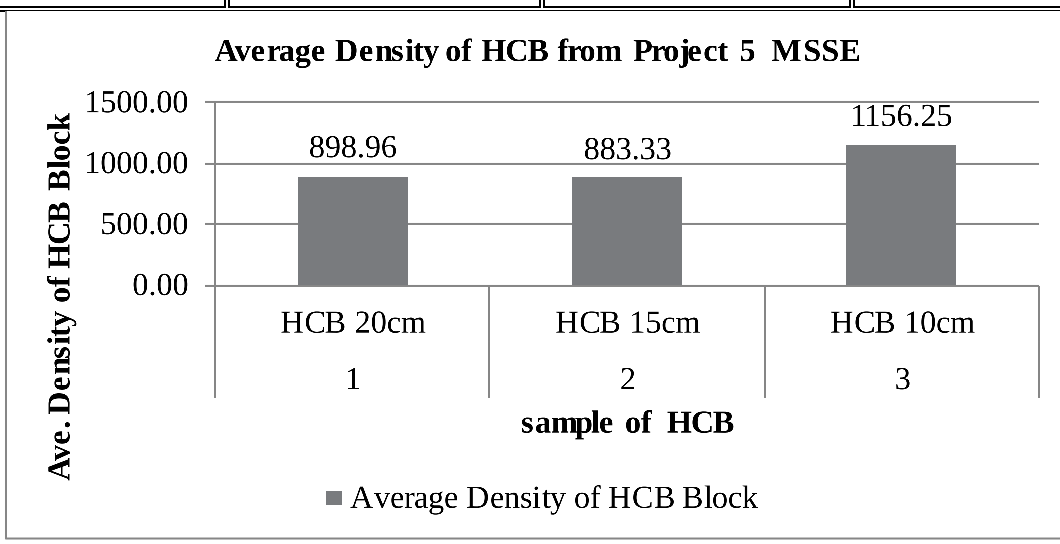

Figure 4.21: - Average Density of HCB Block from Project 5 MSSE

According to the Indian Standard IS 2185-1979 the compressive strength result of those all blocks attain in Class B and in Ethiopian standard for hollow blocks ES 596:2001 attain Class D, Compressive strength result was determined by depending on and also the density in Indian Standard IS 2185-1979 the result of all size blocks was fully not satisfactory or without standard but according to Ethiopian standard the blocks of 40x20x20cm size in project 1, 2 & 3 was Class

D and the rest two project 4 & 5 were attain Class A, B and C or load bearing unit, 40x10x20cm size in all enterprise were project 1, project 2, p,3, project 4 and project 5 was Class A, B and C or load bearing unit and satisfactory strength of Ethiopian standard and the blocks of this 40x15x20cm size in p,1, 2& 4 was Class A, B and C and the rest tow p3& 5 were attain Class D or non-load bearing unit but blocks 40x20x20cm and 40x15x20cm size somehow satisfactory and 40x10x20cm full satisfactory strength of Ethiopian standard for hollow blocks ES 596:2001.

Table 4.13 Summery results of HCB in compressive strength, density with class of blocks.

Age of concrete	Types of HCB (cm)	Projects	compressive strength	Density	Class of blocks	
					Load bearing units or class A,B & C	Non Load bearing units or class D
28 days	20 x20 x 40	Project 1	2.00	838.5		✓
		Project 2	2.16	803.1		✓
		Project 3	2.00	847.9		✓
		Project 4	2.10	951.0	✓	
		Project 5	2.24	899.0	✓	
	15 x 20 x40	Project 1	2.31	906.9	✓	
		Project 2	2.00	931.9	✓	
		Project 3	2.10	848.6		✓
		Project 4	2.36	938.9	✓	
		Project 5	2.17	883.3		✓
	10 x 20 x40	Project 1	2.85	1247.9	✓	
		Project 2	2.59	1079.2	✓	
		Project 3	2.73	1141.7	✓	
		Project 4	2.88	993.8	✓	
		Project 5	2.81	1156.3	✓	

4.8. Comparative Cost Analysis of Enterprise with Standard Mix Ratio in HCB Production

There were types of concrete block production plants and that have stationary concrete block machines that produce around 300pcs per day that produce.

To compute the unit cost of a block produced by stationary machines all the direct and indirect cost components are discussed as shown below.

1) Material Cost

The Material requirement depends on the type of material used. For the sake of simplicity let's take 20 x 20 x 40cm hollow concrete block produced, as can be seen from given table below

2) Labor Cost

The machine needs manpower during production time. The total labor requirement including their pic of blocks wage is given below

3) Equipment Cost

When calculating the cost of Equipment we consider both stationary machines and the tools costs. In the hollow concrete production plant, the major machines considered are the blocks making machine.

On the literate review part of proportioning was discussed about the standard mix ratio which is the combined aggregate content in the concrete mix used for making hollow blocks should not be more than 6 parts to 1 part by volume of Portland cement. If this ratio is taken in terms of weight basis this may average approximately at 1:7 (cement: aggregate).

Table 4.13 Hollow concrete blocks produced with standard ratio

HCB PRODUCTION		machine rental/day: 200 birr				LABOUR D/ OUTPUT: 300 BLOCKS		
HCB produced with standard ratio		Agg.00	M3	280	Birr	EQU D/ OUT PUT: 300 BLOCKS		
1:6 ratio		Agg.01	M3	350	Birr	Agg. 00	0.286	m^3
40x20x20	64 BLOCKS	N. sand	M3	313	Birr	Agg.01	0.428	m^3
		PPC	Qnt	220	Birr	N. sand	0.143	m^3
						PPC cement	1.98	Qnt

Table 4.14 Total Direct Production Cost with standard ratio

Material Cost					**Labor Cost**					**Equipment Cost**				
Type of Material	Unit	Quant *	Rate	C/ Unit	Labor by Trade	No.	UF	Daily wage	cost/ unit	Type of Equ.	No.		rent/ day	cost /unit
Agg. 00	m3	0.004	280	1.25	Forman	1	0.002	80	0.13	Tools	2	0.0033	3	0.02
Agg.01	m3	0.007	350	2.34	D/Lab	2	0.003	60	0.4	Machine	1	0.0033	200	0.67
N. sand	m3	0.002	313	0.70										
PPC Cement	Qnt	0.031	220	6.81										
Total material cost/block 11.10					**Total labor cost/block 0.53**					**Total equ. cost/ block 0.69**				
TOTAL DIRECT PRODUCTION COST										**12.32 BIRR/ BLOCKS**				

DIRECT COST= Labor Daily Output*total direct cost

=300 blocks*12.32 birr/blocks

= <u>3694.91 birr</u>

INDIRECT COST=**2%*** direct cost

= 0.02 * 3694.91 birr

= <u>73.8982 birr</u>

TOTAL COST= direct cost+ Indirect Cost

=3694.91 birr + 73.8982 birr

=<u>3768.81 birr</u>

SELL COST= Equipment Daily out Put* sell pic of block in market

=300 blocks*11.00 birr/blocks

=<u>3300 birr</u>

OUTPUT COST= Sell Cost - Total Cost

= 3300 birr - 3768.81 birr

= <u>-469 birr</u>

<u>or</u>

= sell cost/pic of block – direct cost

=11 birr/block – 12.30 birr/block

= -1.30 birr/pic of block

From the standard mix ratio on those all enterprise cannot be profitable because of the result was loss. In this case the compressive test result, we can conclude that as the profit hollow concrete block increases, the comprehensive strength quality decreases, this could be a result of mix ratio

Table 4.15 Hollow concrete blocks produced by enterprise ratio

WORK ITEM : HCB PRODUCTION		machine rental/day		200	birr	LABOUR DAILY OUTPUT: 300 BLOCKS		
HCB produced by enterprise ratio		Agg. 00	M^3	280	Birr	EQUIPMENT DAILY OUT PUT: 300 BLOCKS		
1:12 ratio		Agg.01	M^3	350	Birr	Agg. 00	0.154	m^3
40x20x20 HCB	100 BLOCKS	N. sand	M^3	313	Birr	Agg.01	0.615	m^3
		PPC Cement	Qnt	220	Birr	N. sand	0.154	m^3
						Cement	1.1	Qnt

Table 4.16 Total Direct Production Cost with enterprise ratio

Material Cost					**Labor Cost**					**Equipment Cost**				
Type of Material	Unit	Quant*	Rate	C/Unit	Labor by Trade	No.	UF	Daily wage	cost/unit	Type of Equipment	No.		rent/day	cost/unit
Agg.00	m^3	0.002	280	0.43	Forman	1	0.002	80	0.13	Tools	2	0.003	3	0.02
Agg.01	m^3	0.006	350	2.15	D/Lab	2	0.003	60	0.4	machine	1	0.003	200	0.67
N. sand	m^3	0.002	313	0.48										
PPC Cement	Qnt	0.011	220	2.42										
Total material cost/block 5.48					**Total labor cost/block 0.53**					**Total equ. cost/ block 0.69**				
TOTAL DIRECT PRODUCTION COST									**6.70 BIRR/ BLOCKS**					

DIRECT COST= Labor Daily Output*total direct cost

=300 blocks*6.70 birr/blocks

= 2011.48 birr

INDIRECT COST**=2%*** direct cost

= 0.02 *2011.48 birr

= 40.2297 birr

TOTAL COST= direct cost+ Indirect Cost

=2011.48 birr + 40.2297 birr

= 2051.715 birr

SELL COST = Equipment Daily out Put* sell pic of block in market

=300 blocks*11.00 birr/blocks

=3300 birr

OUTPUT COST= Sell Cost - Total Cost

= 3300 birr - 2051.715 birr

=1248.28 birr

Or

= sell cost/pic of block – direct cost

=11 birr/block – 6.70 birr/block

=4.30 birr/pic of block

During my observation, the enterprise were use (1:12) mix ratio for all production of HCB but the standard specify (1:6) mix ratio for production of HCB for better quality. The enterprises were not satisfying in the standard specification due to this the strength or qualities of all HCB were low. The above cost comparative indicate that the cost variation and profitability/loss of mix ratio used. On the standards the total direct cost per pic of block was 12.32 birr/ block and the enterprise of total direct cost per pic of block has 6.70 birr/ block but the sell price in the pic of block on market were 11.00 birr/ block, in the standards mix ratio they have quality and they can't be profitable but in the enterprise the results show that profitable or when profit increases, the quality of blocks is decreases.

4.9 Result analysis on the questioner data

Table 4.17 Result from questioner on those all enterprise

No	TYPES OF QUESTION	Description	Name of project (Enterprise)				
			1	2	3	4	5
		Masonry wall	✓	✓	✓	✓	✓
2	Size of block	20	✓	✓	✓	✓	✓
		15	✓	✓	✓	✓	✓
		10	✓	✓	✓	✓	✓
3	Sources of aggregate	Dura	✓	✓	✓	✓	✓
		Chila	✓	✓	✓	✓	✓
		Derka	✓	✓	✓	✓	✓
		Medebay welela	✓	✓	✓	✓	✓
		Adikarni	✓	✓	✓	✓	✓
4	Types of cement	PPC	✓	✓	✓	✓	✓
		OPC	✓	✓	✓	✓	✓
5	HCB produced 100 kg of cement	20	80	100	100	90	110
		15	90	104	108	110	100
		10	100	90	110	120	115
6	Water used for mixing	Drinking				✓	✓
		From river	✓	✓			
		drilled water			✓		
7	Methods of Mixing	Manually	✓	✓	✓	✓	✓
8	Time for mixing	Mix/min	3	5	6	5	3
9	Time for vibration	Randomly	✓	✓	✓	✓	✓
10	Time for curing	Cure(day)	3	7	3	7	7
11	Storage and cure place	Under the shade				✓	✓
		Outside the shade	✓	✓	✓		
12	Time of Storage after manufacturing	Storage(days)	3-2	3-2	3-2	3-2	3-2
13	HCB used for testing	Pic of blocks	3-6	3-6	3-6	3-6	3-6
14	Sample of tests	Density	✓	✓	✓	✓	✓
		Compressive strength	✓	✓	✓	✓	✓
15	Workers	Forman	1	1	1	1	1
		d/workers	2	3	1	2	2

The result that obtained from questioners was shown that; the types of HCB blocks that produced from selected project-1 up to project-5 were used for masonry wall purpose. In addition to this;

the selected five projects produced 40*20*20cm, 40*20*15cm and 40*20*10cm size of HCB block. the aggregate source that used for HCB block production in project-1 up to project-5 from Adikarni, chila, dura, derqa and Medebay welela. Whereas, the types of cement that used for HCB-block production was Type-II (PPC) cement that is locally available in Aksum town for all selected small scale enterprise. The water source that used for concrete mix in HCB block production were Potable water, River water and ground drilled water.project-1 and project-2 were used river water, project-4 and project-5 were used potable water whereas, project-3 was used ground drilled water.

The mixing method of the concrete that used for HCB block production in the selected enterprise was manual or hand mixing method. The mixing hours or min. of the concrete mix was 3-6 min and vibrator was used for compaction purpose to produced well compacted HCB block. In addition to this, the curing time of the produced HCB block was 3-7 days depend up on the selected enterprise. The result shown that project -1 and project-3 were cured 3-days whereas; project-2, project-4 and project-5 were 7-days of the produced HCB blocks as shown figure 4.22

The HCB blocks that produced by the selected enterprise were stored under the shade and outside the shade. Project-1, project-2 and project-3 were stored outside the shade on other hand; project 4 &5 were stored under shade.

In the selected enterprise; the produced HCB block most of the time test for density and compressive strength and amount of sample were taken 3-6 number of HCB block.

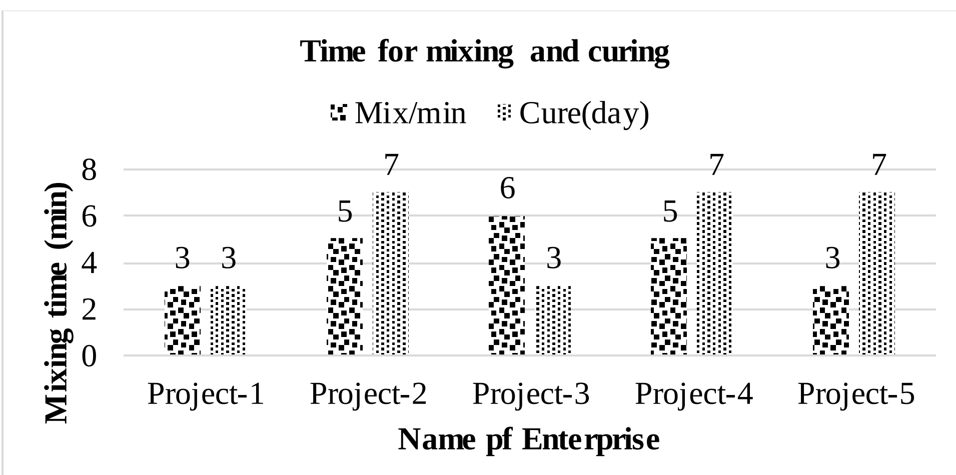

Figure 4.22: Curing and Mixing time of HCB blocks in selected each enterprise

The amount of HCB block produced per 100 kg cement for 40*20*20cm, 40*20*15cm and 40*20*10cm size of blocks 80-110, 90-110 and 90-120 number of HCB block for all selected in small scale enterprise as shown in figure 4.23.

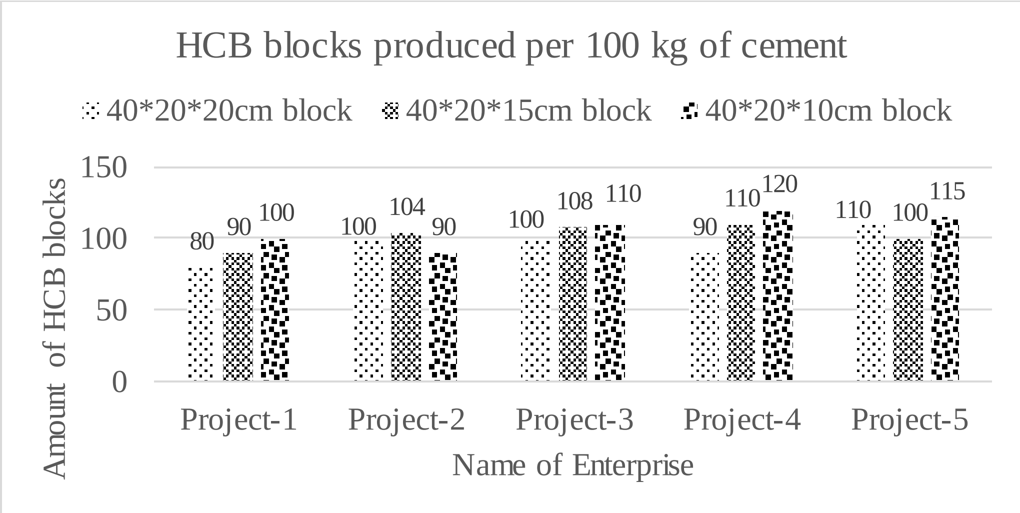

Figure 4.23 Amount of HCB blocks that produced per 100kg of cement

The number of workers used in HCB block production of the enterprise with single Forman and 1-3 daily labors. Project-1, project-4 and project-5 use only two daily labors whereas; project-2 and project-3 have one and three daily labor respectively as shown in figure 4.24.

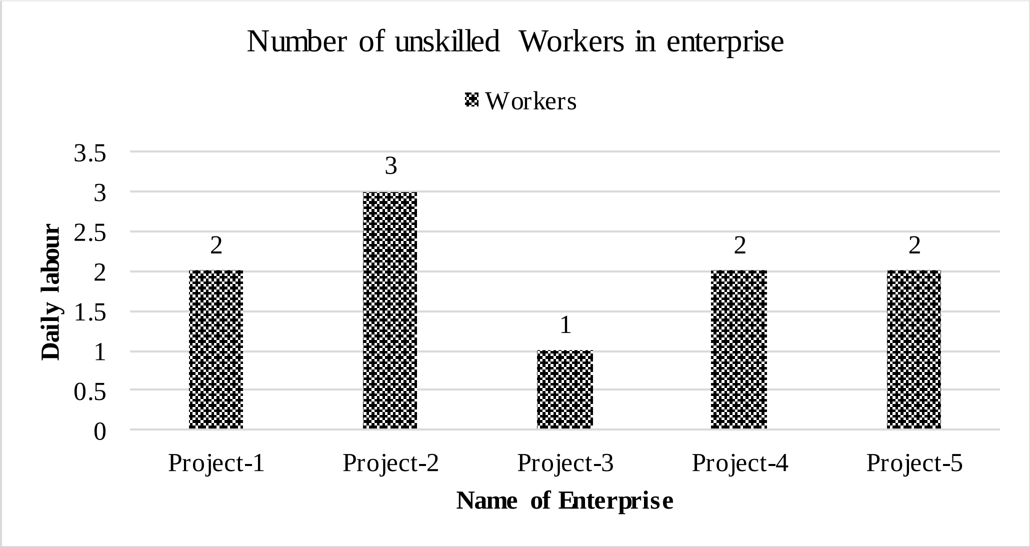

Figure 4.24 Number of unskilled workers in the selected enterprise

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

The research carried out has shown some of the problems associated with quality control practice on the enterprises and made to show the impact of improper quality control practice on the quality of hollow concrete block productions. The following conclusions and recommendations are drawn out from the investigation undertaken on the enterprises.

5.1 Conclusions

1. Concrete block needs careful attention during storage of cement, time of mixing, time of curing, place separately and storage of aggregate those all factors can affect the quality of hollow concrete block.

2. When the curing observed, those producers are most of the curing time is done outside of the shade, the time of keeping 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.

3. According to Ethiopian standard the size of 40x10x20cm and 40x15x20cm both blocks was used for wall partition or surface covering and 40x20x20cm this size of block can carry or transfer load the next part of structure based on the result of compressive strength we can conclude that this size of block was can't carry load and it have poor quality and 40x15x20cm size somehow satisfactory and 40x10x20cm full satisfactory strength but both are wall partition.

4. Compliance control is a check made to ensure the submission of the product with the specification. As 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.

5. According to Ethiopian standard ES 596:2001, the results were not affected in case of material quality but the final outputs of HCBs were poor. This may be because of lack of improper mix ratio the result were decrease.

6. According to Ethiopian standard, all producers attain Class D, and from the compressive strength result and density we can conclude that the hollow concrete blocks produced in micro and small scale enterprise or in production areas is substandard.

7. The overall experimental compressive test results show that as the size of the hollow concrete block increases, the comprehensive strength decreases.

8. From the standard mix ratio on those all enterprise cannot be profitable because of the result was loss. In this case the compressive test result, we can conclude that as the profit hollow concrete block increases, the comprehensive strength quality decreases, this could be a result of mix ratio.

9. From the questioner result, the mixing hours or min. of the concrete mix was 3-6 min and curing time of the produced HCB block was 3-7 days depend up on the selected enterprise. The amount of HCB block produced per 100 kg cement for 40*20*20cm, 40*20*15cm and 40*20*10cm size of blocks 80-110, 90-110 and 90-120 number of HCB block for all selected in small scale enterprise. In addition to this, the number of workers used in HCB block production of the enterprise with single Forman and 1-3 daily labors. Project-1, project-4 and project-5 use only two daily labors whereas; project-2 and project-3 have one and three daily labor respectively.

5.2. Recommendations

1. The production guideline is very important, manuals are prepared in simple language and it should be applicable. Because during observation in enterprise selected for study, any manuals and guide lines were not available on the producers; and it is necessary

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

3. The housing agency must secure safety of workers involved in construction activities.

4. 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.
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 producer and workers to improve quality. In addition to this, they must have enough man power for controlling purpose during observation some enterprise assign only one skilled person for one production area.
7. It is important that the effect of the manufacturing process on the quality of hollow concrete blocks could be clearly studied. Here, the effects of curing process, shade, the block making machine and degree of compaction could be addressed.

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ANNEX A

Questioners for Hollow concrete blocks producers in micro and small scale enterprise.

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 enterprise?

- HCB for masonry wall
- HCB for ribbed slab

2 What is the size of HCB used in this enterprise?

Hollow Concrete Block (L x W x T)

- 40 x 20 x 20
- 40 x 20 x 15
- 40 x 20 x 10

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

Coarse aggregate: - ______________ ______________ ______________

Fine aggregate: - ______________ ______________ ______________

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

- OPC
- PPC

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

____

____

____

6. How much HCB produced per 100 kg of cement? (L x H x W)

Hollow Concrete Block

40 x 20 x 20 ________

40 x 20 x 15 ________

40 x 20 x 10 ________

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

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

8. How do you mix your ingredients?

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

9. For how long do you mix the ingredients?

____

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

____

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

____

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

- Under the shade
- Outside the shade

13. For how long your HCB store on the site after manufacturing?

____

14. How many sample of hollow concrete block used for testing?

____

15. What are the tests made for Hollow concrete block please specify?
    - Dimension Density
    - Water absorption
    - Compressive strength

16. How many workers participate in this enterprise?

    Un Skilled person___________

    Skilled person______________

Thank you for your cooperation!

ANNEX B

Detail result of HCB

Table B128 Days compressive strength & Specimen Density test results for sample Project 1

40*20*20 size HCB Block										
Age of concrete	sample No.	Dimension (in mm)				Vol.(m3)	Weight of specimen (Kg)	Specimen Density (Kg/m^3)	Peak load (KN)	Compressive strength (Mpa)
		L	W	H	T					
+28 days	1	0.4	0.2	0.2	0.03	0.016	13.5	843.75	163.52	2.04
	2	0.4	0.2	0.2	0.03	0.016	13	812.5	161.4	2.02
	3	0.4	0.2	0.2	0.03	0.016	13.2	825	160.49	2.01
	4	0.4	0.2	0.2	0.03	0.016	13.3	831.25	158.5	1.98
	5	0.4	0.2	0.2	0.03	0.016	13.8	862.5	159.13	1.99
	6	0.4	0.2	0.2	0.03	0.016	13.7	856.25	157.13	1.96
Average								838.54	160.03	2.00 Mpa
40*10*20 size HCB Block										
+28 days	1	0.4	0.1	0.2	0.02	0.008	9.8	1225	115.27	2.88
	2	0.4	0.1	0.2	0.02	0.008	10.6	1325	110.85	2.77
	3	0.4	0.1	0.2	0.02	0.008	10.4	1300	116.3	2.91
	4	0.4	0.1	0.2	0.02	0.008	9.6	1200	110.7	2.77
	5	0.4	0.1	0.2	0.02	0.008	9.5	1187.5	115.8	2.90
	6	0.4	0.1	0.2	0.02	0.008	10	1250	115.2	2.88
Average								1247.9	114.02	2.85 Mpa
40*15*20 size HCB Block										
+28 days	1	0.4	0.15	0.2	0.025	0.012	10.5	875	134.56	2.24
	2	0.4	0.15	0.2	0.025	0.012	10.7	891.67	148.52	2.48
	3	0.4	0.15	0.2	0.025	0.012	10.8	900	134.3	2.24
	4	0.4	0.15	0.2	0.025	0.012	11	916.67	130.3	2.17
	5	0.4	0.15	0.2	0.025	0.012	11	916.67	145.4	2.42
	6	0.4	0.15	0.2	0.025	0.012	11.3	941.67	139.22	2.32
Average								906.94	138.72	2.31 Mpa

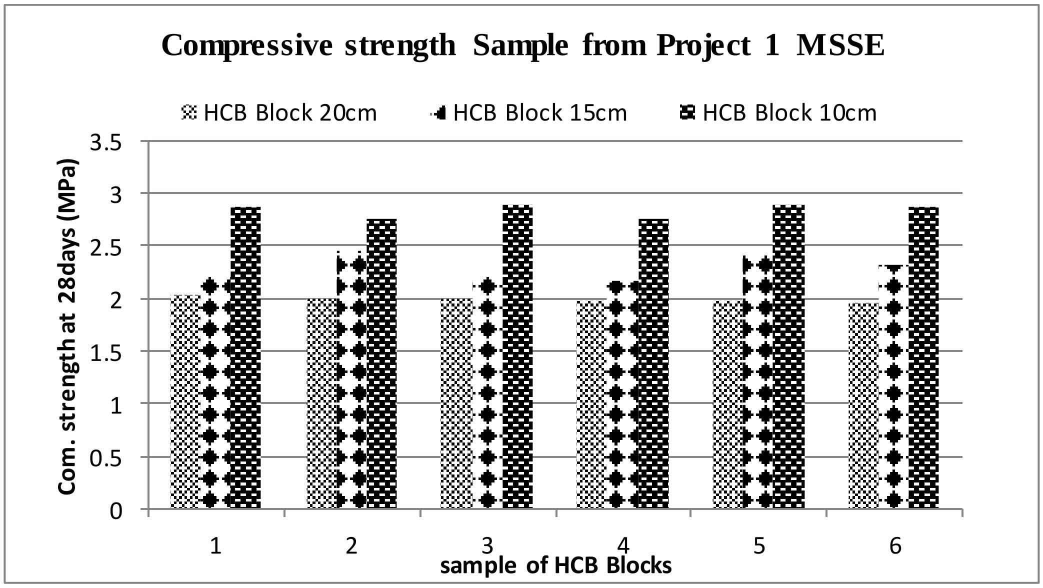

Figure B1: - 28 Days compressive strength test results for sample Project 1

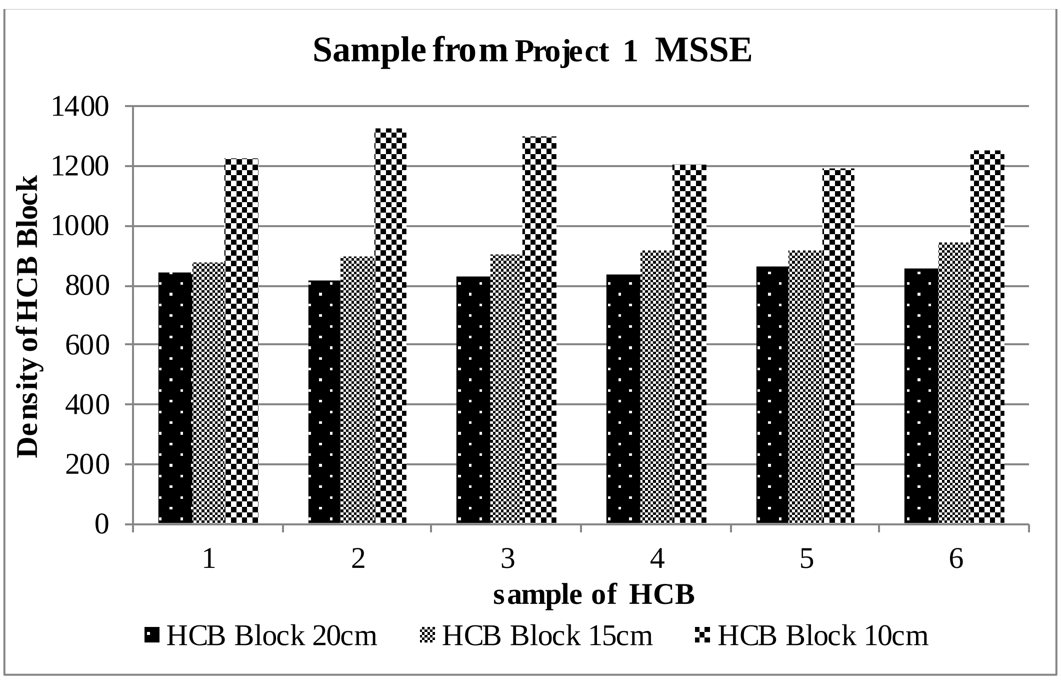

Figure B2: - Specimen Density test results for sample Project 1

Table B228 Days compressive strength & Specimen Density test results for sample Project 2

40*20*20 size HCB Block										
Age of concrete	sample No.	Dimension (in mm)				Vol.(m3)	Weight of specimen(Kg)	Specimen Density (Kg/m^3)	Peak load (KN)	Compressive strength (Mpa)
		L	W	H	T					
+28 days	1	0.4	0.2	0.2	0.03	0.016	12.8	800.00	170	2.13
	2	0.4	0.2	0.2	0.03	0.016	13	812.50	176.1	2.20
	3	0.4	0.2	0.2	0.03	0.016	12.6	787.50	173.1	2.16
	4	0.4	0.2	0.2	0.03	0.016	12.7	793.75	180	2.25
	5	0.4	0.2	0.2	0.03	0.016	12.9	806.25	169.9	2.12
	6	0.4	0.2	0.2	0.03	0.016	13.1	818.75	170.4	2.13
Average								803.13	173.25	2.16 Mpa
40*10*20 size HCB Block										
+28 days	1	0.4	0.1	0.2	0.02	0.008	8.8	1100.00	100	2.50
	2	0.4	0.1	0.2	0.02	0.008	8.5	1062.50	103.6	2.59
	3	0.4	0.1	0.2	0.02	0.008	8.3	1037.50	101.1	2.53
	4	0.4	0.1	0.2	0.02	0.008	8.6	1075.00	110.7	2.77
	5	0.4	0.1	0.2	0.02	0.008	8.9	1112.50	99.9	2.50
	6	0.4	0.1	0.2	0.02	0.008	8.7	1087.50	106.6	2.67
Average								1079.2	103.65	2.59Mpa
40*15*20 size HCB Block										
+28 days	1	0.4	0.15	0.2	0.025	0.012	11.6	966.67	120.3	2.01
	2	0.4	0.15	0.2	0.025	0.012	10.6	883.33	122.1	2.04
	3	0.4	0.15	0.2	0.025	0.012	11.2	933.33	119.8	2.00
	4	0.4	0.15	0.2	0.025	0.012	11.4	950.00	115.7	1.93
	5	0.4	0.15	0.2	0.025	0.012	10.9	908.33	120.2	2.00
	6	0.4	0.15	0.2	0.025	0.012	11.4	950.00	123.1	2.05
Average								931.94	120.20	2.00Mpa

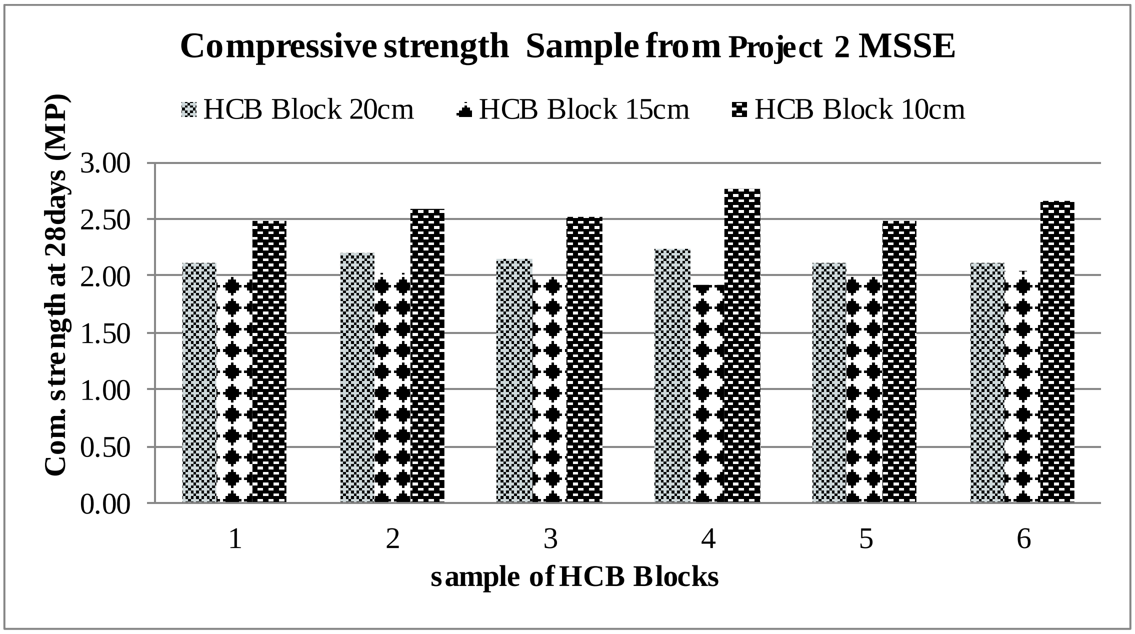

Figure B3: - 28 Days compressive strength test results for sample **Project 2**

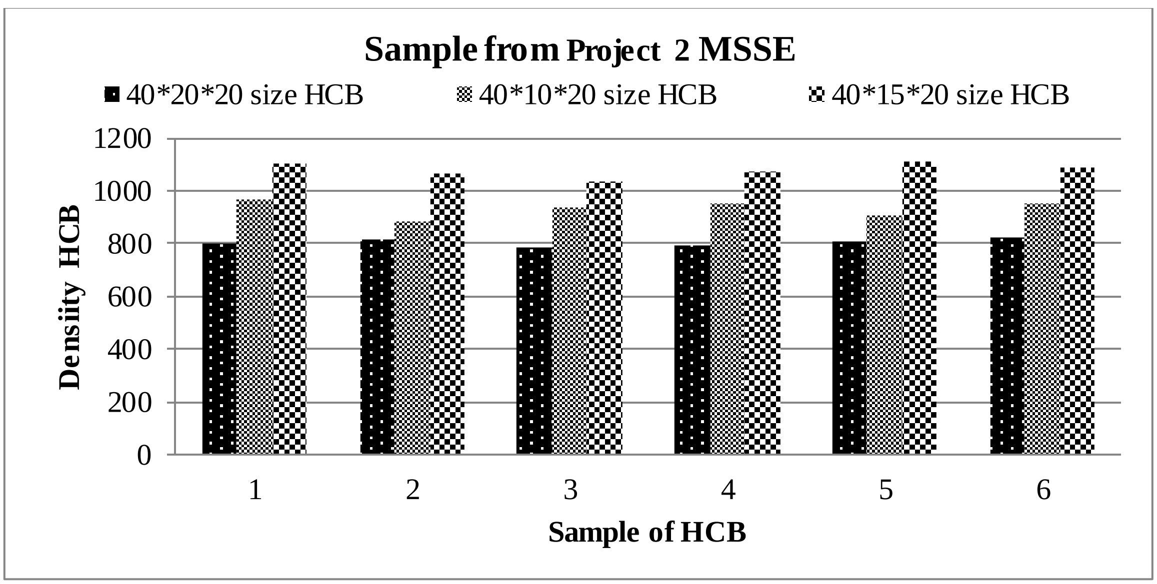

Figure B4:- Specimen Density test results for sample **Project 2**

Table B3 28 Days compressive strength & Specimen Density test results for sample Project 3

Age of concrete	sample No.	Dimension (in mm)				Vol.(m3)	Weight of specimen(Kg)	Specimen Density (Kg/m^3)	Peak load (KN)	Compressive strength (Mpa)
		L	W	H	T					
40*20*20 size HCB Block										
+28 days	1	0.4	0.2	0.2	0.03	0.016	14	875	160.5	2.01
	2	0.4	0.2	0.2	0.03	0.016	13	812.5	159.2	1.99
	3	0.4	0.2	0.2	0.03	0.016	13.2	825	159.5	1.99
	4	0.4	0.2	0.2	0.03	0.016	13.3	831.25	160.9	2.01
	5	0.4	0.2	0.2	0.03	0.016	13.8	862.5	160.3	2.00
	6	0.4	0.2	0.2	0.03	0.016	14.1	881.25	158.2	1.98
Average								847.92	159.77	2.00Mpa
40*10*20 size HCB Block										
+28 days	1	0.4	0.1	0.2	0.02	0.008	9	1125	100	2.50
	2	0.4	0.1	0.2	0.02	0.008	9.9	1237.5	110.5	2.76
	3	0.4	0.1	0.2	0.02	0.008	8.9	1112.5	112.2	2.81
	4	0.4	0.1	0.2	0.02	0.008	9	1125	110.7	2.77
	5	0.4	0.1	0.2	0.02	0.008	9	1125	111.1	2.78
	6	0.4	0.1	0.2	0.02	0.008	9	1125	109.5	2.74
Average								1141.7	109.00	2.73Mpa
40*15*20 size HCB Block										
+28 days	1	0.4	0.15	0.2	0.025	0.012	10	833.33	122.9	2.05
	2	0.4	0.15	0.2	0.025	0.012	10	833.33	128.9	2.15
	3	0.4	0.15	0.2	0.025	0.012	10.3	858.33	130.1	2.17
	4	0.4	0.15	0.2	0.025	0.012	10	833.33	122	2.03
	5	0.4	0.15	0.2	0.025	0.012	10.7	891.67	125.1	2.09
	6	0.4	0.15	0.2	0.025	0.012	10.1	841.67	126.7	2.11
Average								848.61	125.95	2.10Mpa

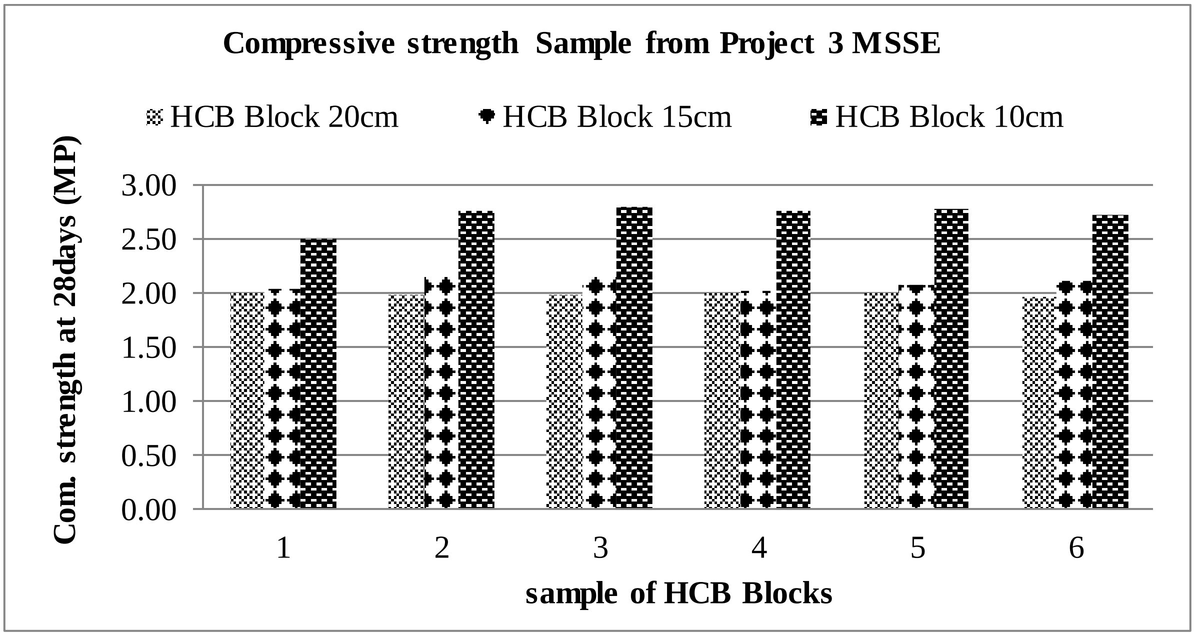

Figure B5: - 28 Days compressive strength test results for sample **Project 3**

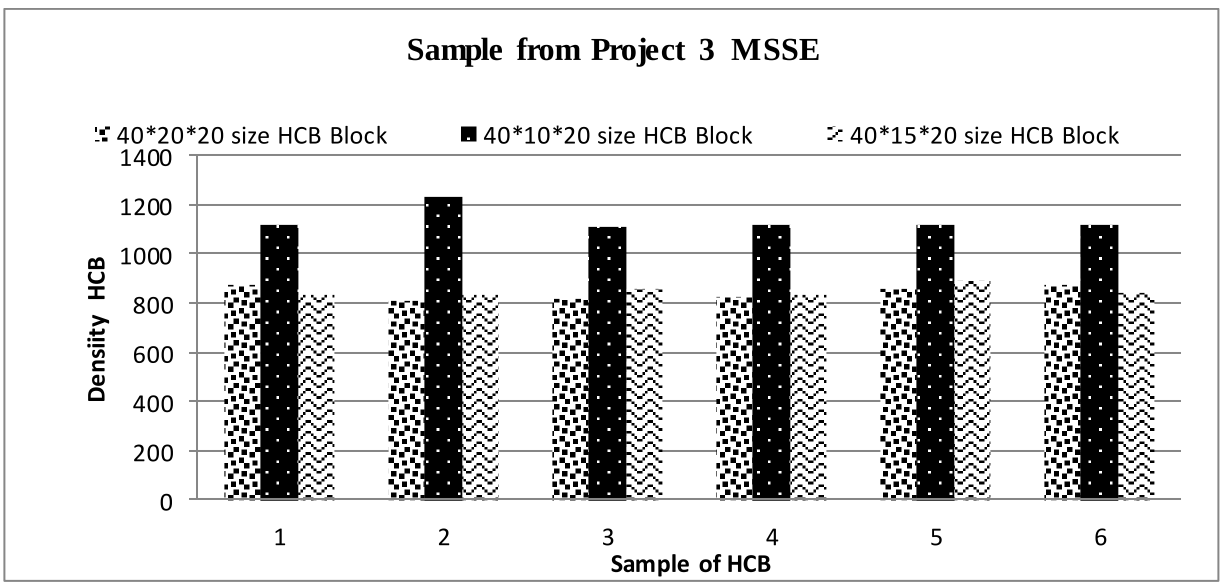

Figure B6: - Specimen Density test results for sample Project 3

Table B4 28 Days compressive strength & Specimen Density test results for sample Project 4

40*20*20 size HCB Block										
Age of concrete	sample No.	Dimension (in mm)				Vol.(m3)	Weight of specimen(Kg)	Specimen Density (Kg/m^3)	Peak load (KN)	Compressive strength (Mpa)
		L	W	H	T					
+28 days	1	0.4	0.2	0.2	0.03	0.016	15	937.5	170	2.13
	2	0.4	0.2	0.2	0.03	0.016	15.4	962.5	169.3	2.12
	3	0.4	0.2	0.2	0.03	0.016	15.6	975	165.9	2.07
	4	0.4	0.2	0.2	0.03	0.016	15	937.5	170	2.13
	5	0.4	0.2	0.2	0.03	0.016	15.3	956.25	163.7	2.05
	6	0.4	0.2	0.2	0.03	0.016	15	937.5	170	2.13
Average								951.04	168.15	2.10Mpa
40*10*20 size HCB Block										
+28 days	1	0.4	0.1	0.2	0.02	0.008	7.2	900	117.9	2.95
	2	0.4	0.1	0.2	0.02	0.008	7.5	937.5	116.1	2.90
	3	0.4	0.1	0.2	0.02	0.008	8	1000	110	2.75
	4	0.4	0.1	0.2	0.02	0.008	8.1	1012.5	109.9	2.75
	5	0.4	0.1	0.2	0.02	0.008	8.9	1112.5	119.5	2.99
	6	0.4	0.1	0.2	0.02	0.008	8	1000	118	2.95
Average								993.75	115.23	2.88Mpa
40*15*20 size HCB Block										
+28 days	1	0.4	0.15	0.2	0.025	0.012	10.5	875	139.8	2.33
	2	0.4	0.15	0.2	0.025	0.012	11	916.67	142.9	2.38
	3	0.4	0.15	0.2	0.025	0.012	10.8	900	141.9	2.37
	4	0.4	0.15	0.2	0.025	0.012	12	1000	140.1	2.34
	5	0.4	0.15	0.2	0.025	0.012	12	1000	145.4	2.42
	6	0.4	0.15	0.2	0.025	0.012	11.3	941.67	140.4	2.34
Average								938.89	141.75	2.36Mpa

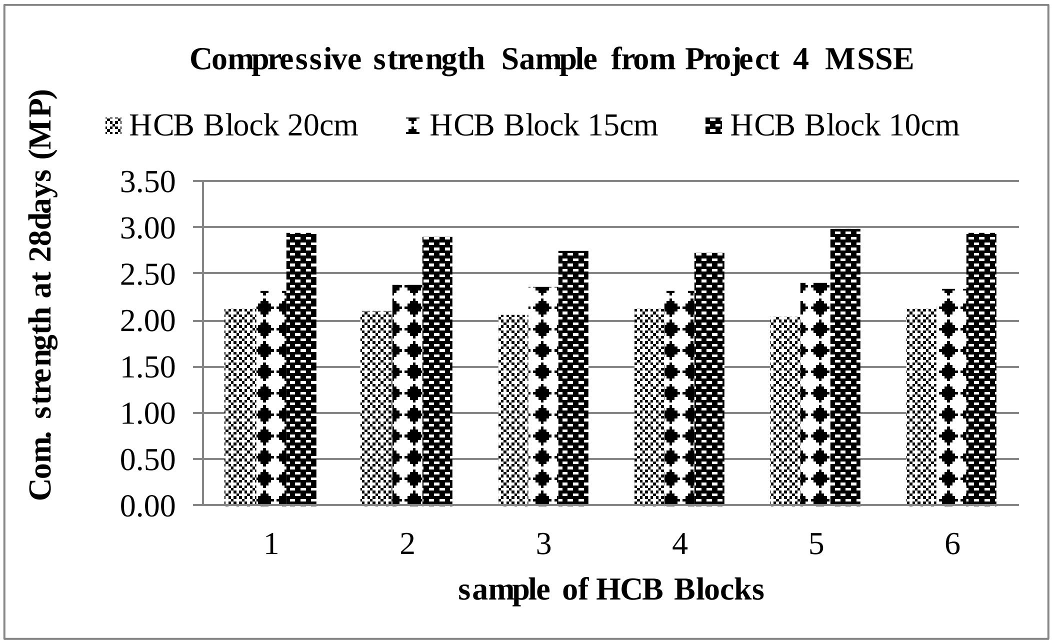

Figure B7:- 28 Days compressive strength test results for sample Project 4

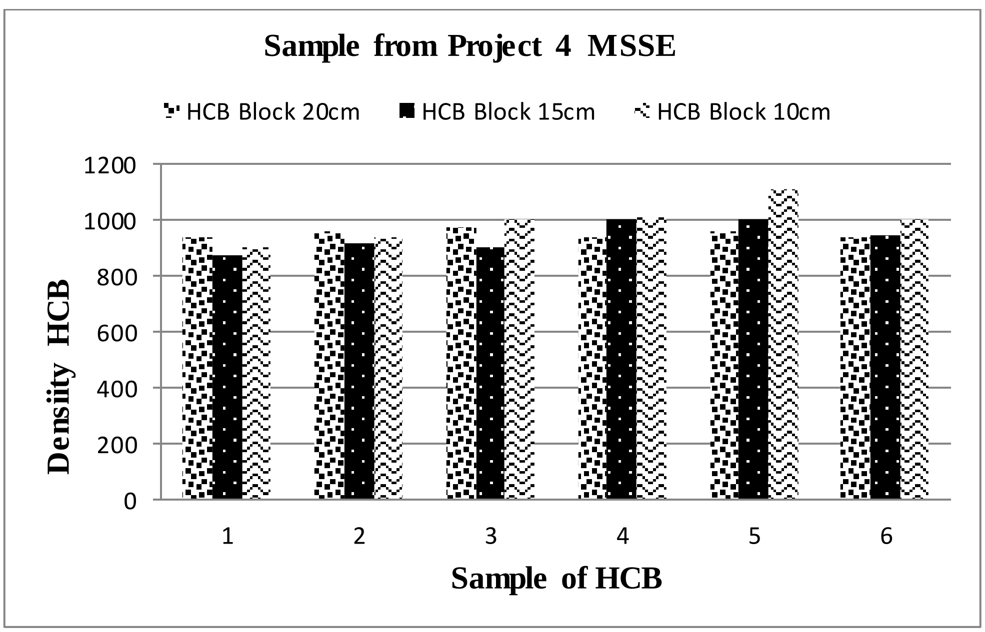

Figure B8: - Specimen Density test results for sample **Project 4**

Table B5 28 Days compressive strength & Specimen Density test results for sample **Project 5**

40*20*20 size HCB Block										
Age of concrete	sample No.	Dimension (in mm)				Vol.(m3)	Weight of specimen(Kg)	Specimen Density (Kg/m^3)	Peak load (KN)	Compressive strength (Mpa)
		L	W	H	T					
+28 days	1	0.4	0.2	0.2	0.03	0.016	14.5	906.25	189	2.36
	2	0.4	0.2	0.2	0.03	0.016	14	875	178.2	2.23
	3	0.4	0.2	0.2	0.03	0.016	14.4	900	168	2.10
	4	0.4	0.2	0.2	0.03	0.016	14.2	887.5	174.3	2.18
	5	0.4	0.2	0.2	0.03	0.016	14.9	931.25	180.8	2.26
	6	0.4	0.2	0.2	0.03	0.016	14.3	893.75	185.5	2.32
Average								898.96	179.30	2.24Mpa
40*10*20 size HCB Block										
+28 days	1	0.4	0.1	0.2	0.02	0.008	9	1125	114.3	2.86
	2	0.4	0.1	0.2	0.02	0.008	8.7	1087.5	110.1	2.75
	3	0.4	0.1	0.2	0.02	0.008	9.5	1187.5	109.8	2.75
	4	0.4	0.1	0.2	0.02	0.008	9.6	1200	110.7	2.77
	5	0.4	0.1	0.2	0.02	0.008	9.5	1187.5	111.3	2.78
	6	0.4	0.1	0.2	0.02	0.008	9.2	1150	117.7	2.94
Average								1156.3	112.32	2.81Mpa
40*15*20 size HCB Block										
+28 days	1	0.4	0.15	0.2	0.025	0.012	10.5	875	129	2.15
	2	0.4	0.15	0.2	0.025	0.012	10.7	891.67	126.7	2.11
	3	0.4	0.15	0.2	0.025	0.012	10.5	875	134.3	2.24
	4	0.4	0.15	0.2	0.025	0.012	10.1	841.67	130.3	2.17
	5	0.4	0.15	0.2	0.025	0.012	10.5	875	133.7	2.23
	6	0.4	0.15	0.2	0.025	0.012	11.3	941.67	127.3	2.12
Average								883.33	130.22	2.17Mpa

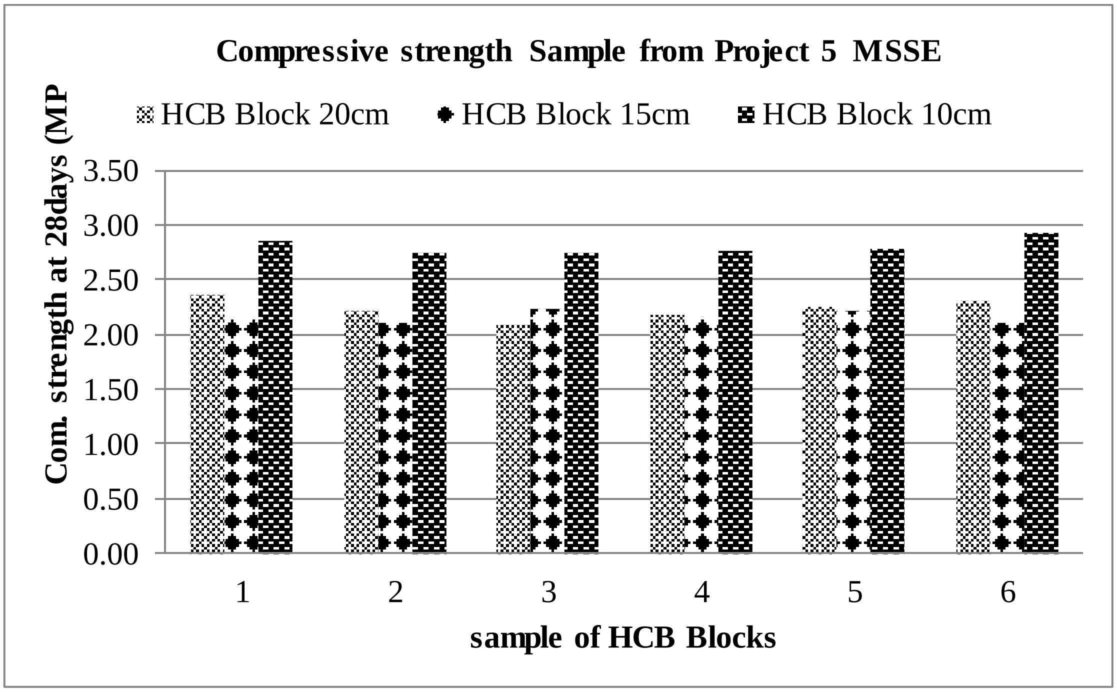

Figure B9: - 28 Days compressive strength test results for sample Project 5

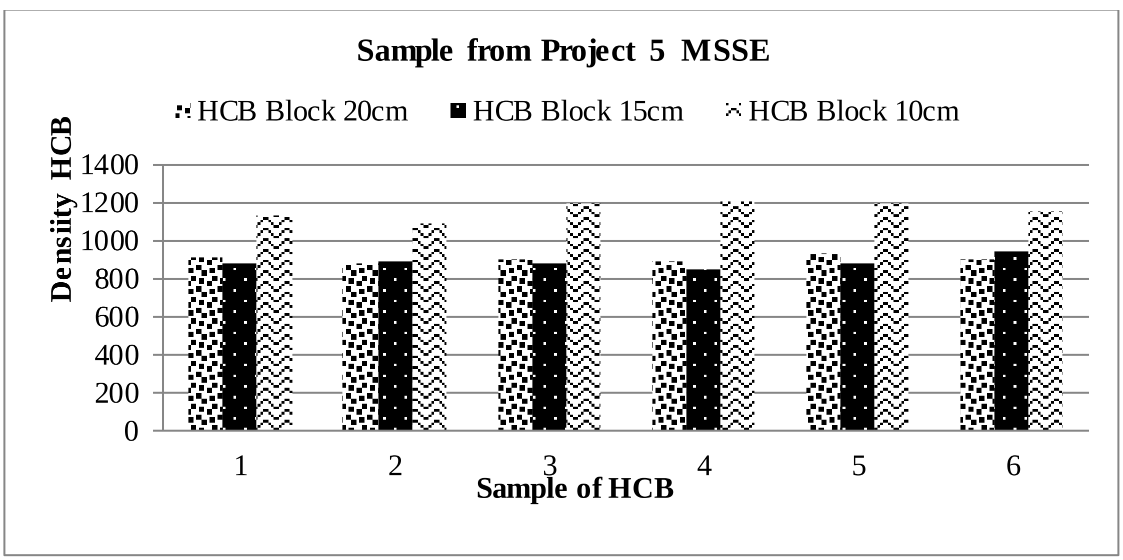

Figure B10: - Specimen Density test results for sample Project 5