ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

DEPARTMENT OF CONSTRUCTION TECHNOLOGY AND MANAGEMENT

POST GRADUATE PROGRAM IN CONSTRUCTION MANAGEMENT

PROJECT FOR THE FULFILLMENT OF MASTER OF ENGINEERING IN CONSTRUCTION TECHNOLOGY AND MANAGEMENT

PROJECT TITE**: HOLLOW CONCRETE BLOCK PRODUCTION AND QUALITY CONTROL (A CASE OF ADAMA TOWN)**

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Acronyms

HCB	Hollow Concrete Block
MOWUD	Ministry Of Works And Urban Development
GTZ	German Technical Corporation
IS	Indian Standard
ES	Ethiopian Standard
ASTM	American Society For Testing And Material
HDPO	Housing Development Project Office
BATCODA	Building and Transport Construction Design Authority
BS	British Standard
IMX	Small and Medium Enterprise
AASHTO	American Association of State Highway and Transportation Officials

Abstract

HCB is one of the most popularly used wall construction material in Ethiopia as well as Adama Town. This project study the types of materials used the production process and the quality of HCB product in Adama town by randomly selecting 30 producers of HCB for interview and observation and suggest quality controlling and improvement mechanisms. The quality of the product is depending on the quality and type of ingredient material used and the production process. This study shows:- The type of ingredient material used, the production process, and the quality of the final product of HCB in Adama town is not as per the desired Ethiopian standard recommendation.

The proportioning of the raw materialsis recommended to be using standard measuring boxes with specified dimensions in the Ethiopian standard, but the proportioning by the respondents is using wheelbarrow which is much greater than the measuring boxes recommended.The mixing is recommended to be done only using mixer in the standards but only 13.3% of the respondents produce using mixer, the rest 86.7% are using hand mixing.

Ethiopian Standard recommends for manufactured blocks on the site shall be cured in water tank or a curing yard by being kept thoroughly moist with water for at least a period of 7days or for 14 days by watering at least 3 times a day. But Only 30% of the producers cure the blocks for 14days or more.

The class of HCB product in Adama town is unknown and sub-standard. Among the compressive test conducted the maximum compressive test result attained is 7.52 kg/cm^2 (0.75MPa), which is much less than the recommended for class C, which is 20kg/cm^2(2MPa). This much difference is occurred due to the absence of controlling body on the material selection, production process and the final product ready for sell.

There is no controlling body on the type and quality of ingredient materials used, the production process as well as the quality of HCB produced in the town. No test is conducted on the ingredient materials as well as the produced HCB. There should be quality controlling body and quality control manual and system from the town administration for the conformance of the quality of the product.

Chapter One

1. Back ground

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 several precast concrete products used in construction. 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. In use, concrete blocks are stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall.

The construction of buildings, 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 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 that can produce up to 2,000 blocks per hour.

These hollow blocks were produced at that time to substitute for stone or wood in the building of homes in United States. The earliest known example of a house built in this country entirely of concrete block was in 1837 on Staten Island, New York. The homes built of concrete blocks showed a creative use of common inexpensive materials made to look like the more expensive and traditional wood-framed stone masonry building. This new type of construction became a popular form of house building in the early 1900s through the 1920s. House styles, often referred to as "modern" at the time, ranged from Tudor to Foursquare, Colonial Revival to Bungalow. While many houses used the concrete blocks as the structure as well as the outer wall surface, other houses used stucco or other coatings over the block structure. Hundreds of thousands of these houses were built especially in the mid western states, probably because the raw materials needed to make concrete blocks were in abundant supply in sand banks and gravel pits throughout this region. The concrete blocks were made with face designs to simulate stone textures: rock-faced, granite-faced, or rusticated. At first considered an experimental material, houses built of concrete blocks were advertised in many portland cement manufacturers' catalogs as "fireproof, vermin proof, and weatherproof" and as an inexpensive replacement for the ever-scarcer supply of wood. Many other types of buildings such as garages, silos, and post offices were built and continue to be built today using this construction method because of these qualities. (Koski,Johan A,1992.)

It is after this time that it has been propagated to other countries including Ethiopia to be used for house construction. Similar to USA, houses had been built from wood and dry stones in the ancient time in Ethiopia, later through technology transfer and sharing of Ideas hollow block as a walling and slab materials introduced in Ethiopia.

Hence, due to the increase in demand of Hollow concrete block from time to time, many private and enterprise companies engaged on the production of hollow concrete block in Ethiopia.

The enforcement of construction of multi-story buildings along the main road sides, the attractiveness of rental price of buildings for business sectors and the increase of the need for shelter increases the need of HCB production in Adama town. However, the hollow block produced by these private organization and enterprises are slightly different in composition, conformance and production process which in turn changes the required quality and standard. The observation of different material usage which is a lime like material, the absence of sand in the mix, and using wheelbarrow for batching and proportioning initiates the checkup of responsible body for the material usage, production process and quality control of HCB production. But no responsible body is observed from IMX office, as well as other governmental offices in Adama Town.

Therefore, it is from this understanding that this paper aimed to study the production quality of hollow block in Adama Town.

Chapter Two

2. Introduction

2.1. Statement of the Problem

The enforcement of construction of multi-story buildings along the main road sides, the attractiveness of rental price of buildings for business sectors and the increase of the need for shelter increases the need of HCB production in Adama town. However, the hollow block produced by these private organization and enterprises are slightly different in composition, conformance and production process which in turn changes the required quality and standard. The observation of different material usage which is a lime like material, the absence of sand in the mix, and using wheelbarrow for batching and proportioning initiates the checkup of responsible body for the material usage, production process and quality control of HCB production.

From the pilot survey to decide on doing the study on this topic, it is observed as no tests are conducted by the producers on the aggregates, cement and water used for the production which directly affect the quality of HCB to be produced.

Due to their poor quality many blocks are broken and wasted during transportation and construction which incur additional cost to the construction of buildings.

In order to achieve producing hollow blocks having good quality fulfilling the required specification, good quality control system should be established. However the availability of controlling body for the produced HCB as well as for the production process and material usage is in question.

The knowledge and skill of individuals involved in the production are also in question.

No researches have been done on the quality of HCB production in Adama town previously.

This observation in the day today life and construction related works Initiates the study of HCB production through this project and propose remedial major.

Therefore the aim of this project is to study the production process and quality of HCB products of enterprises in Adama town to fill the gaps at, constituent material selection and proportioning, and the production process. Finally, to suggest a compiled quality control manual for best implementation of producing better quality of HCB product in Adama town.

2.2. Objectives

2.2.1. General Objectives

- To study the quality of HCB production and to prepare a quality control manual

2.2.2. Specific Objectives

- To study/ survey the production process of HCB in Adma town
- To conduct tests on the produced HCB
- To prepare quality control manual

2.3. Project questions

- How do the producers select the ingredients for HCB production?
- How do they check the quality of the ingredients for HCB production?
- How do they proportion the ingredients for HCB production?
- How do they mix the ingredients for HCB production?
- How do they produce the HCB?
- How do they check the quality of the produced HCB?
- How do they cure the produced HCB?
- How do they store the production?
- How do they control the quality of the production?

2.4. Project Methodology

Literature review:- Reviewing different literatures written about Hollow concrete block (HCB) production, referring Ethiopian standard written about; quality required, standard dimension, required compressive strength, production methodology, classes of the HCB, etc.

Data collection and sampling:-Then collecting information and raw data on the registered HCB producing enterprises from IMX office In order to identify their number (population of the study), location, level of education and other information. Study the trend for quality control of the HCB production in the town. Select representative samples (20 producers) using systematically random sampling based on the number of registered HCB producers (population), which are more than 100 and their location for site visit and Interview.

Tests conducted:-Representative samples of HCB produced taken from, among the enterprises selected for interview for **compressive test** and accuracy of dimensions as per Ethiopian standard. The Sampling and testing procedures is as per the Ethiopian standard recommendation which is 6 blocks from each producers, and the result obtained compared with the minimum strength requirement of class C HCB, according to the percentage of strength attainment.

The dimension of the HCB will be checked (measured) using meter.

It would be better if tests are conducted on the ingredient materials because their quality affects the quality of final product. But the tests to be conducted are many and requires much time that it can't be completed with this limited time. Therefore, the tests to be conducted and their methodology are simply specified in the recommendation.

From the literature reviewed, interview, observation and tests conducted the results discussed and conclusion and recommendation are given. The result and discussion is given with comparison of interview and observation with recommended standards of Ethiopia for quality of products and quality control manual. Below is the schematic diagram of the methodology followed for the project.

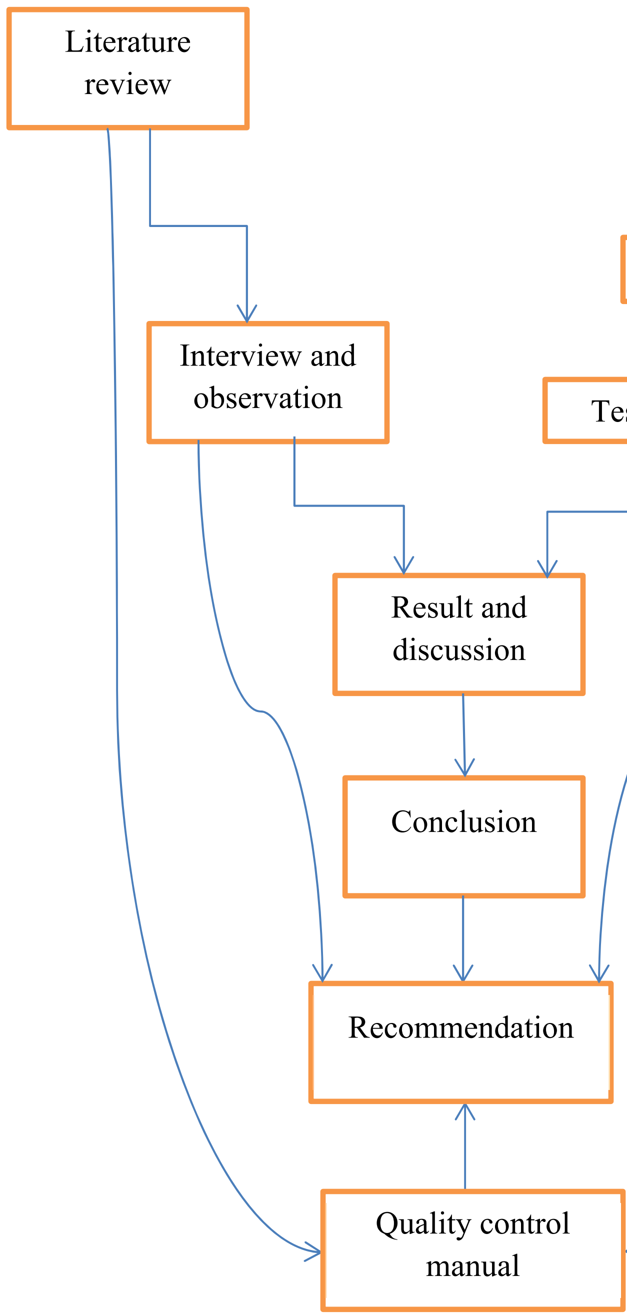


Fig. 2.1. project methodology diagram.

2.5. Project scope and limitation

Due to the limitation of time the project focused on the material usage and production process of HCB blocks produced by limited enterprises in Adama town. Detail Interview and observation of the proses of production are done for 20 producers of HCB.

The recommended material to be used in the production like sand and fillers (00aggregate) is not used in the production so that no test is done on them. The water used are tap water used for drinking and the cement used is a factory made in a controlled manner for its quality unless there is a problem in storage and transportation, so no need of conducting any test on them.

Compressive strength Test is conducted for five of the twenty interviewed producers since their production process, material usage, and test result of all the producers are almost similar and far below the standard. In addition the cost of the test is expensive, because it was supposed to buy the test specimens, rent a pickup car to collect them and take them to Saba Engineering P.L.C. Located in Addis Ababa and pay for the test of each specimen. The test result, material usage and handling, production process and storage studied from the interview and observation is compared with the required standards of Ethiopia to judge on the quality of HCB production in the town. Finally conclusion and recommendation is given for the improvement of the quality of the product. The data collection and storage system of the administration is so poor and not updated concerning the HCB producers that it was not possible to get their exact number in Adama town currently.

Chapter Three

3. Literature review

In order to study the quality of products we should deeply understand what quality means and quality related concepts.

3.1. Important terms and concepts

Quality is degree to which a set of inherent characteristics fulfills requirements [ISO 9000:2000]

Quality is A totality of features and characteristics that bear on the ability of a product or service to satisfy a given need (British Standard 4778 - British Standards Institution, 1991)

Quality is a total composite product and service characteristics of marketing, engineering, manufacture, and maintenance through which the product and service will meet the expectations of the customer (Feigenbaum, 1961)

Quality management is the settlement, supply and required level control required with the systematic monitoring and deliberate action on conditions and factors influencing the production quality.

Quality management has increasingly been adopted by construction companies as an initiative to solve quality problems and to meet the needs of the final customer (Kanji & Wong, 1998).

Nunnally (2007) argued that quality management and quality assurance on the other hand have been adopted to include all aspects of producing and accepting a construction project which meets all required quality standards. He further asserts that quality management includes such activities as specification development, process control, product acceptance, laboratory and technician certification, training and communication. The author concluded that quality control, which is a part of the quality management process, is primarily concerned with the process control function.

Quality Management System is the organizational structure, responsibilities, procedures, processes, and resources for implementing quality management.

Quality Assurance means controlling equipment, materials, processes and staff training throughout manufacture. QA is all about setting and meeting standards in the manufacture process.

Quality Control is all about ensuring the finished product meets the standards set in the specification and by various controlling bodies.

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

Quality assurance; The American Association of State Highway and Transportation Officials (AASSHTO) has defined Quality Assurance (QA) as "(1) All those planned and systematic actions necessary to provide confidence that a product or facility will perform satisfactorily in service; or (2) making sure the quality of a product is what it should be." Regardless of the delivery method, the agency cannot assign the responsibility of acceptance to the contractor.

Quality Assurance is process oriented and focuses on defect prevention, while **quality control** is product oriented and focuses on defect identification.

Product quality control is performed on the product's standardization base and technological processes.

Building materials are materials used at different component parts for the construction of buildings

We can classify building materials used for different components of building as factory and non-factory products, depending on their production such as, concrete and hollow concrete blocks are non- factory products which are mostly produced on site from three basic ingredients; namely, cement, aggregate and water sometimes admixture are used to improve some properties like workability, setting times…. Hence, there are various factors that bring variation on quality.

These factors are quality of ingredients and variation in production processes. As a result, proper quality control is extremely necessitated.

3.2. Introduction to Concrete and Concrete Blocks

3.2.1. Concrete

Concrete is a conglomerate, stone like material composed essentially of three materials: Cement, water and aggregate. Sometimes a fourth material, an admixture (additive for concrete) is added for a variety of specific purposes, such as acceleration or retardation of setting or hardening.

The strength and quality of concrete depend not only on the quality and quantity of the materials, but on the procedures used in combining these materials and the skill involved in the placing and curing of concrete.

To produce concrete as economically as possible with appropriate workability, strength and durability so that care has to be taken during concrete production because poor quality of concrete even from well designed mix can be happen due to lack of attention in production [2].

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

3.2.2. Concrete block (concrete masonry unit)

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 several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. . In use, concrete blocks are stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall.

3.2.2.1. Types of concrete blocks

Concrete blocks are mainly classified into two main groups:

- Solid Blocks
- Hollow Blocks

Solid blocks are blocks which are produces by concrete by a desired dimension without holes. They are used for fence wall construction, load bearing masonry of basements, etc.

Hollow concrete blocks are blocks made of concrete having one or more hollow cavities of specified dimension, and their sides may be cast smooth or with a design made mainly for building wall construction.

Hollow blocks have better thermal properties than solid blocks of the same material and total Thickness, have certain advantages over bricks, they are only about one 3rd of the weight of the same number of bricks and they can be laid about four times more rapidly and are of ample strength for all purposes for which ordinary bricks are. They have the advantages of hollow walls as regards insulation against heat and sound.

While comparing with other masonry units, HCB masonry is a cost and time efficient and economical solution in construction.

Fig 3.1. Hollow concrete block Fig. 3.2. solid concrete block

Hollow Concrete Blocks (HCB) are manufactured into moulds, to achieve the required physical strength and dimensions to requirements and standards.
They are produced, to construct:

a Load bearing walls (Class A & B)
b Non load bearing walls (Class C)

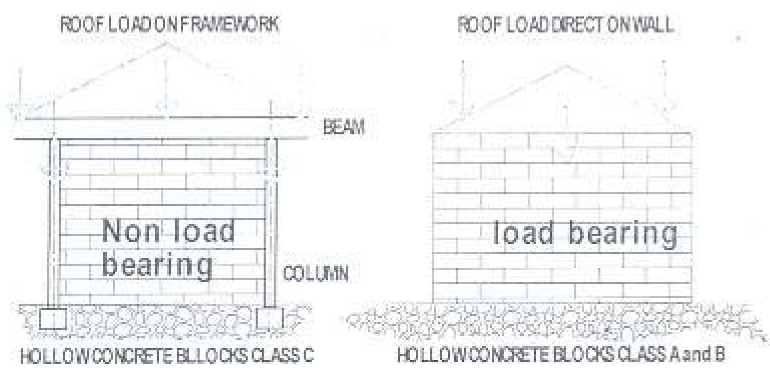


Fig. 3.3. Non load bearing and load bearing wall

3.3. Classes and dimensions of Hollow Concrete Blocks

3.3.1. Classes

Ethiopian standards ESC D3.301 and MoWUD: 2001 hollow concrete block shall conform three classes depends on their strength, as Class A, B and C. Similarly the standard prepared by

BATCODA specified as class AAA, AA, for load bearing solid blocks and classes A, B, C for hollow concrete blocks.

Where:- MoWUD stands for Ministry of Works and Urban Development and BATCODA stands

Class A: According to Ethiopian standard class A is 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/m3.

Class B: These 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/m3 per the Ethiopian standard whereas the Indian standard IS: 2185 (Part I) – 1979 recommended minimum density within the range of 1000-1500 kg/m3 but class C is recommended for non-load bearing wall.

Class C: This class is 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/m3.

According to standard specification compiled by building and road materials construction design S.C Adis Ababa.[15]

Classes A and B are load bearing units and are suitable for

- External walls pointed , rendered and plastered
- The inner leaf of cavity walls or stone masonry
- Internal walls or partitions
- Panels in steel framed and reinforced steel framed buildings

Class C non load bearing units suitable for

- Non – load bearing and partitions
- Non – load bearing internal panels in steel frame and reinforced concrete buildings.

Note:- six full sized samples shall be taken from a lot of 4000 blocks or fraction thereof for the compression test.

3.3.2. Dimensions

Table 3.1. **Standard dimensions of hollow block produced in the production to ESC.DC.301**

Type of hollow blocks	**Dimensions of hollow blocks in cm (l x h x t)**
Hollow concrete block for external wall	40 x 20 x 20
Hollow concrete block for Internal wall/ partition	40 x 20 x 15
Hollow concrete block for Internal wall/ partition	40 x 20 x 10

Table 3.2. The nominal dimensions of HCB according to standard specification of building and road materials construction design S.C Adis Ababa.

Breadth (b) in mm	Height (h) in mm	Length (l) in mm	Face shell (d) in mm	Web (e) in mm	Max. unit weight(kg/m3)
100	200	400	20	20	1200
150	200	400	25	25	1200
200	200	400	30	25	1200
250	200	400	35	30	1200
300	200	400	40	30	1200

3.4. Compressive Strength of Blocks

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/mm2, separately for each unit and as the average for the six units will be recorded [19].

On the other hand British standard BS: 6073 (part I) 1981 recommended for blocks having a thickness of 75 mm or more to test for compressive strength and their average compressive strength of 10 blocks shall not less than 2.8MPa or individual block shall not less than 80 % of the minimum permissible average compressive strength.

The following are the minimum compressive strength requirements for blocks at the age of 28 days. The mix proportions of the material components are to be adjusted as required to obtain the required compressive strength according to BATCODA specification manual (section **043321**).

Table 3.3. **The minimum compressive strength for HCB at 28 days according to BATCODA specification manual (section 043321)**

Class	**Average of 6 Blocks**	**Individual Block**
Class A	42kg/cm2	38kg/cm2
Class B	35kg/cm2	32kg/cm2
Class C	20kg/cm2	18kg/cm2
* Class AA	70kg/cm2	65kg/cm2
* Class AAA	50kg/cm2	46kg/cm2

Solid blocks

- Class AA 120kg/cm^2 load bearing below grade
- Class AAA 85kg/cm^2 load bearing above grade

Table 3.4. **The minimum compressive strength for HCB at 28 days according to ESC D3.301 and MoWUD:2001 is indicated below.**

class	Average of 6 units		Individual units	
	Mpa	Kg/cm2	Mpa	Kg/cm2
A	4.2	42	3.8	38
B	3.5	35	3.2	32
C	2.0	20	1.8	18

3.5. Block Density

According to Ethiopian standard ES 596:2001 and Indian standard IS:2185(part1)-1979 three blocks sample to be taken to conform to the specified requirements. 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. Hollow concrete block is most probably known by its low density. This is due to the cavities or holes in its structure. In addition, it depends primarily 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 (ACI Committee 213, 2003). Specially, in Adama town most of the HCB production ingredients are of low density such as pumice, scoria and red-ash.

Table 3.5. **Classification of Density 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	600-900	1000-1500
D		800 - 1000

3.6. The Ingredient materials, classification and their requirements for HCB production

3.6.1. Aggregates

Material retained on a 4.75 mm sieve is classified as **coarse aggregate**, and below that size as **fine aggregate or sand**. The material passing a 75-micron sieve is generally considered to be clay, fine silt or fine dust in an aggregate. [14]

Sand, Gravel (00 and 01 aggregate), Red Ash, black ash and pumice: should be clean, stored separately close to the mixing plant. All aggregates used for production have to be approved by an independent concrete laboratory. [15]

3.6.1.1. Sand

The quality of the HCB is directly linked to the characteristics and condition of the sand. Sand and aggregates must be free from clay, loam, vegetables and any other organic material. Clay or dirt coating on aggregates prevents adhesion of cement to aggregate, slows down the setting and hardening process and reduces the strength of the concrete. Therefore, clay and silt content should not exceed 6%, otherwise the sand needs to be washed.

3.6.1.2. Lightweight aggregate

Aggregate having a loose bulk density not more than 1 200 kg/m3 for fine aggregate or not more than 1 000 kg/m3 for coarse aggregate

A) Pumice and scoria

Pumice and Scorea are a natural volcanic igneous rock containing air voids and having an open texture. Pumice is formed as a result of steam or gas bubbling out of molten lava leaving behind empty pockets that give the solidified lava spongy appearance. It has a granular texture and is very light to the extent it can float on water. It is usually white-gray to yellow in color, but may be red, brown or sometimes black, according to the oxides, or impurities it contains. Scoria or volcanic ash (red ash), has generally a porous rough surface, and is usually red to

black in color.

Pumice

lime like material

Fig. 3.4. Raw materials used for HCB production in Adama town

B) Expanded clay, shale and slate

Aggregates produced by the pyroprocessing of certain argillaceous materials

C) Processed pulverized-fuel ash (fly ash)

Aggregates produced by pelletizing fly ash and stabilizing by pyroprocessing or other means

D) Furnace bottom ash

A fused residue from furnaces fired with pulverized coal

E) Foamed blast furnace slag

Aggregates manufactured by foaming molten blast furnace slag with sufficient water or other suitable medium to produce a cellular product

F) Pelletized expanded blast furnace slag

Expanded blast-furnace slag produced in pelletized form

G) Clinker

A fused residue from furnaces fired with coal which has not been pulverized

3.6.1.3. 00 and 01 aggregate

00 and 01 aggregate are crushed stone of maximum size 4.75mm and 12.5mm respectively, usually used as surface treatment and base coarse in pavement construction. These are good if used in HCB production giving strength and better quality product.

3.6.2. Cement

Portland Cement (O.P.C.) shall be used for the production of HCB.

Cement should be stored in a dry and moisture free place. Limit the height of stocking to prevent lumping up under pressure.

Most Portland cements are transported by truck. Cement is a moisture-sensitive material; if kept dry, it will retain its quality. Cement stored in contact with damp air or moisture, sets more slowly and has less strength than cement that is kept dry [5] so that all cracks and openings in walls and roofs should be closed. Cement bags should not be stored on damp floors but should rest on pallets and stacked close together to reduce air circulation but should never be stacked against outside walls.

In addition to this Bags should be covered with tarpaulins or other waterproof covering when stored for long periods and its arrangement should be follow first in are the first out method.[9]

On small jobs where a shed is not available, bags should be placed on raised wooden platforms (pallets) above the ground. Waterproof coverings should fit over the pile and extend over the edges of the platform to prevent rain from reaching the cement and the platform. Rain-soaked platforms can damage the bottom bags of cement. Cement stored for long periods may develop what is called warehouse pack. [9]. This can usually be corrected by rolling the bags on the floor. At the time of use, cement should be free flowing and free of lumps. If lumps do not break up easily, the cement should be tested before it is used in important work. Standard strength tests or loss-on ignition tests should be made whenever the quality of cement is doubtful.

In addition to this Bags should be covered with tarpaulins or other waterproof covering when stored for long periods and its arrangement should be follow first in are the first out method.

3.6.3. Water: must be clean and free of un-purifications

Not only the quality, but equally important the quantity of the water is important for producing good concrete products.

a. Type and quality

Almost any natural water that is drinkable and has no pronounced taste or odor can be used as mixing water for making concrete products. Water suitable for making concrete, however, may not be fit for drinking.

b. **Seawater**

Seawater should not be used as mixing water for concrete.

c. Collected rainwater from roofs

Rainwater collected from roofs can be used for mixing concrete.

d. Oils

Various kinds of oil are occasionally present in mixing water. Water mixed with any kind of oil should not be used for mixing concrete.

e. Water storage

Water should be stored where no contamination is possible. Water stored in clean drums or covered tanks is preferred. The age of the water, or the storage time does not affect the concrete product quality in any way.

3.7. Tools, Machinery & Equipment used for HCB production

Must be in perfect condition and sufficient in numbers to suit the daily production needs.

Regular cleaning, maintenance of all machinery & equipment is essential to keep the agreed quality standards.

An adequate stock of spare parts for all machinery has to be kept, in order to safe guard production.

Before starting to work, the appropriate hand tools and equipment have to be carefully selected. Tools should always only be used for their intended purpose.

A tool which is regularly maintained, cleaned and kept in a dry place will last longer and will also be more pleasant to use.

Below a list of tools/equipment for manufacturing concrete products:

- building block machine (compact and mould the block)(8)
- sand sieves (big and small) (pic. 1 and pic. 2)
- sand mixing boxes (pic. 3)
- trowels (pic. 4)
- shovels (pic. 5)
- watering cans
- buckets (pic. 6)
- wooden plates
- plastic canvas (for covering the products in order to keep them moist)
- mixer(7)

- measuring boxes

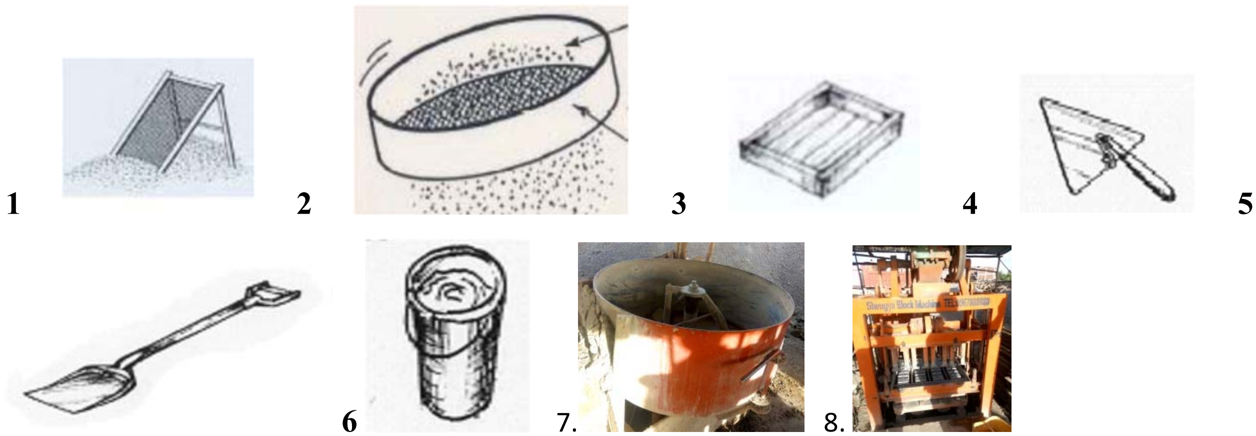


Fig. 3.4. Tools, Machinery & Equipment used for HCB production

3.8. The production process of hollow concrete blocks

In hollow concrete block (HCB) productions there are two paramount important activities one is related to ***raw materials*** and the other is ***related to the process*** involved in its production. In order to produce good quality of HCB care has to be taken for both steps. [6]

If due attention is not taken for materials on their quality and handling mechanism, poor quality of HCB products might be obtained what so ever the production process is correct. For example the following are some problems that are encountered related to materials and handling. [9]

- **Poor quality of aggregates**:- If no tests are conducted on the aggregates before using them they may contain much amount of organic impurities, silt or dust, and any other impurities leads to low strength of HCB. If the strength of the aggregate itself is less it also affect the strength of the HCB.
- **Poor handling and storage of cement:-** if atmospheric moisture gets the cement through any hole of the cement bag or if the bag has any contact with water on the floor the cement will immediately set and harden so that it will loses its binding property.
- **Utilization of unclean or contaminated water:-** if we don't use the tap water for drinking, unpurified water may contain acids, bases, silt or dust and other impurities which may chemically or physically affect the quality of the HCB as well as the persons on production.

In similar way, there are problems occurred related with process management unless otherwise strong monitoring system is in place. Such as, inadequate curing time, problem of mixing ratio, problem of drying time, poor/no recording time of production, shortage of testing the produced block frequently...etc .

If there is any quality problem or defect with the constituent materials or/and production process then there will be quality problem on the produced HCB. This maximizes the tendency of getting poor quality of HCB product.

However the awareness of individuals in the production about all these consequence is in question?

The HCB production area must be even and smooth surface for all facilities for production. That are :- Aggregate storage places, Mixing plant, and Material storages.

The storage places should be as close as possible to the production area.

The production process of HCB involves the following major steps;

- Batching or proportioning of ingredients
- Mixing
- Compacting/Vibrating
- Drying
- Curing

Before production can commence, all materials have to be approved by an official concrete lab.

The mixing and batching will be strictly done on the mix ratio provided by the official concrete lab.

3.8.1. Batching /Proportioning

The determination of suitable amounts of raw materials needed to produce HCB of desired quality under given conditions of mixing, placing and curing is known as proportioning. As per Ethiopian Standard specifications (Addis Ababa condominium housing projects HCB production training manual), 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 for class C HCB and not more than 4 parts to 1 part by volume of Portland cement for class B and A. The water cement ratio of 0.7 by weight basis according to EBCS -2 (table 8.2 in case of completely protected against weather) can be used for concrete hollow blocks.

3.8.2. Mixing

The objective of thorough mixing of ingredient aggregates, cement and water is to ensure that the cement-water paste completely covers the surface of the aggregates. As per the Indian experience, 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. However, the Ethiopian experience is that the main ingredients usually pumice/scoria, red ash, aggregate(of 0.00 &01 aggregate; max. 4.75mm and max. 12.5mm size respectively), sand, cement and water are mixed manually or by mixer until the paste is uniformly mixed thereafter added to the HCB mold for vibration.

A) Hand mixing

Hand mixing is adopted where in smaller quantities of aggregates are involved or the involvement or procuring of mixing machines is out of reach. Mixing shall always be done on a watertight platform in order to avoid cement water seepage.

Procedure for proper hand mixing: [14]

- Spread the measured quantity of sand in a layer of about 10 cm on the mixing platform;
- Place the cement on top of the sand and mix the two thoroughly together until they form an even color;
- Pile the mixture into a heap and make a hollow in the middle;
- Pour in water slowly in small quantities and mix until a smooth paste is formed;
- If you choose to use aggregate, add now the correct amount of aggregate and mix until every aggregate is properly coated.
- Check your mix: take a handful of the mix and form a small ball. If the ball in your hand does not crack, and your hand is a little bit wet, the mix is ready to be moulded.

Flatten the dry mix with a trowel, if properly Add water only once a uniform gray color is mixed a uniform gray color is visible.

B) Machine mixing

Machine mixing is required for large quantities of concrete work and for good workability for placing the concrete in a short time and with no wastage. Concrete having coarse aggregates is mixed in concrete mixers.

Procedure for machine mixing: [14]

- Measure the quantities of each ingredient;

- First add the aggregates and some amount of water, then the cement, then the sand;
- Mix and add more water until the right consistency is reached;
- Empty the mixer completely when discharging each batch;
- Clean the concrete mixer thoroughly on completion.

Different mix ratios

Based on customer's needs and different qualities of products, the mix ratio for concrete can be various. In general, the more cement used in the mix the higher the quality will achieved but also the more expensive your product will be for the costumer [14].

To make a **high quality concrete hollow block**, which can be used for walls of houses, the mix ratio should be: 1 part good quality cement + 2 parts clean river sand + 3 parts rough gravel + sufficient water Keep in mind that for building houses always best quality blocks are to be used as the safety of families moving into the houses[14]. According the manual prepared for training HCB producers for condominium building projects for class B blocks 1 part of cement + 1 part sand + 1 part of red ash + 1 part 00 aggregate + 1 part 01 aggregate. For class C 1part cement + 2 sand + 3 part red ash + 0.5 part 00 aggregate + 0.5 part 01 aggregate [table7.5and 7.6].

3.8.3. Compacting/ Vibrating

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. Semi-automatic vibrating table type machines are widely used for making cement concrete hollow blocks. The machine consists of an automatic vibrating unit, a lever operated up and down metallic mould box and a stripper head contained in a frame work. Wooden pallet is kept on the vibrating platform of the machine. The mould box is lowered on to the pallet. Concrete mix is poured into the mould and evenly leveled. The motorized vibrating causes the concrete to settle down the mould. More of concrete is then raked across the mould level. The stripper head is placed over the mould to bear on the leveled material. Vibration causes the concrete come down to its limit position. Then the mould box is lifted by the lever. The molded hollow blocks resting on the pallet is removed and a new pallet is placed and the process repeated. The machine can accommodate interchangeable mould for producing blocks of different sizes of hollow blocks.

3.8.4. Drying

Drying is defined as the change in linear dimension of test specimen due to drying from saturated condition to an equilibrium weight and length under specified accelerated drying condition. Dimensional changes of units has a significant effect on cracking that may be takes place during the early curing and drying which leads to a reduction in volume due to loss of moisture. 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 (Indian standard IS 2185(part 1).

The Ethiopian standard, MoWUD check list for supervisors, 2001 reveal that hollow concrete blocks are properly dried under shade for at least 14 days before they are used for construction.

3.8.5. Curing

Curing is one of the most important activities in the production process. The purpose of curing is to replace the evaporating water through sun and / or air. Also the hydration process which is a chemical reaction, needs water to set / harden the mortar. Once the HCB`s are dropped on the floor, they must be protected from sun and kept constantly moist. This may take about 24 hours in a shelter away from sun and winds as per the Indian standard. 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.

Indian standard IS: 2185 (Part I) – 1979 recommends for manufactured blocks on the site shall be cured in water tank or a curing yard by being kept thoroughly moist with water for a period of at least 14 days. When the blocks are cured in an immersion tank, the water of the tank shall be changed at least every 4 days. On the other hand, steam curing can be adopted for the purpose of reduction curing time. The blocks shall be stocked on a clean and level platform free from earth or other impurities during the curing process, and shall be stocked in honeycomb fashion with voids horizontal to facilitate through passage of air. The blocks shall not be used prior to one month after production in order to complete initial shrinkage before blocks are laid in the wall.

As per the GTZ low cost housing manual prepared under Ethiopian context Volume I recommends 10 days of curing time, in addition to this, date of production must be write on blocks for the purpose of identification whether it is ready or not for construction. According to Ethiopian standard, hollow blocks shall be kept moist for at least seven days after casting (MoWUD check list for supervisors, 2001)

3.8.6. Stockpiling

Take care that there is always a sufficient stockpile of cement, aggregates and HBC`s on site to buffer delivery problems and to safeguard production on site. [1]

3.8.7. Keeping Records and Reporting

Every daily HCB production has to be marked with the production date, in order to avoid errors in storage/curing time. [1]

The amount of daily production has to be in accordance with the product order, store size and market expectation. The products should be recorded on a daily base, and the quality achieved.

The official concrete laboratory will on a monthly base take samples of blocks and aggregates and check those samples in their lab.

Results are to be reported to producers as well as controlling body.

3.8.8. Operational Staff and Supervision

In order to achieve the best possible quality a specific group of workers should be trained on:[1]

- batching
- mixing
- pouring into the mould
- operating the block making machine
- transporting the blocks
- curing and stocking

If the need of HCB production requires shift works, then the precast yard has to be layed out accordantly.

Supervision / Quality control will be carried out, the concrete lab. the Resident engineer and the site manager of the implementing agency.

Chapter four

4. Data collection and sampling

Simple random sampling where all the group members has equal probability to be selected is adapted to identify the number of groups or entities with whom to conduct the interview. The total numbers of enterprises of HCB producers are about 100 enterprise/entities licensed and engaged on HCB production according to the information from the IMX office of Adama town and Adama town HCB producers' organization. Among them 20 respondents (HCB producers) are randomly selected.

After the numbers of samples/ respondents have been determined, questions prepared which are simple and can directly touch the objective of the project. Thereafter, conduct interview by asking those questions and record the response from each respondent selected using simple random sampling among the enterprises.

Finally, the required data were collected as per the questions presented to the 20 respondents and analyzed by using different statistical tools. The questioner and response the respondents are specified in Appendix A and B of this project paper respectively.

Then from the twenty interviewed respondents five of them were selected using systematic random sampling. Among the 20 respondents only three of them have mixer for mixing therefore only one the three selected and the other four from the rest 17 respondents who have no mixer. Six HCB block samples are taken from each enterprise (as per ESC D3.301, MoWUD:2001, BATCODA(section 043321) and taken to SABA Engineering PLC laboratory found in Adis Ababa for Compressive Strength test.

First, measurement is taken for their dimension on three of the six samples taken from each respondent to compare with the standard dimension requirement before the compressive strength test. The test result is specified on Appendix C.

Chapter five

5. Result and Discussion

5.1. Quality of Raw Materials

The raw materials or ingredients used for production of hollow block production in Adama town are pumice ((commiche) local name)), scoria (red ash and black ash), white gray clay ((beleche) local name)), limestone like material which is the waste of aluminum sulphate factory, The producers are directly using these materials just as it arrives from quarry site without conducting any test.

During interview the respondents explained that there is no test or any other method to check the quality of these aggregates. In addition to this it is observed that the aggregate materials were damped here and there at the production site mixed with local clay and dust particles. Hence, if aggregates are not properly handled and proper quality test is not conducted progressively for sure it brings quality problem on the produced HCB.

5.2. Hollow Block production process

Production process is composed of batching, mixing, compaction (vibration), drying and curing. Finally, those hollow concrete blocks must complied with the requirements stated in the recommended standards in terms of dimension, density, water absorption, linear shrinkage and compressive strength by testing on sample of blocks. And the number of samples and selection procedures should follow right procedure which is stated in the recommended standard (Ethiopian Standard). Accordingly, this project will going to evaluate and analyze the Adama town hollow block production process quality against the Ethiopian standards based on the collected data through interview, observation and conducted tests.

5.2.1. Material selection and usage

The materials recommended by Ethiopian standard for HCB wall of condominium buildings of Addis Ababa are cement, Sand, Rad ash, 00 aggregate, 01 aggregate and water. However from the observation and interview, the materials used for production of HCB in Adama Town are, Cement, Red ash, Black ash, pumice (comiche), beleche (light gray clay), limestone like material which is a waste from aluminum sulphate factory, and water. This indicates that the producers in

Adama Town use Pumice (comiche) and light gray clay(beleche) instead of sand, 00 aggregate, and 01 aggregate which are very much different in properties like density, compressive strength and others. Which can strongly decreases the compressive strength of the HCB produced because the strength of the aggregate affects the strength of concrete [10]. The producers use the limestone like material to mix with water to be used for mixing. They respond as it increases the binding properties of the HCB production and make the HCB whitish so that the customer will bay it even at 7 days because it makes the HCB simce dry and cured. That is to fake or put false image to the buyers. However its chemical composition and effect when it reacts with cement is not known. Therefore, from these we can conclude that material selection is among one of the main reasons that strongly decreased the compressive strength of the HCB produced in Adama Town.

Lime like material mixed with water

The storage of the material is also the one that affects the quality of the HCB produced but from the observation, the materials used are not properly stored and handled. The cement used for the production should be stored in a situation that it shouldn't have contact with moisture. But from the observation in 13 of the 20 respondents (65%) it is stored in corrugated steel walls store which has openings and holes that it would be prone to moisture specially if there is rain and humid atmosphere. When it is stored, the height of stocking should be limited to prevent lumping up under pressure. Ethiopian standard [ES 1177-1:2005] limit 8 bags high and protected by waterproof structure. But it is stocked upto the roof (22bags) in the store of some of the HCB producers and almost all of cement sellers.

Fig.5.1a. cement storage. Fig.5.1b. Cement storage inside and side view

Fig5.1a. Shows Good storage house but too many bags (22) vertically arranged up to the roof of the storage

Fig.5.1b. Shows good cement storage which is the cement bag is not in contact with the floor and only a maximum of 5 bags vertically arranged. But the store house is of poor qualities which have many openings and made of corrugated steel wall from three sides.

All the aggregates to be used should be free from silt, dust organic impurities and stored separately to each other [1] [8] [14]. But from the observation most of them stored the aggregates together partially mixed, which can affect the proportion. The storage is in such a way that it is exposed to silt, dust and organic impurity, but the entrance of these particles in the mix decreases the binding property of the cement and its compressive strength. See fig 5.2 and 5.3.

Fig. 5.2. material storage around ASTU (res. 03)

Fig. 5.3. Material storage at silase site (res. 04)

The water thanks are open and exposed to dust, silt, and organic matter which affect the quality of water, then the strength of the HCB if this water used for mixing. From the interview it is responded that the water is used for curing but also for mixing the ingridients during the absence of tap water.

Fig. 5.4.Water thank in front of Cherkacherk (resp. 15)

Fig. 5.5. Water thank around ASTU(resp.02)

5.2.2. Batching/ 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 Ethiopian Standard specification, 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 1:6 (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 concrete hollow blocks.

However, the data collected from HCB producers in Adama town revealed that almost all of them are using volumetric for batching which is by wheel barrow. But only one of the respondents use measuring box of 50 * 40 * 20 cm for proportioning the ingredients. The wheelbarrow contains much more amount of aggregates than the standard box recommended by the Ethiopian standard. This increases the amount of other ingredients batched with 1 bag of cement. For instance The volume aggregate carried by wheel barrow like in the figure bellow approximately 0.097m3 whereas the volume of box for class C HCB is 0.036m3. This shows they are using 2.69m3 times of the recommended volume of box per 1 bag of cement.

Fig. proportioning using wheelbarrow at gendegara site (res. 01)

During data collection it has been observed that, there was very weak controlling during batching because there are aggregates which are simply added by shovel not included in the proportion like limestone like material by mixing it in water. Generally, as per the data collected the proportion they are using is more or less similar which is 1: 6 in average. which means for one bag or 50kg of cement 6 wheel barrow of aggregate of different type(red ash, black ash, pumice, light gray clay (beleche)). The main problem here is that, the wheel barrow is big and not matches with the standard batching box. Therefore, even though 1: 6 ratios is acceptable per the standard but this 6 part aggregate should have to be measured with the common standard batching box not with big wheel barrow which is equal to 2.69times of the volume of the measuring box. We can observe this from the number of HCB they produced from one bag of cement, as they respond during the interview most of them produced 40block of 20cm thick but the standard says not more than 17blocks can be produced. They produce more than twice of the number of HCB to be produced with one bag of cement. That is why the compressive strength results of the tests conducted are much less than the expected result recommended by the standard. Therefore batching or proportioning is one of the main factors that affect the compressive strength and quality of the HCB produced in Adama town.

5.2.3. Mixing

The objective of thorough mixing of ingredient aggregates, cement and water is to ensure that the cement-water paste completely covers the surface of the aggregates. As per the Indian experience, 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.

Regarding to mixing of ingredients 85% of the respondents (17 of the 20) are using hand or manual mixing of ingredients only 3 of them (15%) are using machine mixer but the Ethiopian standard recommend to use mixer for mixing. During the data collection it have been tried to observe how the producers are mixing on the ground, at that time, everybody were running just to manufacture many HCB blocks per day rather than giving due attention to thorough mixing of ingredients. While mixing on the ground the probability of dust and other unnecessary materials to be entered in the mix is high. This has impact on the quality of the final product, since dust decreases the binding property of the cement. There will be also aggregate particles not mixed with the cement and water during hand mixing (mixing with shovel). this also decreases the quality of the HCB produced. Those producers who use mixer have the probability to solve these problems. The mixer they use is the one which is bought with the block producing machine designed for controlling volume of one batch. The block producing machine of one of the producers of HCB have a conveyor belt attached to the mixer. The belt feeds the mix to the block producing machine this helps to control the time interval between mixing and molding.

Fig. 5.6. Hand mixing and proportioning

Fig.5.7. Mixer for HCB production at Atana Tera

5.2.4. Compaction

The purpose of compacting/vibrating 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. Semi-automatic vibrating table type machines are widely used for making cement concrete hollow blocks. The machine consists of an automatic vibrating unit, a lever operated up and down metallic mold box and a stripper head contained in a frame work wooden pallet is kept on the vibrating platform of the machine. The mold box is lowered on to the pallet. Concrete mix is poured into the mold and evenly leveled. The motorized vibrating causes the concrete to settle down the mold. More of concrete is then raked across the mold level. The stripper head is placed over the mold to bear on the leveled material. Vibration causes the concrete come down to its limit position. Then the mold box is lifted by the lever. The molded hollow blocks resting on the pallet is removed and a new pallet is placed and the process repeated. The machine can accommodate interchangeable mold for producing blocks of different sizes of hollow blocks.

There are, two vibrating machine are employed in Adama town HCB producers, such as Electric operated vibrating machine and manual operated machine. Those using electric operated machine are producing many hollow blocks per day than the manual. The electric operated machine can produce up to six HCB blocks at a time while the manual one produce one HCB block at a time. In terms of quality it is obvious that electric operated is the better one since it is manageable and adjustable to the required amount and limit excessive compaction. That means excessive compaction leads to formation of water pockets or layers with higher water content and poor quality of the product. However, during the interview it is understood that there is no fixed time for every compaction or the producers don't know for how long or to what extent vibration can be done. From the observation during the production visit and interview most of the producers vibrate and compact the mix in the machine 30 to 40 seconds for each production. However the standard recommends the process to be done in one minute. This minimizes the extent of compaction and binding of the ingredient materials of the HCB produced, which strongly affect the strength.

5.8. Automated HCB producing machine around Atanatera (res. 17)

5.2.5. Drying and Curing

After it is moulded and compacted in the machine Drying is the next step. Once the HCB`s are putted on the floor on its plate, they must be protected from sun and kept constantly moist. This may take about 24 hours in a shelter away from sun and winds as per the Ethiopian standard. Curing is one of the most important and key activities for quality production of hollow block. The purpose of curing is to replace the evaporating water through sun. Also the hydration process, a chemical reaction needs water to set / harden the mortar. 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. From my observation and interview the curing process is done by sprinkling water twice or three times a day. While sprinkling, the water will not be uniformly distributed through the whole HCBs to be cured. In addition the curing period will be depending on the availability of the market. If buyer comes the HCBs will be sold within 7 to 10 days of curing. These will strongly decrease the strength attainment of the HCBs. The problem will be aggravated since most of the producers are not curing under shade. This moisturization of HCBs using sprinkling of water 2 to 3 times a day is not satisfactory because the water will be lost due to evaporation since it is not kept in moist condition. The standard says HCB must be well cured: kept continuously moist for 7 days under shad or for 14 days by watering at least 3 times a day.

But from the observation no producer is curing in moist condition at all.

Among the 20 manufacturers only 4 of them are curing under shade which is only 20% of the total sample.

Even if they don't keep it moist, 17 of the 20 producers (85%) cure at least for 7 days.

Since most of the producers are curing the blocks by sprinkling water three times a day we should consider at least 14days of curing. 6 of the 20 producers cure for 14days or more which is 30% of the producers.

Table 5.1 curing period of the respondents

curing in days	10	15	7	7	12	3	8	15	10	3	15	15	15	15	4	7	8	8	7	10
enterprise	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

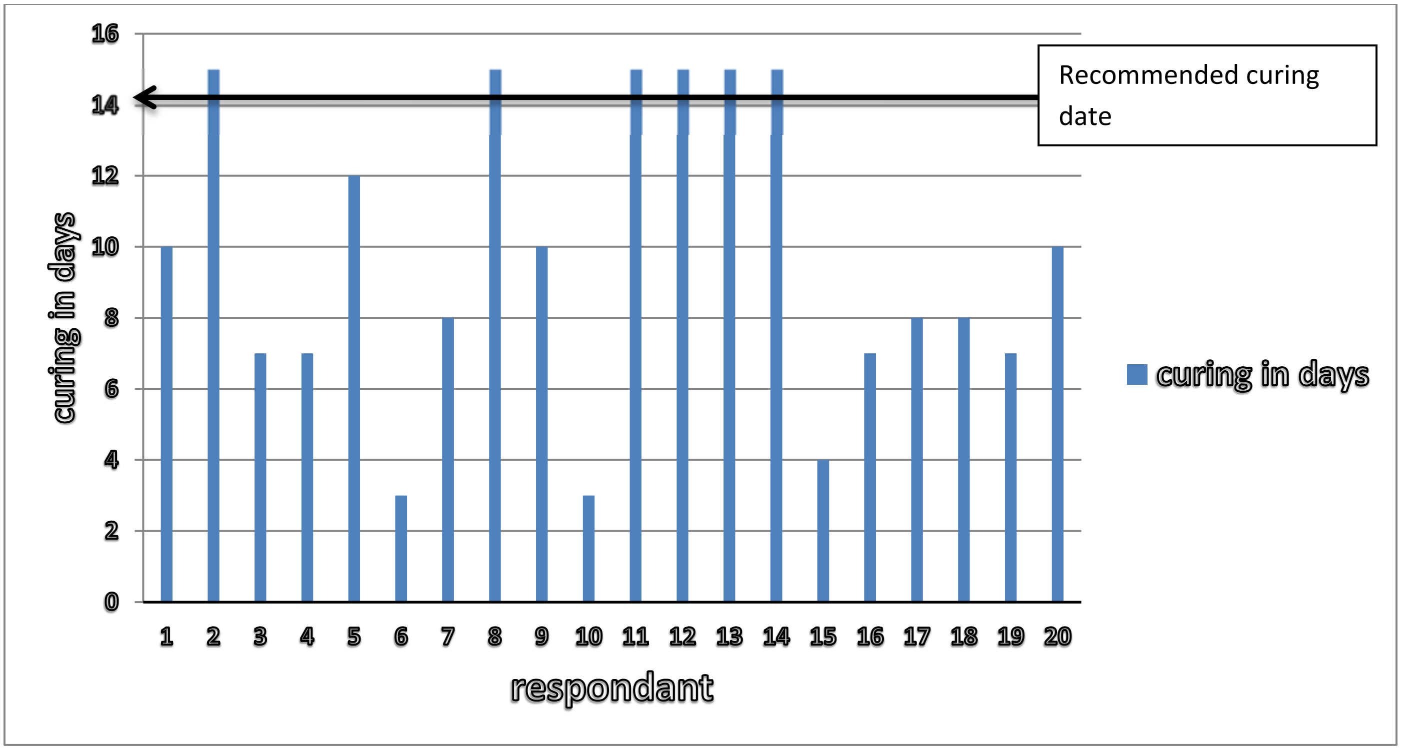


Fig. 5.9. Histogram of curing in days of respondents

Fig. 5.10. Dying process at gendegara site   Fig. 5.11.curing process by sprinkling tap water around Cherkacherk

5.3. Quality Standard and Conformance

As it is indicated in the literature review part in detail hollow blocks shall be tested in the laboratory for the conformance of Compressive strength, block density, water absorption, drying shrinkage and moisture movement.

According to the MoWUD check list for supervisors, 2001 a minimum amount of blocks selected for test sampling should be 6 blocks per 1000 blocks of blocks. And Ethiopian standard [ES 596: 2001] the blocks required for carrying out tests is 12 hollow concrete blocks from every consignment of 10,000 blocks.

However, as per the data collected through interview 100% of the respondents do not conduct test for quality conformance. Regarding to the frequency of testing, there is no respondent which conduct laboratory test even once yearly. Therefore, this implies that 100% of HCB blocks produced are used for construction without laboratory test.

This shows there is no responsible body for the conformance of the quality of HCB production in Adama town.

5.4. Classes, Dimensions and texture of Hollow Blocks

5.4.1. Class

Classes of hollow blocks are determined by the compressive strength of the blocks to be used for load bearing or non-load bearing walls according to Ethiopian standards (ES).

However, the actual information collected from the targeted respondents is amazing, which means the producers are just using constant mix ratio and do not know class of hollow block. As mentioned above, they are not conducting laboratory test at all, so that the absence of class of hollow block is not surprising. During the survey, respondents replied that, no one has asked them about the class of hollow block, so that they don't know even its existence.

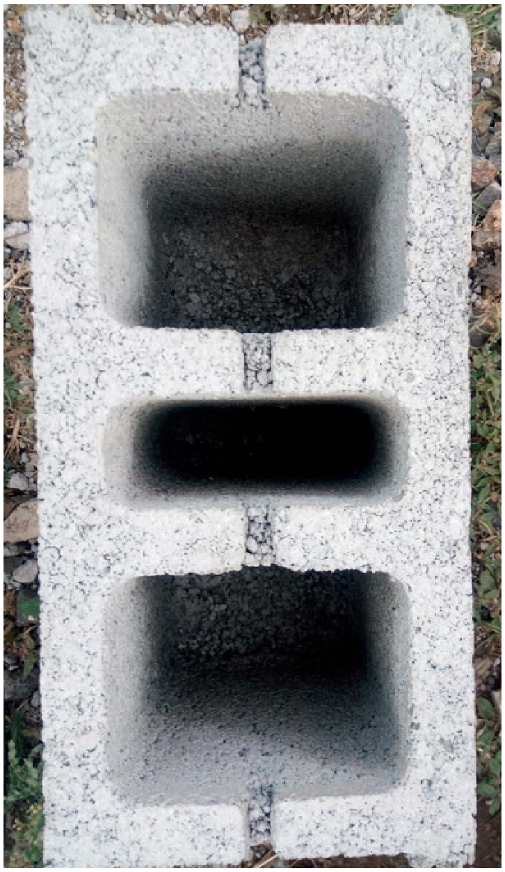
Among the compressive tests conducted the maximum compressive test result attained is 7.52 kg/cm^2 (0.75MPa), which is much less than the recommended for class C i.e. 20kg/cm^2 (2MPa). This much difference is occurred due to the aggravated effect of the raw material used, proportioning, mixing and curing are not as per the standards and absence of controlling body on the whole process.

Respondent	Avg. compressive strength in Kg/cm2	Avg. compressive strength in MPa
01	5.73	0.57
02	5.60	0.58
03	7.01	0.70
04	7.52	0.75
05	5.50	0.55
Avg. Compressive strength Recommended in ES for class C	**20**	**2**

Therefore, according to the data gathered, it is possible to conclude that HCB produced in Adama town are not as per any standard. As shown in the table above the average compressive strength is much less than the lower class which is class C.

Dimension

Regarding to the dimension of the HCB, almost all respondents are producing 40x20x20, 40x20x15 and 40x20x10 in similar way. However, 20cm & 15 cm thick produced without order because the demand is high whereas 10cm thick is produced with order, the respondents said. The dimensions of the products are accurate as per the standard. The dimensions of three of the 6 blocks bought for compressive test from each producer of the 5 respondents selected for compressive test has been measured and all the dimensions are as per the Ethiopian standard. However it is observed that most of the respondents produced HCB of 3holes keeping the external dimension as it is. They respond as the hole at the middle which is added is good for dividing the HCB in case of a half blocks is needed during masonry construction. This helps to minimize wastage of HCBs during masonry construction when half block is used for bonding. Because when the HCB of two wholes is used only one half of it is used for bonding the other half can't be since it will be broken or left with three sides (u shaped). It is also observed that one respondent is producing HCB which is closed from one side, they respond as it is done to minimize the amount of mortar and broken HCB chips added in the holes during masonry works by arranging the closed part upward. The ideas the respondents rising are interesting but needs detail research works from different angles before deciding to make a change from the recommended standards because it may have other draw backs from another perspective.



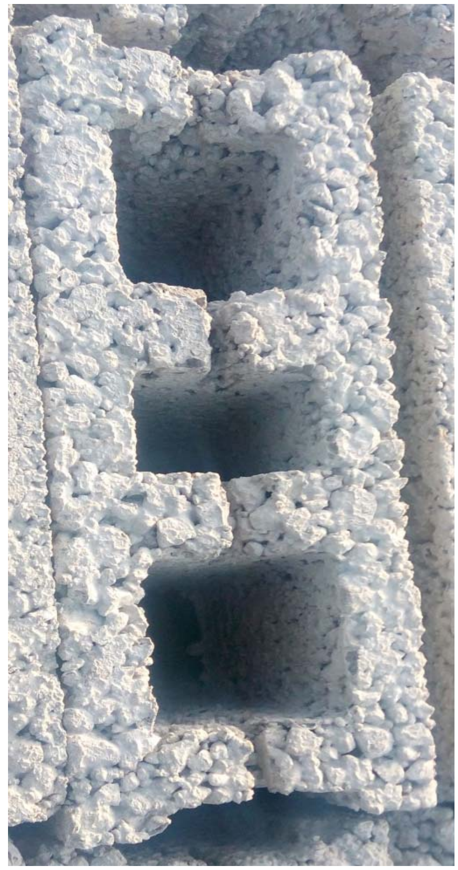


Fig. 5.12. HCB of three holes and good texture Fig. 5.13. HCB of three holes and poor texture

5.4.2. Texture

The textures of the HCBs produced by the three respondents who are using modern and automated producing machine (see fig. 5.8) is good and have difference from those using the commonly used mechanical once. The HCB in fig. 5.12 above is the product of one of the automated machine and use mixer for mixing and having good texture. Whereas, figure 5.13 above is the HCB produced by mechanical producing machine and hand mixing is used for mixing the ingredients. The texture can help to visualize the level of compaction and concentration of cement and fine aggregate in the product which directly related to the strength and the quality of the HCB as we can compare from the figures 5.12 and 5.13 above.

5.5. Production Amount

The amount of production per 50kg of cement is inversely proportional to the quality and strength of HCB. That means, increasing the amount of HCB block per 50kg of cement beyond the standard implies that, the compressive strength will be decreasing and decreasing progressively and finally reach the substandard HCB stage. But, the data collected from Adama town HCB producers are by far beyond the amount recommended in the standard, see table 5.2.

That means, the data revealed that more than 70 hollow block pcs with dimension 40x20x10cm are being produced by 50 kg of cement, 50 to 65pcs of 40x20x15cm blocks are being produced by 50kg of cement and 40 to 50 pcs of dimension 40x20x20cm blocks per one bag of cement. When we take the average value from the table below the amount of 20cm thick blocks produced is 46.7 whereas the recommended value proposed by the manual for HCB of condominium buildings is 17 blocks. That is they produce 2.74 fold of the recommended number of HCB to be produced. Similarly, When we take the average value from the table below the amount of 10cm thick blocks produced is 75 whereas the recommended value proposed by the manual for HCB of condominium buildings is 33 blocks. That is they produce 2.27 fold of the recommended number of HCB to be produced. Therefore, from these we can clearly see the reason that the compressive strength of the tested HCB is much lesser than the recommended value by the Ethiopian standard.

The amount of HCB produced by the enterprises and the recommended amount in the standard using the ingredients prepared for 1 bag of cement is as follows.

Table 5.2 number of HCB produced per 1 bag of cement by the respondents and the recommended amount.

No. of HCB produced per 1 bag of cement	15cm thick	50	60	60	50	50	60	52	57	50	60	60	60	50	57	60	60	65	50	57	60	**56.4**
	20cm thick	45	50	50	40	45	50	42	50	45	50	42	50	40	50	50	48	50	40	47	50	**46.70**
	10cm thick	70	75	80	70	70	80	75	75	70	75	85	75	70	80	70	70	100	70	70	70	**75**
No. of HCB recommended per 1 bag of cement	20cm thick	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	**17**
	10cm thick	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	33	**33**
																						Avg.
respondent		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	

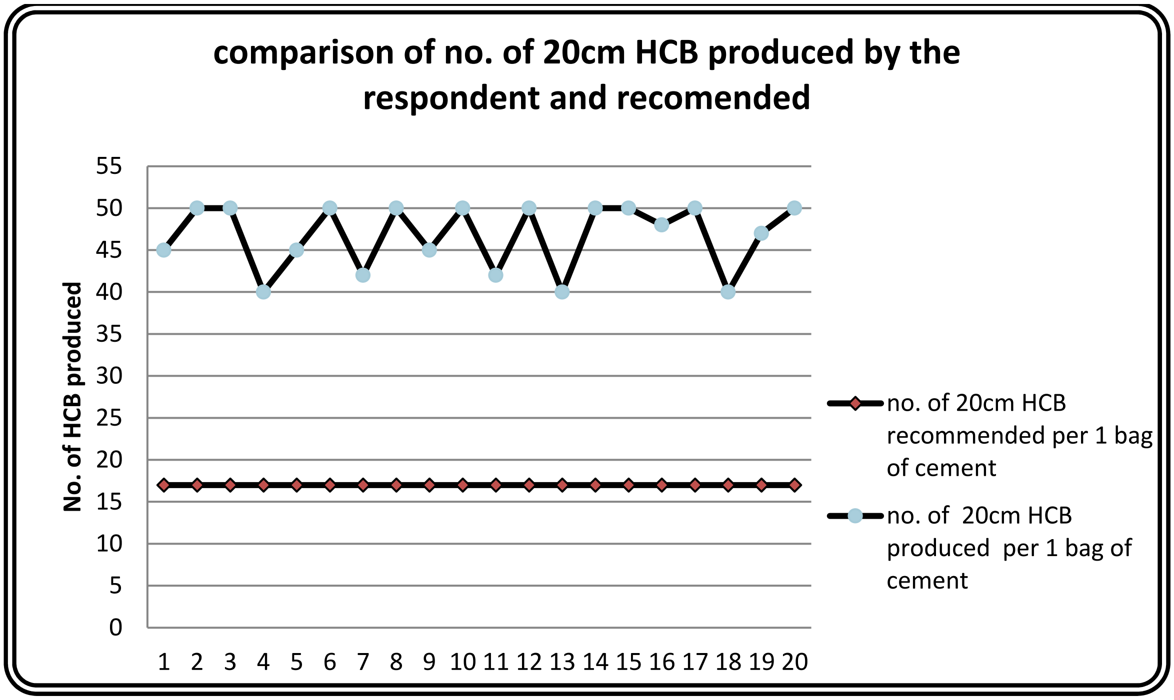


Fig.5.14a. Comparison of number of 20cm thick HCB produced by the respondent and recommended value.

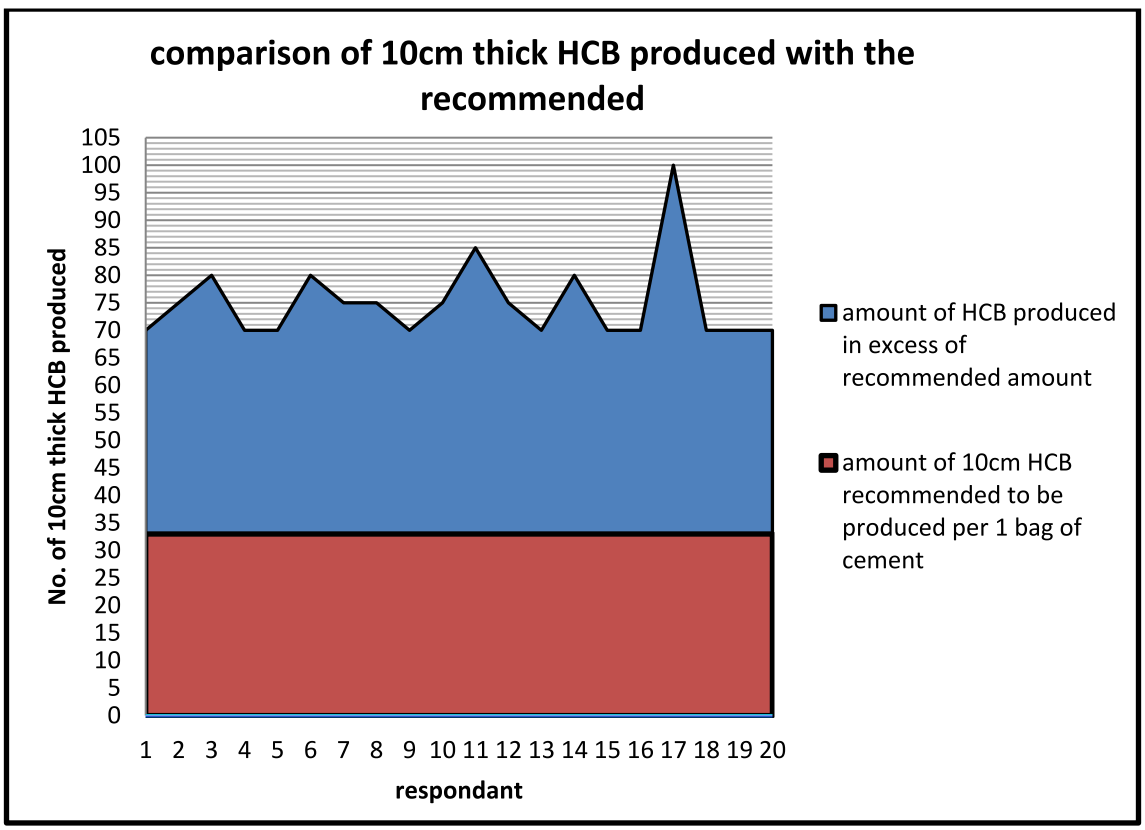


Fig.5.14b. Comparison of number of 15cm thick HCB produced by the respondent and recommended value.

Chapter Six

6. Conclusion

- In Adama town there are many private and micro enterprises engaged in hollow concrete block production. Even the enterprises organized on HCB producers are more than 100 according to the information from IMX office. Among them only 20 enterprises has been selected for interview and observation. However, the survey data shows none of them are conducting laboratory test for conformance of the minimum standard quality.

- Based on their strength HCB are classified in to A, B, and C according to the Ethiopian Standard. Class A and B are used for load bearing walls and class C is used for non-load bearing walls as mentioned in the literature review. But, the response of interview and observation and the conducted test has shown that the producers are manufacturing one type of hollow block for which its class is not known. That means, the producers are using constant proportion throughout and no test is conducted and so that they do not know which class of HCB they are producing.
- The proportioning of the raw materials produced should be using recommended measuring box recommended in the standard for different classes of HCB see table , but the proportion of all classes of block production is using wheelbarrow which is much greater than the measuring box. This result on production of much more amount of blocks per 1 bag of cement recommended to be produced.
- The mixing is recommended to be done only using mixer in the standards but only 15% of the respondents produce using mixer.

- Ethiopian Standard recommends for manufactured blocks on the site shall be cured in water tank or a curing yard by being kept thoroughly moist with water for at least a period of at least 7days or for 14 days by watering at least 3 times a day. Only 30% of the producers cure the blocks for 14days or more. Similarly, the Ethiopian standard, MoWUD check list for supervisors, 2001 reveal that hollow concrete blocks are properly dried under shade for at least 14 days after curing before they are used for construction. But all of the producers sell their product after 7days of curing if there are buyers. This also aggravates the usage of unqualified quality of HCB product in construction.

- The compressive strength results of the blocks tested are shocking which are much lesser than the minimum Ethiopian standard recommended. Among the compressive test is conducted the maximum compressive test result attained is 7.52 kg/cm^2, which is much less than the recommended for class C , which is 20kg/cm^2(2MPa). This much difference is occurred due to the absence of controlling body on the material selection, production process and the final product ready for sell.
- In general this project has tried to study the ingredient materials used, the production process, material handling, and conformance for quality, proportioning & batching, mixing methodology, production amount per 50kg of cement and class and dimension of HCB in Adama town in detail as much as possible. Hence, the survey data collected and compressive test conducted from the targeted respondents revealed that the material selection, production process and the production quality of HCB in Adama town is not as per Ethiopian standard recommendation. The quality of HCB is substandard not meeting the minimum class.

Chapter Seven

7. Recommendation

7.1 General recommendation

- Quality is something that should not be compromised. Therefore, the hollow blocks that are produced should be tested following the sampling and testing procedure of the given standards.
- Therefore, each entity engaged on HCB production should stick to the standards to achieve quality product which satisfy the customers.
- Hollow block production process should be monitored seriously starting from quality testing for raw materials, batching/proportioning, mixing, and curing and drying process should be as per the available standards of Ethiopia.
- It should be given much emphasis to type of material used, batching and proportioning, mixing, and curing as key area for the strength of hollow block. Therefore:-
- The raw material used should be only the once which are mentioned in the standard.
- The raw materials used should be batched and proportioned using recommended measuring box and amount.
- The new produced HCB should be cured under shade for at least three times a day for 14 days by recording and labeling the date of production.
- It has been observed from the survey data that the classes of HCB being produced by respondents are not known before selling due to the absence of laboratory test. This is completely wrong way. Therefore, the produced hollow block must be tested and categorized under one of the common classes A, B, or C before sell or discarded if it fails to achieve one.
- The amount of HCB produced for each class of HCB per one bag of cement should be based on the standard recommendation not based on the need of the producer.

- Strong Monitoring and supervision should be done from the Adama town administration side to insure that different enterprises and other organizations engaged on HCB production are doing their work as per the standard in a way that ensure the desired quality. In addition to this, training and experience sharing to other well performed enterprises should have to be organized from the government side, NGO, or any sector in order to supplement the knowledge of the producers.

- There should be production manual and, quality control manual and check list for the production and for controlling body from the government respectively.
- The production manual, quality control manual and check list for production and quality control are recommended below by compiling from different literatures of Ethiopian standards.

7.2. Quality Control guideline for HCB production

7.2.1. Quality control management system

The organizational structure of the quality control system of the controlling body can be as shown below:[11]

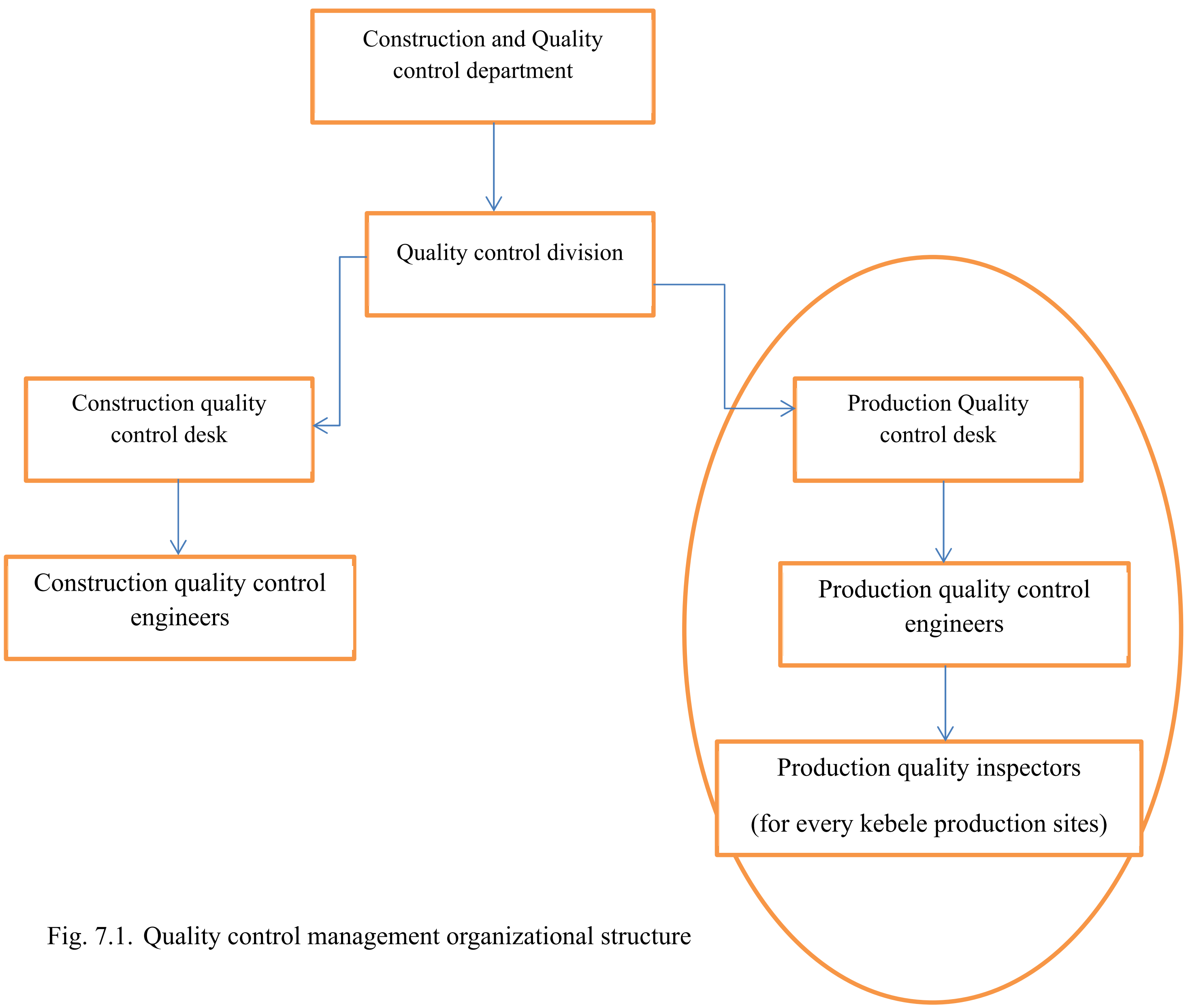


Fig. 7.1. Quality control management organizational structure

7.2.1.1.Objectives Of Quality Control

The objectives of quality control is not to eliminate all variability of the items produced which would be an impossible task, but to constrain this variability to economically feasible limits. This includes the following: [17]

• To take necessary steps to keep the quality of the product from dropping below the desired level during manufacture.

• To avoid as far as reasonable possible, having product which are of low quality than that which is considered acceptable to reach the customer.

• To set up standard of quality that are readily acceptable to the customer and economical to achieve and maintain.

• To analyze the trend and extent of quality deviation in a part or product during manufacturing and to determine the cause of such deviation by statistical techniques when it cannot be reasonably attributed to chance.

7.2.1.2.Ingredient materials quality control

It is very well known that quality of HCB products depends on the quality of the Ingredient material to be used in the production. [11]

Ingredient materials from various sources must be checked for quality. These include such as: Sand, Red ash, and pumice, which are found naturally and others such as 00 and 01 aggregate and cement etc. which are Factory products.

All ingredient material must be checked and approved for fulfilling their respective specification before use in the production of HCB. [11][15]

Therefore, before any purchase or supply is made to production sites their quality must be checked by an appropriate procedure. Thus a body responsible for the purchase or supply has to inform the appropriate personnel of the production quality control department for the checking before any purchase/delivery agreement of the material is conducted.

7.2.1.3.Workmanship quality control

This should mainly focus on insuring that the workforce involved in execution of the work has the skills to carry out the operations to comply with the specification. This work force primarily encompasses both the production staff and the supervising staff competency. [11]

Thus a standard of workforce grade has to be established for each activity and a supervising body has to check if the minimum requirements are met for each production site.

Training on the production and certification should be involved so that no one can participate on the production without having the certificate.

7.2.1.4.Quality control at production area

Adama town Administration shall assign professional production quality inspectors permanently. This professional shall control the quality of products in the production site closely from the qualities of the ingredient materials to the quality of the final product. In all cases, concerning quality a weekly and monthly report shall be submitted to the construction & supervision department (Production quality control engineers) by the respective supervisor and the department shall act accordingly.

7.2.1.5.Documentation & control of documents

To control the quality of production it is necessary to specify the type of document requirements and also establish a document control system.

7.2.1.5.1. Documentation requirements

The following documents constitute the documentation requirements for the establishment of an effective quality control system. These documents shall strictly be adhered along with their contemporary modifications. [11]

a. **Quality control manual**
b. **Construction materials specification**
c. **Check lists:** a document to be availed for all supervisors and site engineers to enable them check each step of production work day to day properly and not to overlook an item of work.
d. **Inspection certificates:** are formats to be filled by the producer and supplied to the supervisors or site engineers for inspection of the works and approval for each ingredient materials and the final product ready to be sold.
e. **Periodic reporting formats:** these include the weekly and monthly production quality reporting format.

7.2.1.5.2. Documents & record control

Documents & record required for quality control system shall be controlled as established here.

a. Only approved documents shall be used
b. Documents shall have unique version number
c. Insure that relevant documents only are in use and a register of current document distribution is maintained to ensure relevant changes.
d. Insure that prevention is made obsolete or irrelevant documents are used
e. Insure records are legible, readily identifiable & retrievable
f. Establish system for storage, protection, retention time & disposition of records.
g. A copy of obsolete documents shall be maintained & suitably identified for the purpose of traceability.

7.2.2. Sampling for Quality Conformance

According to the MoWUD check list for supervisors, 2001 a minimum amount of blocks selected should be 6 blocks per 1000 blocks. Similarly, according to Ethiopian standard [ES 596: 2001] the blocks required for carrying out tests is 12 hollow concrete blocks from every consignment of 10,000 blocks or part thereof of the same size and same batch of manufacture can be taken from stack in which case the required number of blocks shall be taken at random from across the top of the stacks, the sides accessible and from the interior of the stacks by opening trenches from the top and those block shall be kept under cover and protected from extreme conditions of temperature, relative humidity and wind until they are required for test. The tests shall be undertaken as soon as practicable after the sample has been taken. From these samples, the blocks shall be taken at random for conducting the tests.

• Set up equipment, tools and material

• Sieve the sand, as a first step with 1 cm^2 sand sieve in order to separate bigger rocks. As a second step sieve with smaller mesh sieve (such as 4,5 mm^2) in order to get fine sand. The sand must be clean from dirt, garbage, and mud.

7.2.3. Guidelines or check lists for quality conformance for quality control of HCB

7.2.3.1. The following are the checklist for supervisors to use on site for quality control of hollow block (MoWUD, 2001)

1. The hollow concrete blocks are free from laminations, cracks and other defects that would impair the proper setting, strength or permanence of the construction.

2. The hollow concrete blocks are well compacted, properly cured and uniform color and texture.

3. The hollow concrete blocks manufactured should be as of the quality of cement and aggregate as described for concrete works.

4. All blocks are manufactured in an approved special hollow block machine and under shed.

5. Before any manufacturing in big scale starts on the site, test samples are made, cured and sent for testing and test results are approved by the designer.

6. For curing of hollow blocks, that they are kept moist, at least for seven days after casting.

7. That the blocks are properly dried under shade for at least 14 days before they are used for construction.

8. Hollow blocks produced should be kept free from soil and other kind of dirt.

9. If load bearing HCB (class A and B) are needed special care is taken for proportioning and production.

10. A minimum of 6 blocks per 1000 pcs. for site manufactured blocks are tested

7.2.3.2. Quality Control guide line at Hollow Concrete block (HCB) Production.

7.2.3.2.1. Preparatory Criteria: Production area and facilities. [13] [15]

Before any production commences the sufficiency of the area, facilities & equipment for the intended purpose has to be checked. Therefore the administrative body of Adama should have regulation and check the availability of the following before giving the license.

1. Production area accessibility to take products using heavy trucks.
2. Availability of sufficient clean, dry and ventilated cement store
3. Availability of sufficient area under shade for production, curing and storage of HCB
4. Availability of shade to accommodate at least seven days production for curing
5. Availability of sufficient area to accommodate fourteen days production for drying

6. Availability of sufficient clean & compact area for storage of materials such as sand, gravel without contamination with foreign materials etc.
7. Availability of clean water source
8. Availability of electrical line if machines are electric driven
9. Availability of HCB machinery, concrete mixers, proper moulds and the required size of boxes.
10. Availability of required experienced personnel in HCB production

Note: - Before any manufacturing in big scale starts on the site, test samples are made, cured and sent for testing and test results has to be approved.

7.2.3.2.2. Ingredient materials to be checked before production starts

I. Cement

1. Cement has to be stored in a ventilated dry store
2. Record date of manufacture/arrival of cement for all batches of cement
3. Insure cement of similar date of manufacture/arrival are stored separately
4. Remove damaged bags of cement during transport, loading, unloading etc.

II. **Fine aggregates/ Sand**. [12] [13][15]

1. Fine aggregate/sand shall consist of natural sand, manufactured sand or combination of both.
2. Fine aggregates/sand must always be from approved source
3. Check the sand in laboratory at least for organic impurity, clay content and gradation for a given source of sand

a. **Grading Requirement**

Table 7.1. Fine aggregate /sand shall fulfill the grading requirement given below

Sieve Size (mm)	**ASTM, C33/ESC.D3.201 (% pass)**
9.50	100
4.75	95 - 100
2.36	80 – 100

1.18	50 – 85
0.60	25 – 60
0.30	10 – 30
0.15	2 – 10

Table.7.2. Fine aggregate shall fulfill the following requirements when tested by the following methods. [12] [13][15]

Item No.	**Type of Test**	**Method**	**Allowable Limits**
1	Organic impurity content	ASTM C40	Max. Plate No. 3
2	Silt and clay content a) For concrete subjected to abrasion b) All other concrete	ASTM C117 " "	 Max 3% Max 5%
3	Clay lumps and friable particles	ASTM C142	Max 3%
4	a) Soundness test by sodium Sulfate	ASTM C88	Max 10%
5	Fineness modulus a) Fine sand b) Medium sand c) Coarse sand		 2.20 – 2.60 2.60 – 2.90 2.90 – 3.20
6	Chloride content (Max)	BS812	600mg/lire
7	Sulfate content (Max)	BS812	1000mg/lire

III. Red ash

- Source of red ash must be from approved quarry
- It must be reasonably free from soil/clay, organic matter
- Check that oversized red ash (greater than 6 mm) is removed. Red ash must be sieved to fulfill this criterion. Please note that this is one of the reasons for failure of HCB made with a proper mix.

IV. Coarse aggregate /Gravel

Coarse aggregate shall consist of gravel, crushed gravel, crushed stone

- Each grades of aggregates (00 & 01) shall be stored separately and labeled
- Intermixed aggregates shall be immediately removed from the site as is difficult to keep the required proportion.
- Check the gravel in laboratory at least for abrasion, organic impurity, clay content and gradation.

Table 7.3. In general coarse aggregate to be used for HCB production, like those used for concrete shall fulfill the following requirements when tested by the method adopted below. [12][13] [15]

Item No.	Type of Test	Method	Allowable Limits
1	Coal and lignite content	ASTM C142	1%
2	Clay lumps and friable particles content	ASTM C142	1%
3	Dust Content	ASTM C117	1%
4	a) Soundness test by sodium Sulfate b) Soundness test by Magnesium Sulfate	ASTM C88 ASTM C88	Max 12% Max 18%
5	Los Angeles abrasion (%) wear a) For aggregates to be used in concrete wearing surfaces	ASTM C131	Max 30
	b) For aggregates to be used in all other concrete work	“	Max 50

6	Aggregate crushing value	BS812	Max 45%
7	Flakiness index	BS812	Max 35%
8	Chloride content (Max)	BS812	600mg/litre
9	Sulfate content (Max)	BS812	1000mg/litre

V. Water

Water used for mix and curing should sufficiently be clean and free from organic matter, acid, alkaline and substances in suspension or solution. The city water supply water is suitable for this purpose and all other sources must be tested before use.

7.2.3.2.2. During production. [13] [15]

The following points has to be checked during production of HCB

Check that only approved materials are used in the production

1. Box sizes are of the specified dimensions for the respective type and class of HCB
2. Correct number of boxes are used for the corresponding number of cement bag
3. Cheek the correct mould is used for the type and class of HCB to be produced
4. Mixing must always be with machine
5. Blocks are manufactured using an approved special HCB machine
6. Production must always be under shade
7. Blocks are well compacted and uniform in color & texture

7.2.3.2.3. Post Production. [13] [15]

1. Care is taken in handling and moving the fresh HCB
2. Fresh HCB is kept under shade for 24 hrs on the pallet
3. Each day production has labels/tag of production date and quantity
4. HCB must be well cured: kept continuously moist for 7 days under shad or for 14 days by watering at least 3 times a day.
5. Dried under shade for 14 days afterwards
6. HCB should not be transported for long distance from the production area to the consumption area as this may create substantial damage and invisible hair cracks.

7.2.3.2.4. Tests.[13]

- Six full size sample shall be taken to represent for every 4000 blocks or a fraction thereof for the compression test
- Compressive Strength tests shall be conducted for every 4000 blocks of production or a fraction thereof. However this may not be practical and the major quality control is achieved through day-to-day close supervision to keep production process consistently accurate insure the use of quality materials as described above.
- Failed batch is separately stored or removed from site
- The hollow concrete blocks are free from laminations, cracks and other defects that would impair the proper setting, strength or permanence of the construction.

7.2.4. Production procedure Guidelines.[16]

1. Identifying the type and class of blocks to be produced
2. Identifying the proportion of ingredients for the desired type and class of HCB
3. Selecting the raw materials fulfilling the required quality
4. The raw materials should be stored in a situation that it is Isolated from other materials and each other.
5. Measuring the raw materials using the required amount
6. Mixing the raw materials using a mixer thoroughly without water
7. Mixing the dry mix adding the desired amount of water
8. Inserting the mix in to the HCB moulding and compacting machine and compact it.
9. Putting the produced HCB (green HCB) under shed for 24 hours
10. Properly curing the HCB
11. Making compressive strength test and commence the mass production if it satisfies the desired compressive strength.

7.2.5. Raw material type and the measurement used for HCB production

Table 7.4. The raw material type and their measurement is as follows according to Addis Ababa condominium housing projects manual .[16]

Raw material type	measurement	Box size	Box volume	HCB class
Cement	Bag	1bag = 25 * 35 * 40 cm	$0.035m^3$	A, B and C
Sand	M^3	27 * 40 * 50 cm	$0.054m^3$	A and B

Red ash	M^3	27 * 40 * 50 cm	$0.054m^3$	A and B
00 aggregate	M^3	24 * 40 * 50 cm	$0.048m^3$	A and B
01 aggregate	M^3	12 * 40 * 50 cm	$0.024m^3$	A and B
Pure water	Liter			
Sand, red ash, 00 & 01 aggregate	M^3	18 * 40 * 50 cm	$0.036m^3$	C

The raw materials should fulfill the desired requirement

The boxes should be prepared according to the above dimension, free from any hole, properly handled and maintain their volume.

7.2.6. The material Mix ratio used for producing each class is as follows

Table 7.5. HCB Class B mix ratio for 1 bag (50kg) of cement.[16]

Raw material	Box dimension	proportion for Class B
Sand	27 * 40 * 50 cm	1
Red ash	27 * 40 * 50 cm	1
00 aggregate	24 * 40 * 50 cm	1
01 aggregate	12 * 40 * 50 cm	1

Table 7.6. HCB Class C mix ratio for 1 bag (50kg) of cement.[16]

Raw material	**Box dimension**	**proportion for class C**
Sand	18 * 40 * 50 cm	2
Red ash	18 * 40 * 50 cm	3
00 aggregate	18* 40 * 50 cm	0.5
01 aggregate	18 * 40 * 50 cm	0.5

7.2.7. Amount of HCB produced using the ingredients prepared for 1 bag (50kg) of cement.

Table 7.7. The amount of HCB produced using the ingredients prepared for 1 bag (50kg) of cement is as follows. .[16]

Block type	Maximum number of HCB can be produced
20 * 20 * 40 cm	17
10 * 20 * 40 cm	33

If the number of blocks produced for each type is more than the above mentioned in the table, then the quality of HCB produced will be in question.

7.2.8. Human labour and usage for HCB production

Using one block machine of one mould and one mixer the number of labourers and usage is as follows.[16]

Raw material delivering persons 4

Mixing persons 3

For putting the mixed ingredients in to block producing machine 1

Mixer operator 1

Block machine operator 1

Persons taking the moulded HCB using plate for 24 hr drying under shade 2

Persons taking to the dried HCB to curing place and for watering the product 2

Totally 14 persons should be used for working using 1 block machine.

7.2.9. Block producing machine usage and type

Powering on the machine and inserting drying pallet under the moulding part.

Inserting the mix in to the machine mould and allow for compaction and moulding.

Taking out the mould and take to the drying shade

One of the machines that observed from the respondents takes the mix from the mixer with its conveyer belt to the moulding part which makes the process continuous. Minimize the evaporation of water by speeding up the cycle of production.

- Yearly calibration of the production machine can be set as a criteria for renewing the licence for production.

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Appendix A

Questioner for the respondents

1. What are the Ingredients used?
2. What method do they used for proportioning?
3. What are the proportions of ingredients?
4. Do you aware about classes of HCB?
5. What are the tests conducted for ingredient materials?
6. How often the tests are conducted?
7. Where is the Place of curing?
8. What is the Curing method used?
9. For how long it is cured?
10. After how many days the HCB product will be ready for sell?
11. What are the dimensions of HCB produced?
12. How many HCB will be produced for each thickness per 1 bag of cement?
13. What method of compaction do they used?
14. What are the problems faced during production?
15. What mixing methodology is used?
16. Where is/are the quarry location for red/black ash?
17. Where is/are the quarry location for pumice?
18. Where is/are quarry location for beleche?
19. What is/are the type of Cement used?
20. What are the tests conducted before selling?
21. Is there Controlling body on production?
22. How many workers participate for production?
23. How do you store the cement?

Appendix B

Questioner and response of the respondents

Questions	respondent 1	resp. 2	resp. 3	4	5	6	7	8	9
Ingredients used	Black ash			Red Ash	Black Ash	Red ash	Red ash	Red ash	Beleche
	Pumice	Pumice	Pumice	Pumice	Pumice	Pumice	Pumice	Pumice	Red ash
	cement	cement	cement	cement	cement	cement	cement	cement	Pumice
	beleche	beleche	beleche	beleche	beleche		beleche	beleche	cement
	lime like waste from alumunium sulphate factory		lime like material waste from almunium sulphate factory			lime like material waste from almunium sulphate factory		lime like material waste from almunium sulphate factory	lime like material waste from almunium sulphate factory
Method of proportioning	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using cement bag	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow
Proportion of ingredients	2 wb beleche	1 wb beleche	2 wb beleche	1 wb beleche	1 wb beleche	0.5wb lime like material waste from almunium sulphate factory	8 shovel lime like material waste from almunium sulphate factory	10 shovel lime like material waste from almunium sulphate factory	5 shovel lime like material waste from almunium sulphate factory
	2wb Black ash	3wb pumice	3wb pumice	2wb pumice	4wb pumice	1 wb. beleche	5 wb pumice	3wb pumice	3 wb red ash
	2wb pumice			1 wb red ash	0.5wb black ash	4 wb Pumice	1wb beleche	1wb beleche	2 wbPumice
	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement
									2wb beleche
Knowledge about classes of HCB	No	No	No	No	No	no	No	No	no
Testes conducted	No	No	No	No	No	no	No	No	no
How Frequent tests conducted	No	No	No	No	No	no	No	No	no
Place of curing	without shade	without shade	without shade	without shade	under shade	Under shade	without shade	without shade	Under shade
Curing method	By Sprinkling water 3times a day	By Sprinkling water 2times a day	By Sprinkling water 2times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day
Date of curing	10days	15days	7 days	7 days	12days	3 days	8 days	15 days	For 10 days
Readiness for sell	after 10days	After 15 days	after 7days	after 7days	After 15 days	After 10 days	After 8 days	After 15 days	After 15 days
Dimension of HCB produced	40cm*20cm*15cm	40cm*20cm*15 cm	40cm*20cm*15cm	40cm*20cm*15cm	40cm*20cm*15cm	40cm*20cm*15 cm	40cm*20cm*15 cm	40cm*20cm*15 cm	40*20*15cm
	40cm*20cm*20cm	40*20*20cm	40*20*20cm	40*20*20cm	40*20*20cm	40*20*20cm			40*20*20cm
				40cm*20cm*10cm					40*20*10cm
Numb. Of HCB per bag of cement 15cm	50	60	60	50	50	60	52	57	50
20cm	45	50	50	40	45	50	42	50	45
10cm	70	75	80	70	70	80	75	75	70
Method of compaction	By pressing with the molding machine and vibrating	By pressing with the molding machine and vibrating	By pressing with the molding machine and vibrating	By pressing with the molding machine and vibrating	By pressing with the molding machine and vibrating	By pressing with the molding machine	By pressing with the molding machine	By pressing with the molding machine	By pressing with the molding machine
Problems faced during production	Water	Water	Water	Water	Water	Water	Water	Water	Water
	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power
Mixing methodology	using special mixer for HCB production	On ground By shovel	On ground By shovel	using special mixer for HCB production	On ground By shovel	On ground By shovel	On ground By shovel	On ground By shovel	On ground By shovel
Quarry location for red/black ash			wenji,mojo, koka	kidane mihiret, nahmald	kidane mihiret, nahmald	kidana mihiret		kidane mihiret, nahmald	kidane mihiret, nahmald
Quarry location for pumice	adulala mariam	wenji,mojo, koka	kidana mihiret	adulala mariam, wonji	adulala mariam	adulala mariam, wonji	adulala mariam, wonji	adulala mariam, wonji	adulala mariam, wonji
Quarry location for beleche	adulala mariam, wonji	wenji,mojo, koka	wenji,mojo, koka		kidana mihiret	adulala mariam, wonji			
type of Cement used	dangote,national	dangote		dangote	dangote	dangote	dangote	dangote	dangote
Tests conducted before selling	no	no	no	no	no	no	no	no	no
Controlling body on production	no	no	no	no	no	no	no	no	no
total workers for	3	4	3	4	3	2	3	3	2
condition of the cement	good	good	poor	good	good	poor	poor	good	good

Questions	11	12	13	14	15	16	17	18	19	20
Ingredients used	Red ash	Red ash	Red Ash	Beleche		2box Sand	beleche		Red ash	Beleche
	Pumice	Black ash	Pumice	Red ash	Red ash	Pumice	Red ash	Pumice	Pumice	Red ash
	cement	Pumice	cement	pumice	pumice	cement	Pumice	cement	cement	Pumice
	beleche	cement	beleche	cement	cement	beleche	cement	beleche		cement
		beleche			lime like material waste from almunium sulphate factory		lime like material waste from almunium sulphate factory			lime like material waste from almunium sulphate factory
Method of proportioning	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using box of 50*40*20cm	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow	Volumetric using wheel barrow
Proportion of ingredients	2 wb pumice	10 shovel lime like material waste from almunium sulphate factory	2 wb beleche	2 wheel barrow Beleche	6 shovel lime like material waste from almunium sulphate factory	2 box beleche	1wb lime like material waste from almunium sulphate factory	1 wb beleche	2 wb pumice	5 shovel lime like material waste from almunium sulphate factory
	2wb red ash	1wb red ash	3wb pumice	2 Wb. red ash	1 wb. Red ash	3box pumice	0.5 0 aggregate	4wb pumice		1 wb beleche
	2wb beleche	1 wb Black ash	1 wb red ash	2 wbPumice	2 wb Pumice		1wb red ash		2wb red ash	4 wb pumice
	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1 bag cement	1wb beleche	1 bag cement
		2 wb pumice			2 wb beleche		5 wb pumice		1 bag cement	
Knowledge about classes	No	No	No	No	no	No	no	No	No	No
Testes conducted	No	No	No	no	no	No	no	No	No	no
How Frequent tests conducted	No	No	No	No	no	No	no	No	No	no
Place of curing	without shade	without shade	without shade	without shade	without shade	without shade	without shade	without shade	without shade	Under shade
Curing method	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water twice a day	By Sprinkling water 3times a day	By Sprinkling water 2times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day	By Sprinkling water 3times a day
Date of curing	15 days	15 days	15days	For 15 days	4 days	7 days	8 days	8days	Until it is sold	For 10 days
Readiness for sell	After 15 days	After 15 days	After 15 days	After 15 days	After 7 days	after 15days	After 15 days	8days	7 days	After 15 days
Dimension of HCB produced	40*20*15cm	40*20*15cm	40*20*15cm	40*20*15cm	40*20*15cm	40*20*15cm	40*20*15cm	40*20*15cm		40*20*15cm
	40*20*20cm		40*20*20cm	40*20*20cm	40*20*20cm	40*20*20cm	40*20*20cm	40*20*20cm	40cm*20cm* 15cm	40*20*20cm
				40*20*10cm			40*20*10cm			40*20*10cm
Numb. Of HCB per bag 15cm	60	60	50	57	60	60	65	50	57	60
Numb. Of HCB per bag 20cm	42	50	40	50	50	48	50	40	47	50
Numb. Of HCB per bag 10cm	85	75	70	80	70	70	100	70	70	70
Method of compaction	By pressing with the molding machine and vibrating	By pressing with the molding machine	By pressing with the molding machine and vibrating	By pressing with the molding machine	By pressing with the molding machine	By pressing with the molding machine and vibrating	By pressing with the moulding machine	By pressing with the molding machine and vibrating	By pressing with the moulding machine	By pressing with the molding machine
Problems faced during production	Water	Water	Water	Water	Water	Water	Water	Water	Water	Water
	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power	Electric power
Mixing methodology	On ground By shovel	On ground By shovel	On ground By shovel	On ground By shovel	On ground By shovel	using special mixer for HCB production	On ground By shovel	On ground By shovel	On ground By shovel	On ground By shovel
Quarry location for red/black ash		wenji,mojo, koka		kidane mihiret, nahmald	kidane mihiret, nahmald	kidane mihiret, nahmald	kidane mihiret, nahmald	kidane mihiret, nahmald	kidane mihiret, nahmald	
Quarry location for pumice	adulala mariam, wonji	adulala mariam, wonji	adulala mariam, wonji	adulala mariam, wonji	adulala mariam, wonji	adulala mariam, wonji	adulala mariam, wonji	wenji,mojo, koka	adulala mariam, wonji	adulala mariam, wonji
Quarry location for beleche	adulala mariam, wonji	wenji,mojo, koka	wenji,mojo, koka				wenji,mojo, koka	wenji,mojo, koka	wenji,mojo, koka	
type of Cement used	dangote	dangote	dangote	national	dangote	dangote	dangote	dangote	dangote	dangote
Tests conducted before selling	no	no	no	no	no	no	no	no	no	no
Controlling body on	no	no	no	no	no	no	no	no	no	no
total workers for production	4	2	3	3	3	4	2	3	3	4
condition of the cement store	good	poor	good	poor	good	good	poor	good	good	good

Appendix C

Compressive test result of the selected respondents

Production site 01

Sample no.	Date tested	Age in days	Dimension in cm			Weight in kg	Gross unit weight in kg/m3	Gross pressure area in cm^2	Load in KN	Compressive strength in	
			L	B	H					Kg/cm^2	MPa
1		28	40	15	20	8.225	685.42	600	45.7	7.76	0.78
2		28	40	15	20	8.89	740.83	600	30.5	5.18	0.52
3		28	40	15	20	7.81	650.83	600	43.5	7.39	0.74
4		28	40	15	20	7.39	615.83	600	23.3	3.96	0.40
5		28	40	15	20	8.015	667.92	600	32.7	5.56	0.56
6		28	40	15	20	8.235	686.25	600	26.7	4.54	0.45
										AVG. **5.73**	**0.57**

Production site 02

Sample no.	Date tested	Age in days	Dimension in cm			Weight in kg	Gross unit weight in kg/m3	Gross pressure area in cm^2	Load in KN	Compressive strength in	
			L	B	H					Kg/cm^2	MPa
1		28	40	20	20	8	500.00	800	44.8	5.71	0.57
2		28	40	20	20	8.44	527.50	800	45.0	5.73	0.57
3		28	40	20	20	8.365	522.81	800	51.6	6.57	0.66
4		28	40	20	20	8.07	504.38	800	31.6	4.03	0.40
5		28	40	20	20	9.30	581.25	800	44.7	5.70	0.57
6		28	40	20	20	9.32	582.50	800	45.8	5.84	0.58
										AVG. **5.60**	**0.58**

Production site 03

Sample no.	Date tested	Age in days	Dimension in cm			Weight in kg	Gross unit weight in kg/m^3	Gross pressure area in cm^2	Load in KN	Compressive strength in In	
			L	B	H					Kg/cm^2	MPa
1		28	40	20	20	8	500.00	800	32.1	5.71	0.57
2		28	40	20	20	7.725	482.81	800	36.3	5.73	0.57
3		28	40	20	20	7.09	443.13	800	22.9	6.57	0.66
4		28	40	15	20	6.675	556.25	600	35.5	6.03	0.60
5		28	40	15	20	8.46	705.00	600	32.9	5.59	0.56
6		28	40	15	20	5.82	485.00	600	55.4	9.41	0.94
									AVG.	**7.01**	**0.70**

Production site 04

Sample no.	Date tested	Age in days	Dimension in cm			Weight in kg	Gross unit weight in kg/m3	Gross pressure area in cm^2	Load in KN	Compressive strength in	
			L	B	H					Kg/cm^2	MPa
1		14	40	20	20	7.685	480.31	800	58.8	7.49	0.75
2		14	40	20	20	7.205	450.31	800	37.7	4.80	0.48
3		14	40	20	20	8.245	515.31	800	38.0	4.84	0.48
4		14	40	20	20	7.65	478.13	800	63.5	8.09	0.81
5		14	40	20	20	7.70	481.25	800	51.0	6.50	0.65
6		14	40	20	20	7.525	470.31	800	105.1	13.39	1.34
									AVG.	**7.52**	**0.75**

Production site 05

Sample no.	Date tested	Age in days	Dimension in cm			Weight in kg	Gross unit weight in kg/m3	Gross pressure area in cm^2	Load in KN	Compressive strength in	
			L	B	H					Kg/cm^2	MPa
1		28	40	15	20	7.035	586.25	600	35.3	6.00	0.60
2		28	40	15	20	7.42	618.33	600	23.7	4.03	0.40
3		28	40	15	20	8.28	690	600	32.2	5.47	0.55
4		28	40	15	20	8.12	676.67	600	28.7	4.88	0.49
5		28	40	15	20	7.545	628.75	600	24.4	4.15	0.42
6		28	40	15	20	7.965	663.75	600	50.1	8.51	0.85
									AVG.	**5.50**	**0.55**