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Defects on quality and strength of Hollow Concrete Blocks Production in Local Market

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As members of the examining board of the final B.Sc. open defense, we verify that we have read and evaluated the final BSc thesis/project prepared by Abel **Tolossa, Yohannes Aschenaki, Henok Abera, Yitagesu Horsa, Aman Anshiso, Yohannes Ebro,** entitled, **Defects on Quality and Strength of Hollow Concrete Blocks in Local Market Production**, and recommended for acceptance as a fulfillment of the requirement of **B.Sc. in Civil Engineering.**

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Preface

This document is a report as a part of fulfilment for a Bachelor of Science in Civil Engineering. The study is conducted by Abel Tolossa Senbete , Yohannes Aschenaki Tilahun , Henok Abera Yemer , Yitagesu Horsa Foye , Aman Anshiso Sissiso , Yohannes Ebro Seid.

Abstract

In construction industry, defects in HCB production is common challenge in developing countries. The main objective of this paper was to identify the most frequent factors that reduce quality of HCB in local market for the construction industry and to compare the quality of HCB in local market to requirements stated in building codes. The research is carried out by collecting information on qualities of ingredients, method of production through questionnaires and by conducting a compressive strength test of hollow concrete block in the laboratory then compare the result that we have got from the test with minimum strength requirement set on recommended standards.From results of questioner survey and laboratory results, the study help us to known that most block manufacturer do not use the appropriate process and materials quality due to this they become failed through compressive strength test when we compared to the standards so their samples have rejected and the others full fill the requirements listed in standard code so their samples are not rejected. The results of this study may help HCB manufacturers, construction planners and supervisors understand the challenges and improve the quality of HCB.

KEYWORDS: Batching, Mixing, Quality Control, Compliance, Standard Deviation

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List of Abbreviations

EBCS	Ethiopian Building Code of Standard
ES	Ethiopian Standard
HCB	Hollow Concrete Block
Hr	Hour
IS	Indian Standard
MPa	Mega Pascal
OPC	Ordinary Portland Cement
PPC	Portland Pozzolana Cement
BATCODA	Building and Transport Construction Design Authority

1 Introduction

1.1 Background of the study

Defects with HCB production is common challenge in developing countries. From literature, reasons that contribute to HCB defect could be grouped in to the need for a relatively large amount of cement, which can be expensive and difficult to obtain, the need for a relatively large amount of clean water for mixing and curing, which can be a serious problem in dry regions and the need for special knowledge and experience in the production process (*Original: Concrete Block Producing Equipment 3—Appropedia: The sustainability wiki*).

A relatively large amount of cement can be expensive and difficult to obtain. This means suppliers are not willing to invest the amount of money that used to produce the material. So this scenario brings about the inappropriate use of cement amount for the required mix design then there is a large occurrence of workability, strength and quality failure on the material they produced. Even if they know the standard requirement for a production process they will not properly satisfy the intended requirements in order to be profitable rather than making a material having a good quality(*Original: Concrete Block Producing Equipment 3—Appropedia: The sustainability wiki*).

The need for a relatively large amount of clean water for mixing and curing. There are different construction materials that needs a pure application of water from those construction material hollow concrete block is the one that is used in the construction firm or industry, though we should have to take care of its preparation steps. From those steps water for curing and mixing is one of them that must be take care of. The water that we use in the mixing and curing process should be clean like a water that is ready for drink purpose because the impurities in water may interfere with the setting of the cement and may adversely affect the strength and durability of the hollow concrete block material(*Original: Concrete Block Producing Equipment 3—Appropedia: The sustainability wiki*,).

The need for special knowledge and experience in the production process. Most of the time there is lack of skilled manpower in our country construction industry. This problem can lead us the production of material that do not fit or satisfy the standard to be followed by the construction firms. This failure will introduce different causes on building construction.

This paper presents a proposal about the defects on quality and strength of hollow concrete block with the intended laboratory test and by questionnaire survey. These proposal is organized into five sections; Section one deals with introduction of the research; Section two deals with literature review; Section 3 deals with methodology; Section four deals with result and discussion; Section five deals with conclusions and recommendations and lastly, references and appendixes are included.

The purpose of this study was therefore to investigate quality and strength of hollow concrete block to establish the standard of hollow concrete block being used and to compare quality and strength of existing product with the standard.

1.2 Research question

This research will answer the following main questions

- Does the quality of HCB production in local market satisfy requirements stated in building codes?
- What are the most frequent factors that contribute to low quality HCB?

The study has the following sub-questions

- How to improve the quality and strength of HCB in local market?

1.3 Objectives of the Study

1.3.1 General Objective

The main objective of the study is to identify the most frequent factors that reduce quality and Strength of hollow concrete block (HCB) in local market for the construction industry.

1.3.2 Specific Objectives

The specific objectives of the study are the following: -

- To improve the quality and strength of hollow concrete block in local market.
- To compare the quality of hollow concrete block in local market to the requirements stated in building codes.
- To reduce maintenance cost of hollow concrete block.

1.4 Significance of the Study

This research paper can be important to help us to improve quality of production of hollow concrete block in local market and help to produce hollow concrete block having a high strength, high durability and a high resistance of load.

On the other hand, to distinguish the defect on the production of hollow concrete block and to make appropriate solution for maintaining and keeping the quality of hollow concrete block.

1.5 Scope of the study

The research addresses the objectives and tries to investigate the defects on quality and strength of hollow Concrete Blocks in Local Market Production based on the existing theories and principles. Investigation is undertaken on randomly selected sites located in Addis Ababa and Wolkite. The sites in which the research is conducted are Mexico, Akaki kaliti, Tulu dimtu and Gubra.

1.6 Limitation of the Study

This study has the following limitations: -

- We have financial problem that result a restriction on doing our research.
- Due to lack of willingness of the production company or the suppliers.
- We are not sure if there is a compressive strength machine in Wolkite university is working.
- Due to covid -19 we could not conduct our research properly in time.

1.7 Organization of the Paper

This study organized into five chapters. The first chapter focused on the introductory part of the study, which includes background of the study, statement of the problem, objectives, significance, scope and limitation of the study. The second chapter contains literature review part of the study in which theoretical and empirical literatures related with the issue were incorporated. The third chapter deals about the research methodology: research design, approach and method; sampling design, sources of data, data collection methods, data analysis were incorporated. The fourth chapter is all about the discussion and results, and finally the fifth chapter ends up by conclusion and gives recommendations and lastly, references and appendices are included.

2 Literature Review

2.1 Introduction

The issue of confirmation of quality of building materials when used in the construction process must be taking serious so as to avoid situations where majority of buildings fail in meeting safety obligations to the general public which may finally result into building collapse. Before any material should be incorporated into building works, there is a need to establish its quality and such thing as quality control (QC), quality assurance (QA) and quality level (QL)(Ayodeji, 2006). There are varieties of definition of quality of which the following are common: the achievement of excellence, fitness for purpose and conformance with requirements. It is therefore better for one to be concerned with quality assurance, quality control and quality management, which are terms used in explaining the word quality and they are much easier to handle(Ayodeji, 2006). The other parameter that can be mentioned as a problem occurred due to the poor quality of hollow concrete block is low resistivity of seismic loads which is applied on the structure. Most of the time there are different areas that are subjected to a highly seismic loads in each consecutive time so that if the wall which was not properly prepared by the producers have been used it will cause the wall to be demolished and this leads us to extra maintenance cost. Placing of block for the purpose of wall also has its own requirements. when a blocks placed on one over another the upper block can put its own pressure and load on the lower block then it becomes broken or cracked due to poor quality of hollow concrete block. So that if blocks could not fulfill the intended quality and strength we will face a big problem when we use them for the wall.

2.2 Process of production of HCB

2.2.1 Raw Materials

Portland cement (OPC or PPC), aggregates and water are commonly raw materials used to make concrete mixture for production of hollow concrete blocks(Kahsay, 2014). But concrete mixture used for blocks has a higher percentage of sand and a lower percentage of gravel and water than the concrete mixtures used for general construction purposes(Kahsay, 2014).This produces a very dry, stiff mixture that holds its shape when it is removed from the block mold. In addition to these, basic components various chemicals called admixtures, can be used to alter curing time, increase compressive strength, or improve workability sometimes pigments may be added to give the blocks a uniform color throughout(Kahsay, 2014).

2.2.2 Batching of Aggregates

Batching is the term used to describe the method of measurement of materials. There are two types of batching: weight and volume. The accuracy of the measurement of the various quantities of each constituent material is important if the required strength of block is to be achieved. Thus, batching by weight is usually preferred to batching by volume(B.K. Baiden and Martin Morgan Tuuli, 2004).

2.2.3 Mixing

In case of hand- molded block where compaction is done manually, concrete mix should be sufficiently consistent to enable remolding immediately after casting. The consistency of the mix should be such that it may cohere when compressed in the hand without free water being visible(Kahsay, 2014).Too little water causes the mix to be friable, while too much water causes difficulty in the immediate withdrawal of the mould. It shall be carried out on a water-tight platform and care shall be taken to ensure that mixing is continued until the mass is uniform in colour and consistency(Kahsay, 2014).

Mixing of materials can be done manually or mechanically. Good quality blocks are produced when mixes are thorough and uniform. For a large number of blocks, mechanical mixing is recommended; however, manual mixing can also be used where a small number of blocks are required. It is important to control the water content during mixing, as excessive water in the mix causes shrinkage and distortion of the blocks on drying(B.K. Baiden and Martin Morgan Tuuli, 2004).

2.2.4 Method of Molding/Production

Various machines and molds are available for use in the production of blocks. These include the electric vibrating machine, the hand press machine, and the local steel/wooden hand mold. These machines will usually produce a different quality of blocks as a result of the different degree of compaction achieved by each. For higher strength and quality blocks, the electric vibrating machine is usually recommended(B.K. Baiden and Martin Morgan Tuuli, 2004).

2.2.5 Compaction and placing

According to Indian standard IS: 2185 (Part I) – 1979, manual compaction, the mixture shall be placed into the mould in layers of about 50 to 75 mm and each layer thoroughly tamped with suitable tampers until the whole mould is filled up and struck off level with a trowel(Kahsay, 2014). In the case of mechanical compaction, the mould shall be filled up to overflow, vibrated or mechanically tamped and struck off level. After remolding the blocks shall be protected against sun and wind by placing on the shade until they are sufficiently hardened to permit handling without damage(Kahsay, 2014).On the other hand, GTZ low cost housing manual Volume I specify to vibrate the mixture for 60 second before extruded as hollow concrete block and transported and remains for 24 hours on wooden pallet then it is being cured covered by plastic sheet to enhance the curing process and preventing the water from evaporation(Kahsay, 2014).

2.2.6 Curing

Curing is the term used to describe the method of maintaining moisture in the newly cast blocks to allow proper hydration and hardening to take place. The Ethiopian standard(ES) specifies a period of 14–21 days of moist conditions and that, immediately after molding, the block should be kept in a shade and protected against the effect of drying winds. Adequate curing is required for blocks to develop full strength. This can be achieved by sprinkling water on the blocks and covering with a tarpaulin or damp sacks(B.K. Baiden and Martin Morgan Tuuli, 2004).

2.2 HCB quality

2.2.1 HCB Standards

The following are the minimum compressive strength requirements for blocks at the age of 28 days(*EBCS PDF*, 1995).The mix proportions of the material components are to be adjusted as required to obtain the required compressive strength according to Ethiopian standard listed in the Table 2-1(B.K. Baiden and Martin Morgan Tuuli, 2004).

The minimum compressive strength for HCB according to BATCODA-Technical Specification is indicated below (BATCODA-Technical Specification).

Table 2-1 Comprehensive Strength of Hollow Concrete Blocks at 28 days

Class	Average of 6 Units		Individual Units	
	MPa	Kg/cm^2	MPa	Kg/cm^2
A	4.2	42	3.8	38
B	3.5	35	3.2	32
C	2.0	20	1.8	18

2.3 HCB Test

2.3.1 Bulk Density

Density is defined as the measure of how many particles of an element or material are squeezed into a given space. The more closely packed the particles, the higher the density of the material. Higher levels, therefore, indicate a corresponding degree of compaction(B.K. Baiden and Martin Morgan Tuuli, 2004).This is the mass of the masonry unit divided by the dimensional volume, mathematically expressed as mass of block dimensional volume of block (m3)]. Ethiopian standard [ES 596:2001] recommends a maximum bulk density of 1,200 kg/m3 for the load-bearing hollow concrete blocks considered for this research(B.K. Baiden and Martin Morgan Tuuli, 2004).

2.3.2 Water Absorption Capacity

This is the weight of water a block unit absorbs when immersed in water at a normal day temperature for a stated length of time. It is expressed as a percentage of the weight of the dry unit of block. The absorption rate is defined as the weight of water absorbed when the unit is partially immersed for 1 min in water. It is expressed mathematically as mass of saturated block mass of dry block /volume of block (m3)](B.K. Baiden and Martin Morgan Tuuli, 2004).

2.3.3 Dimension Check

Basically, the variations in the lengths and widths ~thickness! Of the samples from the suppliers were within the tolerance limits specified in [ES 596:2001]. On the other hand, Ethiopian standard [ES 596:2001] specify maximum dimensional variation (length, height, breadth), it should be + 5mm for nominal dimensions of hollow concrete block(B.K. Baiden and Martin Morgan Tuuli, 2004).

2.3.4 Compressive Strength

Compressive strength is defined as the unit's ability to withstand an axially applied load, whether on the edge or the bed face of the block. It is also the average compressive strength of a test sample of blocks, Compressive strength is expressed mathematically as maximum crushing load(N)/minimum surface area (mm^2)](B.K. Baiden and Martin Morgan Tuuli, 2004).

2.4 HCB quality problems

The factors that contribute to poor quality HCB are Quality of constituent of materials, batching of aggregates, mixing of constituent materials, method of molding or production, curing, transportation and storage mix ratio and water content(B.K. Baiden and Martin Morgan Tuuli, 2004).

3 Research Methodology

3.1 Introduction

Overall description of methodology.

The overall proposed research framework is demonstrated in figure 3-1.

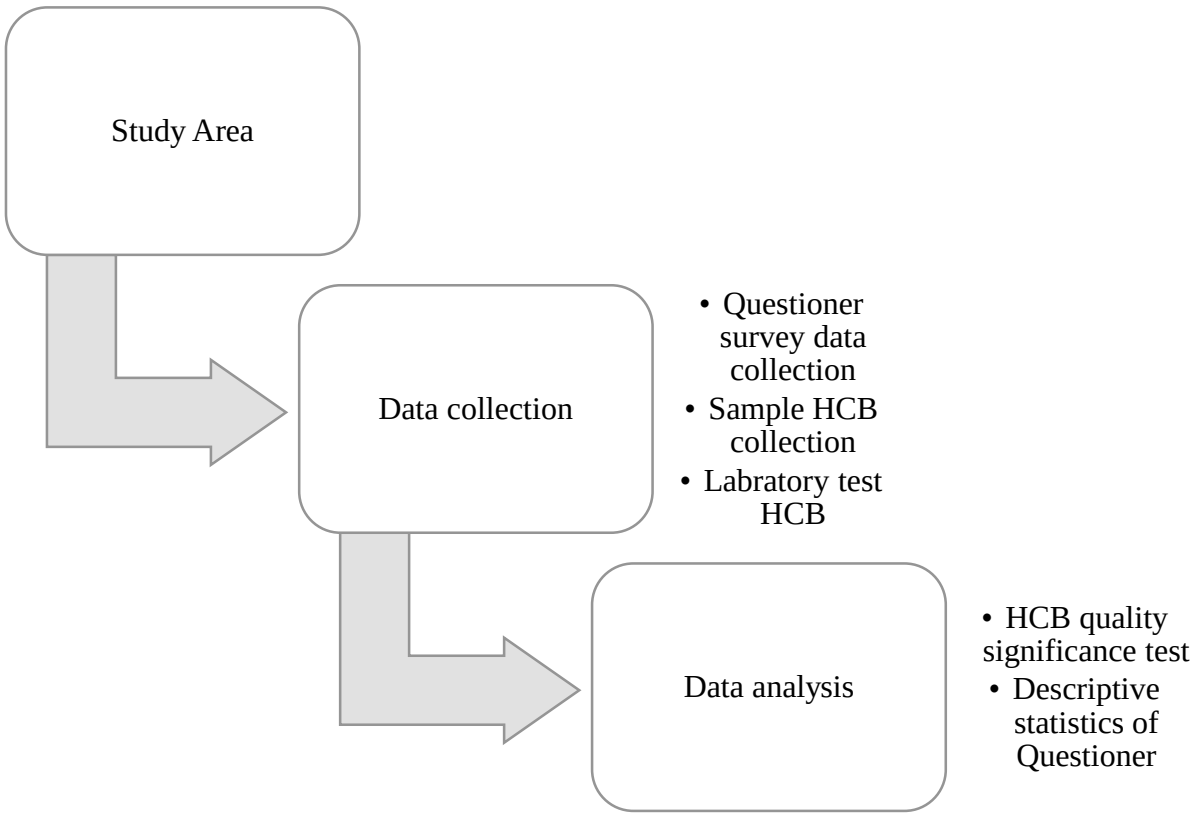

Figure 3-1 Research Frame work used for the study

3.2 Research Design

There are two types of research approaches, namely: quantitative, qualitative. Quantitative study is a study where purely quantitative data and analysis techniques are adopted while qualitative approach makes use of purely qualitative data and analysis.

3.2.1 Study Area

This study focused on Wolkite and different sites located in Addis Ababa.

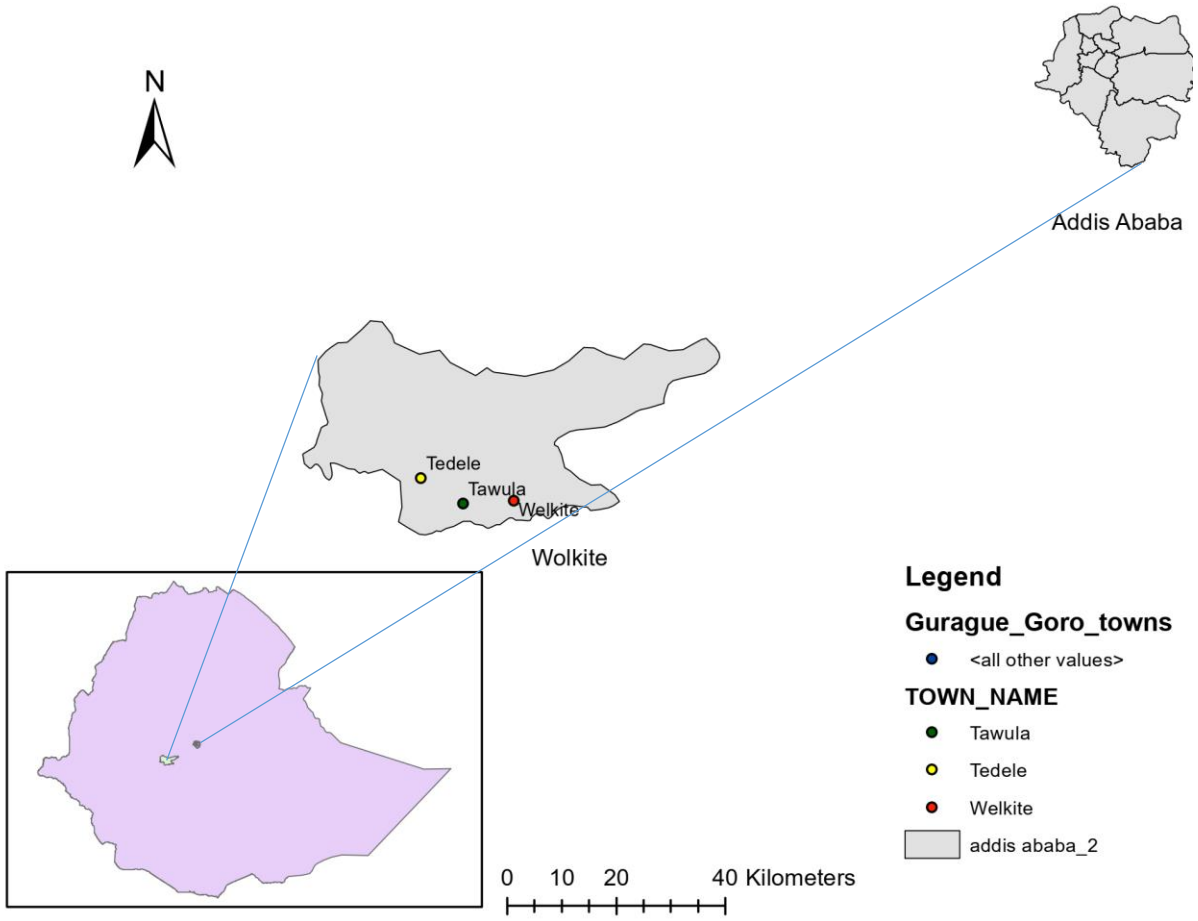

Figure 3-2 Study Area: Ethiopia

3.3 Sample

3.3.1 HCB Sample Size

The methods followed to achieve the objectives are:

- Preparing questionnaire and distribute it to hollow concrete block producers and resident engineers working on construction sites. The questions are both open and closed ended having contents which mainly focus on the quality and strength of hollow concrete block. There are about twenty-five questions related to hollow concrete block production.
- By collecting hollow concrete block samples from producers and also those samples take it to the laboratory in order to check compressive strength.

We have financial problem that result a restriction on doing our research, due to lack of willingness of the production company or the suppliers, we are not sure if there is a compressive strength machine in Wolkite university is working and Due to covid -19 we could not conduct our research properly in time.

3.3.2 Questioner Survey Sample Size

There are about twenty-five questions related to hollow concrete block production that we prepare for the producers. The questioners contain types of hollow concrete block produced by respondents, Aggregate used for hollow concrete block production, Cement used for hollow concrete block production, Water used for hollow concrete block production, mixing technique used for hollow concrete block production, Compaction technique used for hollow concrete block production, curing technique used for hollow concrete block production, Storage technique used at hollow concrete block production site, Quality assurance used at hollow concrete block production site and Open ended question about quality of hollow concrete block at hollow concrete block production site.

3.3.3 Sampling technique for HCB

Our sampling technique for hollow concrete block has been conducted by using the method of direct contact with the producers of hollow concrete block and we choose a block with randomly from the site.

a) HCB under the Shade

b) HCB outside the Shade

c) HCB Sample in the laboratory

Figure 3-3 Sample of Hollow Concrete Block

3.3.4 Questioner survey

A questioner was prepared to understand the overall production technique of local HCB producers in Addis Ababa. A format used for survey is attached in Appendix A. The study contacted volunteer producers of HCB and a questioner was given for them to complete. Our sampling technique for questioner survey has been based on convenience sampling.

3.4 Tests on HCB

3.4.1 Compressive Strength

Compressive strength is defined as the unit's ability to withstand an axially applied load, whether on the edge or the bed face of the block. It is also the average compressive strength of a test sample of blocks, Compressive strength is expressed mathematically as maximum crushing load(N)/minimum surface area (mm^2)](B.K. Baiden and Martin Morgan Tuuli, 2004).

Figure 3-4 Compressive strength test of HCB

3.5 Method of Data Analysis

3.5.1 Data analysis for HCB laboratory result

Analyzing information gathered through test results. Then make a subjective assessment on the current hollow concrete block production practices with respect to the recommended scientific approaches of literatures and also to make a quantitative and qualitative evaluation on quality and strength of hollow concrete block on the production sites.

3.5.2 Hypothesis testing

HCB producer claim is that; the HCB they produce satisfies the minimum compressive strength requirement specified in the standards. for that particular size, class and curing day of HCB.

In order to verify this claim, you have collected 3 samples of a particular HCB size, class and curing. You then tested these three blocks and obtained a compressive strength of x_1, x_2, and x_3 respectively. The average compressive strength based on your test results will be $\bar{X}$

$$\bar{X} = \frac{\sum x_i}{n} = \frac{x_1+x_2+x_3}{3} \text{..... Eq.1}$$

Suppose the minimum compressive strength specified for a particular class, size and curing date of HCB in EBCS1995 is X_s. Hypothesis testing involves generating the null and alternative hypothesis, fitting a statistical model to data and using the model assessing the model with test static(Field, 2013).

First formulate the null and alternative hypothesis

If the sample mean $\bar{X}$ is at least the minimum compressive strength specified in the standard X_s, the manufacturer claim is correct (This is called the null hypothesis)

$$H_0: \bar{X} \geq X_s \text{..... Eq.2}$$

However if the sample mean $\bar{X}$ is less than the minimum compressive strength specified in the standard X_s, the manufacturers claim is in correct (This establishes the alternative hypothesis)

$$H_1: \bar{X} < X_s \text{..... Eq.3}$$

The sample mean $\bar{X}$ is computed as an estimate of population mean μ.

In order to plot the sample distribution, you need the population standard deviation σ. If the population standard deviation is known from previous evidence on several samples, use it. If previous evidence is not available, you can approximate it with the standard deviation of samples σ_s

$$\sigma_s = \sqrt{\frac{\sum(x_i-\bar{x})^2}{n-1}} = \sqrt{\frac{(x_1-\bar{x})^2+(x_1-\bar{x})^2+(x_1-\bar{x})^2}{3-1}} \text{..... Eq.4}$$

Assuming the population of compressive strength of HCB follows normal distribution, the sample distribution is plotted. Weather the data follows normal distribution could be verified using a procedure stated in (Field, 2013). Once, a normal distribution is verified, the distribution can be plotted on Microsoft excel.

Decide the significance level

Significance level is the value you choose for the probability of making Type 1 error(Declercq, 2017). You decide the significance level (1-α) of percentage of error (α) that allows you to conclude or make decision during hypothesis testing.

Researchers common choices of α are 0.05 and 0.01(Field, 2013). If your choice of α =5%=0.05, the significance level is $1-\alpha = 95\%$. If your choice of $\alpha = 1\%$=0.01, the significance level is $1-\alpha = 99\%$. The lower the value of α, the lower the chance of making Type I error (Declercq, 2017).

Hypothesis testing, the P-value approach

The test static

$$z\ test = \frac{\bar{X}-X_s}{\sigma/\sqrt{n}} \ldots\ldots\ldots\ldots \text{Eq.5}$$

P-value approach

$P\ value = Probability\ of\ obtaining\ values\ (Z \leq z\ test)$. The probability of obtaining a mean compressive strength of $\bar{X}$ or lower.

Use Z (normal) distribution tables, to find p value (one sided to the left), you can also use excel

Decision

If $P - value < error(\alpha), reject\ the\ nul\ hypothesis$

If $P - value \geq error(\alpha), do\ not\ reject\ the\ nul\ hypothesis$

If p<α, we reject the null hypothesis (There is sufficient statistical evidence that supports the researchers claim that Sample HCB does not fulfil the compressive strength that is specified in the standards for that particular class). If p>=α, we do not reject the null hypothesis (There is no sufficient statistical evidence that supports the researchers claim that Sample HCB does not fulfil the compressive strength that is specified in the standards for that particular class).

3.5.3 Data analysis for Questioner survey

Descriptive statistics

Analyzing information gathered through questionnaire. Then make a subjective assessment on the current hollow concrete block production practices with respect to the recommended scientific approaches of literatures and also to make a quantitative and qualitative evaluation on quality and strength of hollow concrete block on the production sites.

4 Results

4.1 Introduction

Data analysis contains descriptive statistics of questioner survey and laboratory test of Hollow Concrete Blocks. The analysis below shows qualitative and quantitative results of questionnaire survey and laboratory test. Under questionnaire survey we have open ended and closed ended questions which is describe by different producers and also we have done a compressive strength test for HCB samples, based on this we made analysis and discussion about the data that we get.

4.2 Descriptive statistics of survey questioner

4.2.1 Types of HCB produced by respondents

Among 15 HCB producing enterprises, all of them were engaged in production of masonry wall HCB and most of them (12 respondents) manufacture ribbed slab HCB. (Table 4-1).

Table 4-1 Type of HCB produced by 15 companies in the questioner

Type of HCB produced	masonry wall	ribbed slab
	15	12

4.2.2 Class of HCB produced by respondents

We have checked 15 HCB producing enterprises, from these 12 respondents were engaged in production of Class A HCB, 11 respondents were engaged in production of Class B, 8 respondents manufacture Class C HCB. (Table 4-2).

Table 4-2 Class of HCB produced by 15 companies in the questioner

Class of HCB Produced	Class A	Class B	Class C	Class D
	12	11	8	0

4.2.3 Size of HCB produced by respondents

We have checked 15 HCB producing enterprises, all of them were engaged in production of HCB having a width of 20 cm, 14 respondents were engaged in production of HCB having a width of 15 cm, 14 respondents manufacture HCB having a width of 10 cm. (Table 4-3).

Table 4-3 Size of HCB produced by 15 companies in the questioner

Size of HCB	20 cm	15 cm	10 cm
	15	14	14

4.2.4 Aggregate used for HCB production

From our observation 15 HCB producing enterprises response that 6 respondents were used Light weight aggregate in production of HCB, 6 respondents were used Normal weight aggregate in production of HCB and 10 respondents were used Combined weight aggregate in production of HCB. (Table 4-4)

Table 4-4 Type of Aggregate used by 15 companies in the questioner

Type of Aggregate	Light weight aggregate	Normal weight aggregate	Combined weight aggregate
	6	6	10

4.2.5 Cement used for HCB production

Among 15 HCB producing enterprises, 14 respondents were used OPC in production of HCB and 11 respondents were used PPC for manufacturing of HCB. (Table 4-5)

Table 4-5 Type of Cement used by 15 companies in the questioner

Type of Cement	OPC	PPC
	14	11

4.2.6 Water used for HCB production

Among 15 HCB producing enterprises, 13 respondents were used drinking water in the production of HCB and 8 respondents were used non-drinking water for manufacturing of HCB. (Table 4-6)

Table 4-6 Quality of Water used by 15 companies in the questioner

Quality of Water	Drinking water	non-drinking water
	13	8

4.2.7 Mixing and batching technique used for HCB production

We have checked 15 HCB producing enterprises, 1 respondent used by weight method for measuring the ingredients in order to produce HCB and 12 respondents used by volume method for measuring the ingredients in order to produce HCB. (Table 4-7)

Table 4-7 Type of Batching technique used by 15 companies in the questioner

Type of Batching technique	By weight	By volume
	1	12

From our observation 15 HCB producing enterprises, 3 respondents were mixing the ingredients manually in the process of production of HCB, 7 respondents were mixing the ingredients by mixing plant and 4 respondents were mixing the ingredients by using manually and by mixing plant in order to manufacture HCB. (Table 4-8)

Table 4-8 Method of Mixing technique used by 15 companies in the questioner

Method of mixing	Manually	mixing plant	Manually & mixing plant
	3	7	4

4.2.8 Curing technique used for HCB production

Among 15 HCB producing enterprises, 7 respondents cured the HCB under the shade after the production of HCB and 10 respondents cured the HCB outside the shade after the production of HCB. (Table 4-9)

Table 4-9 Placing of curing used by 15 companies in the questioner

Placing of curing	under the shade	outside the shade
	7	10

4.2.9 Manpower used at HCB production site

We have checked 15 HCB producing enterprises, 3 respondents use skilled manpower in the production of HCB, 2 respondents use unskilled manpower in the production of HCB and 12 respondents use skilled & unskilled manpower to manufacture the HCB. (Table 4-10)

Table 4-10 Man power used by 15 companies in the questioner

Man Power used	Skilled	Unskilled	Skilled & Unskilled
	3	2	12

4.3.0 Quality assurance used at HCB production site

From our data of 15 HCB producing enterprises, 7 respondents checked the dimension of HCB, 3 respondents Checked the density of HCB, 1 respondent Checked water absorption, 1 respondent Checked linear shrinkage of HCB and 6 respondents Checked Compressive strength of HCB. (Table 4-11)

Table 4-11 Type of HCB used by 15 companies in the questioner

Test of HCB	Dimension	Density	Water Absorption	Linear Shrinkage	Compressive Strength
	7	3	1	1	6

4.3.1 Open ended question about quality of HCB at HCB production site

4.3.2 Source of aggregate used for HCB production

Among 15 HCB producing enterprises, 1 respondent use aggregate found in Adulala, 6 respondent use aggregate found in Debrezeit, 4 respondent use aggregate found in Nazret, 1 respondent use aggregate found in Addis Ababa, 3 respondent use aggregate found in Akaki 08 and 1 respondent use aggregate found in Modjo for source of aggregate in production of HCB. (Table 4-12)

Table 4-12 Source of aggregate used by 15 companies in the questioner

Source of aggregate used for HCB production	Adulala	Debrezeit	Nazret	Addis Ababa	Akaki 08	Modjo
	1	6	4	1	3	1

4.3.3 Sources of Cement used for HCB

From our data of 15 HCB producing enterprises, 4 respondents use all cement types that are manufactured from factory,2 respondents use Muger Cement, 2 respondents use Habesha Cement, 3 respondents use Dangote Cement, 2 respondents use Derba Cement and 2 respondents use National Cement. (Table 4-13)

Table 4-13 Source of Cement used by 15 companies in the questioner

Sources of Cement	Cement Factory	Muger	Habesha	Dangote	Derba	National
	4	2	2	3	2	2

4.3.4 Test of aggregate used for HCB production

Among 15 HCB producing enterprises,1 respondent have done clay Test and gradation Test for aggregate, 1 respondent have done Flakness Test and Water Absorption Test for aggregate, 1 respondent have done Strength Test for aggregate and 12 respondents do not Conduct any Test. (Table 4-14)

Table 4-14 Test of aggregate used by 15 companies in the questioner

Tests of Aggregate	Strength Test	Clay Test	Flakness	Water Absorption	Gradation	No Test
	1	1	1	1	1	12

4.3.5 HCB produced per 100 kg of cement

From our data of 15 HCB producing enterprises, HCB produced per 100 kg of cement is different from manufacture to manufacture for each Class of hollow concrete block. (Table 4-15)

Table 4-15 HCB produced per 100 kg by 15 companies in the questioner

		Number of HCB Per 100 kg											
Class A	40 x 20 x 20	18	80	7	48	80	36	96	56	130	26	40	30
Class B	40 x 20 x 15	21	90	13	60	100	48	120	70	173	40	50	36
Class C	40 x 20 x 10		100	15	70	120	64	144	98	260	50	80	49

4.3.6 Test made for the cement

Among 15 HCB producing enterprises, all of them do not Conduct any Test for Cement. (Table 4-16)

Table 4-16 Test of Cement used by 15 companies in the questioner

Test for Cement	No Test
	15

4.3.7 Test made for the Water

From our data 15 HCB producing enterprises, all of them do not Conduct any Test for Water. (Table 4-17)

Table 4-17 Type of water used by 15 companies in the questioner

Test for Water	No Test
	15

4.3.8 Adjustment for Ingredients

Among 15 HCB producing enterprises, 13 respondents Adjustment their Ingredients by volume and No Respondents Adjustment their Ingredients by weight. (Table 4-18)

Table 4-18 Adjustment for ingredients used by 15 companies in the questioner

Adjustment for Ingredients	By volume	By Weight
	13	0

4.3.9 Duration of Mix

From our data 15 HCB producing enterprises, 4 respondents are dependent on a Machine in order to Mix the ingredients, 1 respondent are dependent on Manpower in order to Mix the ingredients, 1 respondent control the duration by observation whether its mixed properly, 2 respondents are dependent on operator in order to control Mix of the ingredients, 1 respondent says that it takes 1-minute in order to Mix of ingredients, 2 respondent says that it takes 5 minute in order to Mix of ingredients, 1 respondent says that it takes 10-minute in order to Mix of ingredients, 1 respondent says that it takes 2-minute in order to Mix of ingredients and 1 respondent says that it takes 3-minute Duration for Mix of ingredients. (Table 4-19)

Table 4-19 duration of mix used by 15 companies in the questioner

Duration for Mix	machine	man power energy	Observation	Operator	1 Min	5 Min	10 Min	2 Min	3 Min
	4	1	1	2	1	2	1	1	1

4.4.0 Corrective measure for Slump

From our data 15 HCB producing enterprises, all of them do not conduct a corrective measure for slump in production of HCB. (Table 4-20)

Table 4-20 Test for slump used by 15 companies in the questioner

Corrective measure for Slump	No Test
	15

4.4.1 Duration for Vibration

Among 15 HCB producing enterprises, 2 respondents are dependent on a Machine in order to vibrate the ingredients, 1 respondent are dependent on a Manpower in order to vibrate the ingredients, 1 respondent control the duration by observation whether its vibrated properly, 1 respondents are dependent on a vibrator type in order to vibrate the ingredients, 3 respondent says that it takes 1-minute in order to vibrate the ingredients, 1 respondent says that it takes 25 second in order to vibrate the ingredients, 3 respondent says that it takes 1-minute in order to vibrate the ingredients, 1 respondent says that it takes 5-minute in order to vibrate the ingredients and 1 respondent says that it takes 15-minute in order to vibrate the ingredients.(Table 4-21)

Table 4-21 Duration of Vibration used by 15 companies in the questioner

Duration for Vibration	machine	1 Min	man power energy	25 Sec	1 Min	5 Min	Observation	15 Min	Vibrator Type
	2	3	1	1	3	1	1	1	1

4.4.2 Time for Curing

From our data 15 HCB producing enterprises, 2 respondents use 20 Days for curing, 1 respondent use 8 Days for curing, 2 respondent use 14 Days for curing, 1 respondents use 48 hours for curing, 1 respondent use 28 Days for curing, 1 respondent use 6 Days for curing, 3 respondent use 7 Days for curing and 3 respondent use 21 Days for curing. (Table 4-22)

Table 4-22 Time of curing used by 15 companies in the questioner

Curing time of HCB	20 Days	8 Days	14 Days	48 Hr.	28 Days	6 Days	7 Days	21 Days
	2	1	2	1	1	1	3	3

4.4.3 Duration of Storage after Manufacturing

Among 15 HCB producing enterprises, 2 respondents store the produced HCB for 20 Days, 2 respondents store the produced HCB for 28 Days, 7 respondents store the produced HCB until a purchaser comes, 1 respondents store the produced HCB for 7 Days and 2 respondents store the produced HCB for 15 Days. (Table 4-23)

Table 4-23 Duration of storing used by 15 companies in the questioner

Duration of storing HCB	20 Days	28 Days	Marketing	7 Days	15 Days
	2	2	7	1	2

4.4.4 Amount of sampling of HCB used for test

From our data of 15 HCB producing enterprises,7 respondent use 6 pieces of HCB for sampling test, 1 respondents use 7 pieces of HCB for sampling test, 1 respondent use 9 pieces of HCB for sampling test, 1 respondent use 2 pieces of HCB for sampling test and 1 respondent use 30 pieces of HCB for sampling test. (Table 4-24)

Table 4-24 Amount of sampling of HCB used by 15 companies in the questioner

Amount of sampling of HCB	6 Pieces	7 Pieces	9 Pieces	2 Pieces	30 Pieces
	7	1	1	1	1

4.4.5 Cause to produce low quality HCB

Among 15 HCB producing enterprises, 3 respondents suggest that a Material quality can be reason out for the occurrence of low quality of HCB, 6 respondent suggest that Mix Ratio can be reason out for the occurrence of low quality HCB, 1 respondent suggest that a cement can be reason out for the occurrence of low quality HCB, 1 respondents suggest that type of Aggregate can be reason out for the occurrence of low quality HCB, 1 respondents suggest that Curing

Time can be reason out for the occurrence of low quality HCB, 1 respondent suggest that a Material Cost can be reason out for the occurrence of low quality HCB, 1 respondent suggest that Transport can be reason out for the occurrence of low quality HCB, 2 respondent suggest that Water Content can be reason out for the occurrence of low quality HCB,2 respondent suggest that Poor Workman Ship can be reason out for the occurrence of low quality HCB,1 respondent suggest that Storage can be reason out for the occurrence of low quality HCB, 2 respondent suggest that Shortage of Water can be reason out for the occurrence of low quality HCB, 1 respondent suggest that Shortage of Cement can be reason out for the occurrence of low quality HCB and 1 respondent suggest that Poor Quality Of Fine Aggregate can be reason out for the occurrence of low quality HCB.(Table 4-25)

Table 4-25 Cause to produce low quality HCB by 15 companies in the questioner

low quality HCB	Material Quality	Mix Ratio	Cement	Fine Aggregate	Curing Time	Material cost	Transport
	3	6	1	1	1	1	1
Water Content	Poor Workman Ship	Storage	Shortage of water	Shortage Of Cement	Poor Quality Of Fine Aggregate		
2	2	1	2	1	1		

4.5 Laboratory test HCB

The graph below shows that the compressive strength test of different classes of HCB that are collected from three categories of manufacturers. (Figure 4-1)

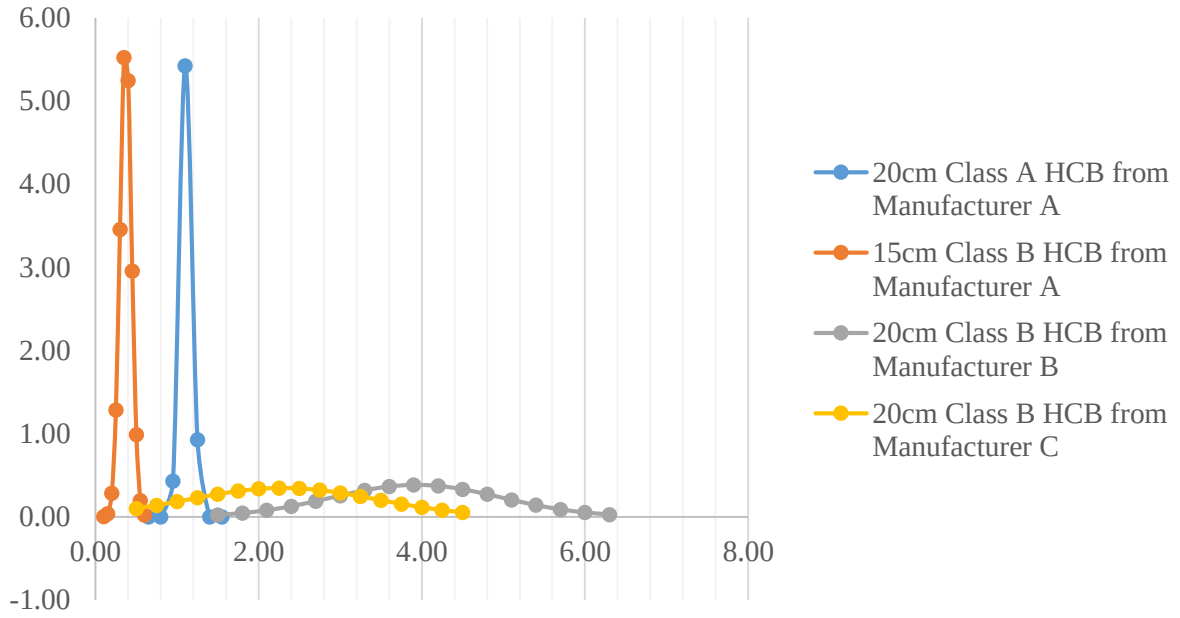

Figure 4-1 Overall Normal Distribution of HCB

4.6 HCB Laboratory Test Vs EBCS standards

4.6.1 Compliance of Class A HCB

a) Compliance of Individual blocks compressive strength

A 20cm Class A HCB taken from Manufacturer A does not full fill the required standard. This means from the three sample that we take and perform a compressive strength test the result became below the standard. (Table 4-26)

Table 4-26 Compliance of individual HCB compressive strength

Load(KN)	Pressure (N/mm^2)	Minimum individual unit strength (N/mm2) for Class A	Compliance
46.12	1.15	3.8	Does not comply
41.37	1.03	3.8	Does not comply
46.36	1.16	3.8	Does not comply

b) Compliance of mean compressive strength

BATCODA Technical - Specification requires the mean strength of 6 blocks to be 4.2MPa ($\bar{X}_s = 4.2MPa$).

Hypothesis

$$H_0: \bar{X} \geq 4.2MPa$$

$$H_1: \bar{X} < 4.2MPa$$

Assuming the test result of compressive strength of HCB blocks follow, a normal distribution and with our sample that has a mean ($\bar{X} = 1.11MPa$) and sample standard deviation ($s = 0.07Mpa$), the normal distribution will be as illustrated in Figure 4-2.

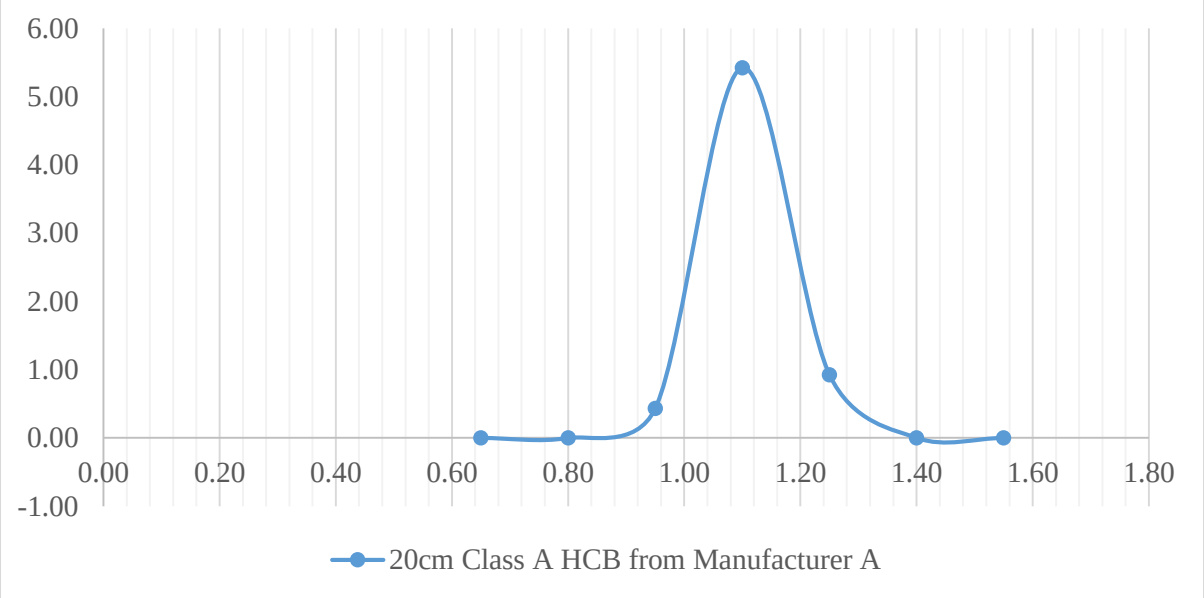

Figure 4-2 Normal distribution 20cm Class A HCB from Manufacturer A

Decide the significance level

Researchers common choices of α are 0.05 and 0.01(Field, 2013). Our choice of α =0.01, the significance level is $1 - \alpha = 99\%$.

Hypothesis testing, the P-value approach

The test static

$$z\ test = \frac{\bar{X} - X_s}{\sigma/\sqrt{n}} = 1.28MPa$$

Check

Because $z_{test} = 1.28MPa < \bar{X}_s = 4.2MPa$, we reject the null hypothesis. Hence there is a sufficient statistical evidence that supports the claim that the quality of 20cm Class A HCB from Manufacturer A is below the standard (p=0.000 <$\alpha = 0.01$).

4.6.2 Compliance of Class B HCB

a) Compliance of Individual blocks compressive strength

A 15cm Class B HCB from Manufacturer A does not full fill the required standard. This means from the three sample that we take and perform a compressive strength test the result became below the standard. (Table 4-27)

Table 4-27 Compliance of individual HCB compressive strength

Load(KN)	Pressure (N/mm^2)	Minimum individual unit strength (N/mm2) for Class B	Compliance
26.37	0.33	3.2	Does not comply
26.2	0.33	3.2	Does not comply
35.74	0.45	3.2	Does not comply

b) Compliance of mean compressive strength

BATCODA Technical - Specification requires the mean strength of 6 blocks to be 3.5MPa ($\bar{X}_s = 3.5MPa$).

Hypothesis

$$H_0: \bar{X} \geq 3.5MPa$$

$$H_1: \bar{X} < 3.5MPa$$

Assuming the test result of compressive strength of HCB blocks follow, a normal distribution and with our sample that has a mean ($\bar{X} = 0.37MPa$) and sample standard deviation ($s = 0.069Mpa$), the normal distribution will be as illustrated in Figure 4-3.

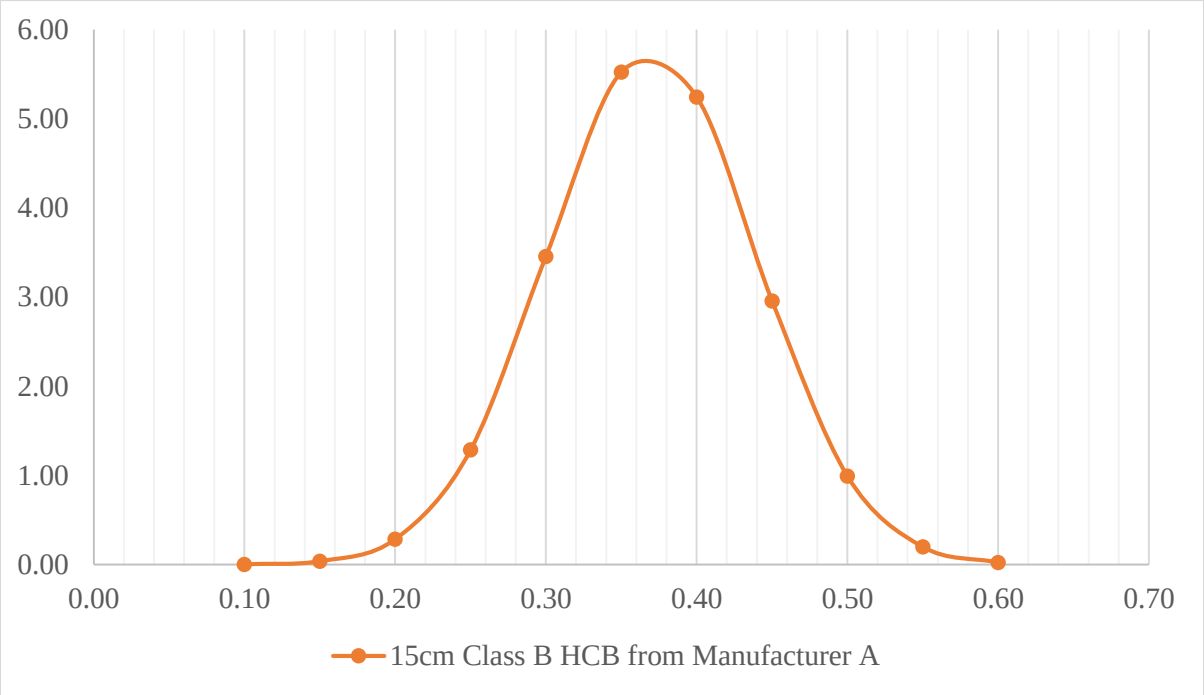

Figure 4-3 Normal distribution for 15cm Class B from Manufacturer A

Decide the significance level

Researchers common choices of α are 0.05 and 0.01(Field, 2013). Our choice of α =0.01, the significance level is $1 - \alpha = 99\%$.

Hypothesis testing, the P-value approach

The test static

$$z\ test = \frac{\bar{X} - X_s}{\sigma/\sqrt{n}} = 0.53MPa$$

Check

Because $z_{test} = 0.53MPa < \bar{X}_s = 3.5MPa$, we reject the null hypothesis. Hence there is a sufficient statistical evidence that supports the claim that the quality of 15cm Class B HCB from Manufacturer A is below the standard (p=0.000 <$\alpha = 0.01$).

4.6.3 Compliance of Class B HCB

a) Compliance of Individual blocks compressive strength

A three sample of 20cm Class B HCB from Manufacturer B has taken for compressive test and we have got a result of two samples satisfy the standards and the other does not full fill the standard. (Table 4-28)

Table 4-28 Compliance of individual HCB compressive strength

Load(KN)	Pressure (N/mm^2)	Minimum individual unit strength (N/mm2) for Class B	Compliance
198.78	4.97	3.2	Does comply
215.454	3.94	3.2	Does comply
232.29	2.9	3.2	Does not comply

b) Compliance of mean compressive strength

BATCODA Technical - Specification requires the mean strength of 6 blocks to be 3.5MPa ($\bar{X}_s = 3.5MPa$).

Hypothesis

$$H_0: \bar{X} \geq 3.5MPa$$

$$H_1: \bar{X} < 3.5Mpa$$

Assuming the test result of compressive strength of HCB blocks follow, a normal distribution and with our sample that has a mean ($\bar{X} = 3.937MPa$) and sample standard deviation ($s = 1.035Mpa$), the normal distribution will be as illustrated in Figure 4-4.

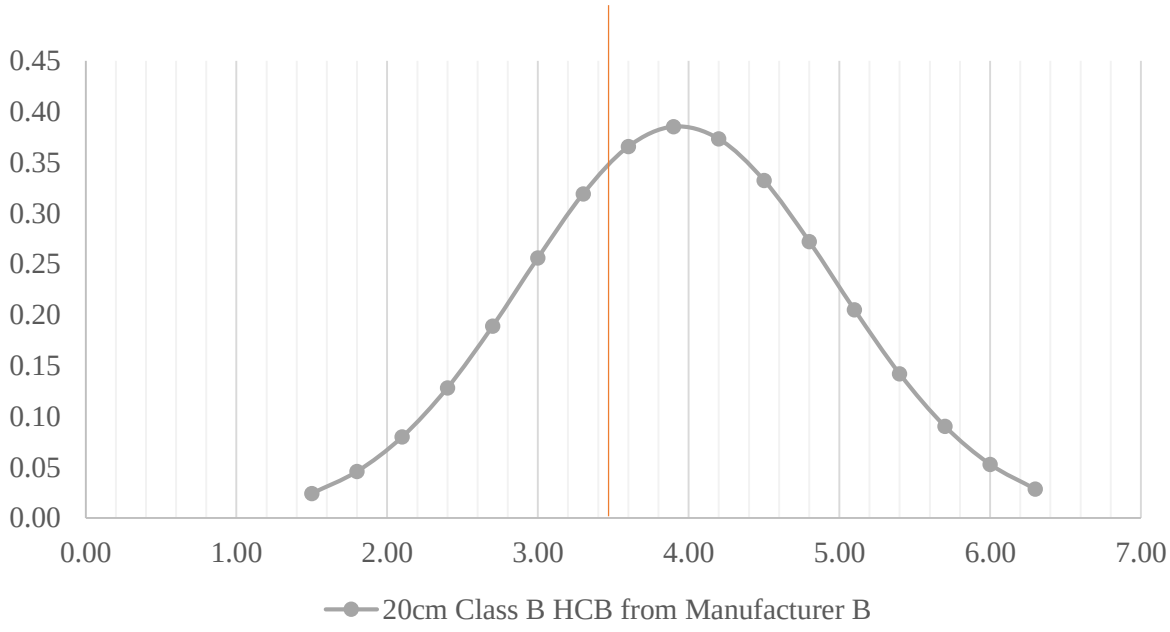

Figure 4-4 Normal distribution for 20cm Class B HCB from Manufacturer B

Decide the significance level

Researchers common choices of α are 0.05 and 0.01(Field, 2013). Our choice of α =0.01, the significance level is $1-\alpha = 99\%$.

Hypothesis testing, the P-value approach

The test static

$$z\ test = \frac{\bar{X} - X_s}{\sigma/\sqrt{n}} = 6.346MPa$$

Check

Because $z_{test} = 6.346MPa > \bar{X}_s = 3.5MPa$, we do not reject the null hypothesis. Hence there is a sufficient statistical evidence that supports the claim that the quality of 20cm Class B HCB from Manufacturer B is above the standard (p=0.665>$\alpha = 0.01$).

4.6.4 Compliance of Class B HCB

a) Compliance of Individual blocks compressive strength

A three sample of 20cm Class B HCB from Manufacturer C has taken for compressive test and we have got a result of two samples does not satisfy the standards and the other full fill the standard. (Table 4-29)

Table 4-29 Compliance of individual HCB compressive strength

Load(KN)	Pressure (N/mm^2)	Minimum individual unit strength (N/mm2) for Class B	Compliance
127.57	3.2	3.2	Does comply
107.28	2.68	3.2	Does not comply
80.61	1.01	3.2	Does not comply

b) Compliance of mean compressive strength

BATCODA Technical - Specification requires the mean strength of 6 blocks to be 3.5MPa ($\bar{X}_s = 3.5MPa$).

Hypothesis

$$H_0: \bar{X} \geq 3.5MPa$$

$$H_1: \bar{X} < 3.5MPa$$

Assuming the test result of compressive strength of HCB blocks follow, a normal distribution and with our sample that has a mean ($\bar{X} = 2.297MPa$) and sample standard deviation ($s = 1.144Mpa$), the normal distribution will be as illustrated in Figure 4-5.

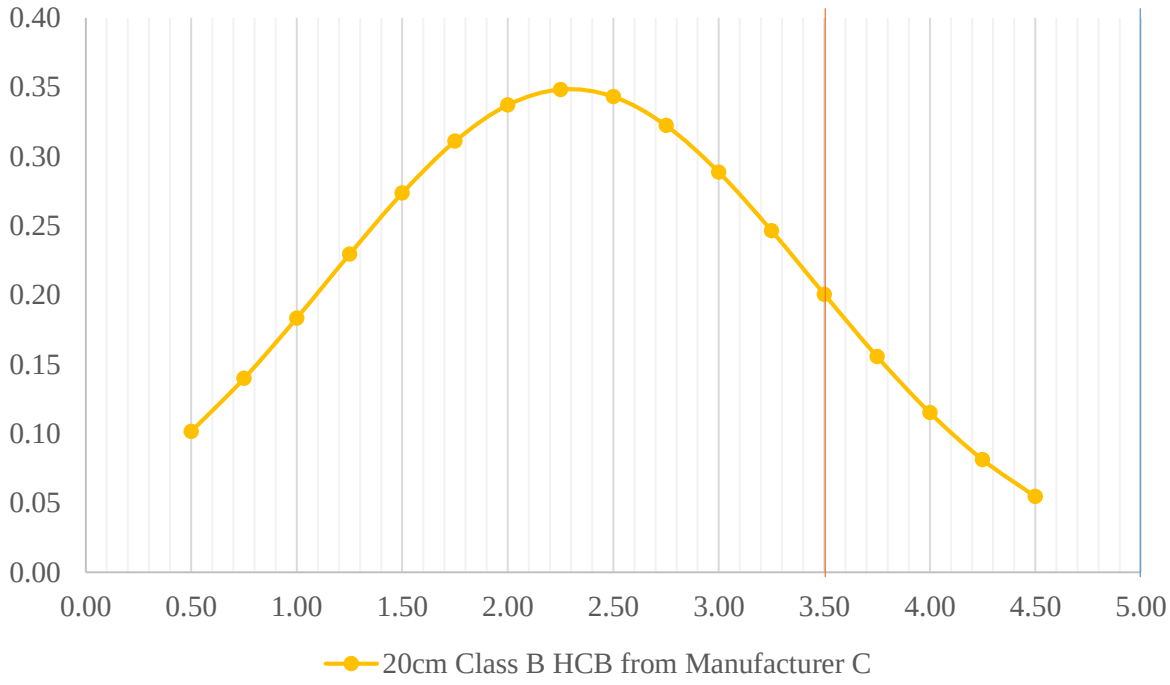

Figure 4-5 Normal distribution for 20cm Class B HCB from Manufacturer C

Decide the significance level

Researchers common choices of α are 0.05 and 0.01(Field, 2013). Our choice of α =0.01, the significance level is $1-\alpha = 99\%$.

Hypothesis testing, the P-value approach

The test static

$$z\ test = \frac{\bar{X} - X_s}{\sigma/\sqrt{n}} = 4.958MPa$$

Check

Because $z_{test} = 4.958MPa > \bar{X}_s = 3.5MPa$, we do not reject the null hypothesis. Hence there is a sufficient statistical evidence that supports the claim that the quality of 20cm Class B HCB from Manufacturer C is above the standard (p=0.147>$\alpha = 0.01$).

5 Discussion

Major result

From the study we had known that most block manufacturer do not use the appropriate process and materials quality due to this they become failed through compressive strength test when we compared to the standards so their samples have rejected and the others full fill the requirements listed in standard code so their samples are not rejected.

HCB quality

Hollow concrete block production starts from selection and proportioning of raw materials such as aggregates, cement and water. Next, production process will be continued; it composed of batching, mixing, compaction (vibration), curing and drying. Based on results of questioner survey, Type and source of aggregate used from manufacturer to manufacturer is different. most respondents use poor quality of aggregate due to the shortage of the source that can be used for preparation of aggregate. This property makes the blocks to have low quality and strength. Type of Cement used from manufacturer to manufacturer is different. Most respondent use OPC for the reason of having low cost when we compare from PPC.PPC has a highly expensive and shortage in the market due to this producer bias for the usage of OPC. Quality of water used for the production is different from producer to producer. Most respondents use drinking water but the others do not use drinking water. Water that passes for drinking is the standard for making blocks. Such water should be free from impurities such as suspended solids, organic matter, and dissolved salts. The presence of such impurities can affect the setting and hardening properties of the blocks(B.K. Baiden and Martin Morgan Tuuli, 2004).

In case of batching of ingredients used for production of hollow concrete blocks, except one respondents all uses volume batching. The accuracy of the measurement of the various quantities of each constituent material is important if the required strength of block is to be achieved. Thus, batching by weight is usually preferred to batching by volume(B.K. Baiden and Martin Morgan Tuuli, 2004).Producer use volume batching because of this some uncertainty of measurement can be mentioned for the block to be a low quality and strength.

Based on results of questioner, the technique of mixing most producers used is mixing plant. The rest are using both manually and mixing plant, this can cause mixes not to be uniform so it can result to be produced a low quality and strength of HCB. A study in Nigeria has found, for a large number of blocks, mechanical mixing is recommended; however, manual mixing can also be used where a small number of blocks are required. It is important to control the water content during mixing, as excessive water in the mix cause shrinkage and distortion of the blocks on drying(B.K. Baiden and Martin Morgan Tuuli, 2004).

The curing technique of most producers is outside a shade and Others uses under the shade. Duration of curing that the respondents use 14 days,21 days and 28 days but the remain do not keep duration of curing.so if the blocks are placed outside of the shade for a long time without proper care it might be subjected to malfunction and destructed. Blocks shall remain under shed and wet cured for a minimum of 7 days after casting. Blocks shall not leave their place of manufacture before the age of 28 days.(BATCODA-Technical Specification, n.d.) A study in Nigeria has found that exposure to heat contributes to low quality of HCB(B.K. Baiden and Martin Morgan Tuuli, 2004).

Based on our questionnaire survey major of the respondents uses both skilled and unskilled labors and some producers uses unskilled man power for the production of HCB. The use of unskilled man power will bring to unbalanced and unproportioned of materials leads to production of low quality and strength of HCB. Use adequate number of skilled workmen who are thoroughly trained and experienced in the necessary crafts and who are thoroughly familiar with the specified requirements and methods needed for proper performance of the work in this section. (BATCODA-Technical Specification)

Based on our data from the respondent duration of storage of HCB are stored until a purchaser comes but if they don’t come to purchase the produced blocks are might be subject to cracks this leads to the reduction of quality and strength of HCB.

On the base of the information that we got from the respondent half of the respondent perform correct test and other are not conduct the correct Ethiopian standard HCB test, which lead to production of low quality and strength of HCB.

laboratory results

We have conduct a compressive strength test for HCB from the test result we have analysed our data. before the test we have collected 12 samples from three manufacturers in two class of class A and class B. After we collect the samples we had conducted the test in a scientific way. As a result, we have got a quantitative data from the laboratory test result in order to analyse. Then we try to compare and differentiate the blocks by using their compressive test result from the BATCODA-Technical Specification Standard. From this result we try to mention the categories of blocks that are rejected and not rejected depends on their compressive strength test result as follows.

20cm Class A Manufacturer A has an average compressive strength of 1.28 MPA, 15cm Class B Manufacturer A has an average compressive strength of 0.53MPA, 20cm Class B Manufacturer B has an average compressive strength of 6.35 MPA and 20cm Class B Manufacturer C has an average compressive strength of 4.958 MPA. In BATCODA-Technical Specification Standard the mean compressive strength of class A and B is 4.2 and 3.8 respectively. So as we can see from the standard Class A and B of manufacturer A are rejected and Class B and C of manufacturer B and C are not rejected.

6 Conclusions & Recommendations

6.1 Conclusions

From the qualitative and quantitative survey results and the discussion most frequent factors that reduce quality and Strength of hollow concrete block (HCB). Most block producers are not using the material that has a good quality for the production of Hollow Concrete Blocks and they do not carry out any form of sample testing on Hollow Concrete blocks. In the production site appropriate mix ratio must be used but most producers are not punctual in order to be profitable in the market they are not willing to use appropriate ratio. The other problems are Producers do not use matured or skilled labours for the production process of Hollow Concrete Block and in the curing process most producers do not cure the blocks sufficiently and widely.

The other process that a producer must to examine is a compliance control. Compliance control is a check made to ensure the compliance of the HCB with the specification but, these criteria has not been practiced on the production site of Hollow Concrete Blocks. As on a result of statistical analysis made on compressive strength test result indicated that the quality control on significant portion of the production is not good.

The result of compressive strength that we get from the laboratory do not full fill as compared to BATCODA-Technical Specification, this is due to careless production control and Compliance control. Compliance testing for HCB is insufficient because Ethiopian standard recommended testing dimension, visual defect, water absorption in addition on testing for Compressive Strength.

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6.2 Recommendations

Construction materials such as aggregates, cements and sand should be passed through necessary tests which helps the construction area by providing a material having a good quality and strength. In addition to this, every production process should follow proper scientific procedures starting from selection of ingredients up to storing of the product(HCB) to keep the quality and strength.

Producers should use appropriate mix ratio to improve the quality and strength. specially the labours that are participated in the production process of Hollow Concrete Block should be skilled in order to produce the HCB will be produced in a good quality and strength.

The blocks should be cure sufficiently and widely under the shade and also block producers should conduct a sample test on Hollow Concrete blocks before they prepare for sale or use. Also, compliance control should be made to ensure the compliance of the HCB with the specification.

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Appendix

Appendix A: Research questioner used for the study in English and Amharic

Questioners for hollow concrete block producers

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

1.Please specify the types of HCB produced in your site?

- ○ HCB for masonry wall
- ○ HCB for ribbed slab

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

HCB for masonry wall

○ A ○ B ○ C ○ D

HCB for precast slab_____

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

Hollow Concrete Block (L X W X T)

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

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

Coarse aggregate: _____ _____ _____

Fine aggregate: _____ _____ _____

5. What type of Aggregate used for production?

- ○ Light weight Aggregate
- ○ Normal weight Aggregate
- ○ Combined Aggregate

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

_____ _____ _____

_____ _____ _____

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

- ○ OPC
- ○ PPC

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

_____ _____ _____

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

Hollow Concrete Block

40 x 20 x 20 _____

40 x 20 x 15 _____

40 x 20 x 10 _____

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

_____ _____ _____ _____

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

- ○ Drinking water
- ○ If non-drinking water;
  - ○ From river Round water
  - ○ From drilled well

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

_____ _____

13. Which batching techniques do you use?

- ○ By weight
- ○ By volume

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

a) Weight batching: _____

b) Volume batching: _____

15. How do you mix your ingredients?

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

16. For how long do you mix the ingredients?

_____

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

_____ _____

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

_____

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

_____

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

- ○ Under the shade
- ○ Outside the shade

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

_____

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

_____

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

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

24. In your production site, what man power used?

- ○ Skilled
- ○ Unskilled
- ○ Both (skilled and unskilled)

25. What are the cause to produce low quality hollow concrete block?

_____

_____

Appendix B: HCB test results

Laboratory report for Hollow Concrete Block Test at Construction Laboratory of Wolkite University

HCB Dimension: 20cm*20cm*40cm

HCB Class: A

Test Results

Load(KN)	Pressure(N\mm^2)
44.71	1.12
45.14	1.13
45.43	1.14
46. 2	1.15
45.73	1.14
45.34	1.13
45.05	1.12

HCB Dimension: 20cm*20cm*40cm

HCB Class: A

Test Results

Load(KN)	Pressure(N\mm^2)
40.16	1.00
40.64	1.01
40.71	1.02
41.37	1.03
40.98	1.02
40.49	1.01
40.15	1.00

HCB Dimension: 20cm*20cm*40cm

HCB Class: A

Test Results

Load(KN)	Pressure(N\mm^2)
45.27	1.13
45.45	1.14
46.21	1.15
46.36	1.16
46.22	1.15
45.64	1.14
45.46	1.13

HCB Dimension: 15cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
23.58	0.30
24.40	0.31
25.42	0.32
26.37	0.33
25.98	0.32
25.13	0.31
24.42	0.30

HCB Dimension: 20cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
23.98	0.30
25.09	0.31
25.86	0.32
26.2	0.33
25.95	0.32
25.14	0.31
23.87	0.30

HCB Dimension: 15cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
33.07	0.41
33.87	0.42
34.14	0.43
35.74	0.45
34.67	0.43
33.86	0.42
33.52	0.41

HCB Dimension: 20cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
197.44	4.94
197.79	4.95
198.26	4.96
198.78	4.97
198.31	4.96
197.84	4.95
197.41	4.93

HCB Dimension: 20cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
214.76	3.91
214.99	3.92
215.22	3.93
215.45	3.94
215.27	3.93
214.74	3.92
214.21	3.91

HCB Dimension: 20cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
231.75	2.87
231.98	2.88
232.17	2.89
232.29	2.90
232.14	2.89
231.87	2.88
231.63	2.87

HCB Dimension: 20cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
126.97	3.17
127.25	3.18
127.47	3.19
127.86	3.20
127.57	3.19
126.8	3.17
126.21	3.16

HCB Dimension: 20cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
105.73	2.65
106.41	2.66
106.75	2.67
107.28	2.68
106.67	2.67
106.01	2.65
105.61	2.64

HCB Dimension: 20cm*20cm*40cm

HCB Class: B

Test Results

Load(KN)	Pressure(N\mm^2)
80.34	0.98
80.48	0.99
80.57	1.00
80.61	1.01
80.54	1.00
80.43	0.99
80.22	0.98