Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Construction Engineering and Management Stream

Investigation of alternative construction material by using coffee husk to produce low cost HCB at Jimma town, Ethiopia

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Civil Engineering (Construction Engineering and Management Stream)

By:

Dawit Ketema

July, 2017

Jimma, Ethiopia

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By:

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Advisor: - Prof. Emer T. Quezon

Co- Advisor: - Getachew Kebede (PhD candidate)

July, 2017

Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis entitled "**Investigation of Alternative Construction Material by Using Coffee Husk to Produce Low Cost HCB at Jimma Town, Ethiopia**" is my original work and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for these have been dually acknowledged.

Candidate:

Mr. Dawit Ketema Tesfaye

Signature: _____________

As Master research Advisors, we here by certify that we have read and evaluate this MSc. Research prepared under our guidance, by Mr. Dawit Ketema entitled: **"Investigation of Alternative Construction Material by Using Coffee Husk to Produce Low Cost HCB at Jimma Town, Ethiopia"**

We recommend that it can be submitted as fulfilling the MSc Thesis requirements.

Prof. Emer T. Quezon: - Advisor ______________ ___________

Signature Date

Getachew Kebede (PhD Stud.):- ______________ ___________

Co- Advisor Signature Date

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ABSTRACT

Recent interest in environment-friendly materials has led to the use of agricultural by-products as raw material for the production of many construction materials. Because of this the material that used in this study was coffee husk and halls which are residues of coffee processing. Today; these materials are burnt on the field or dumped on land or in rivers.

The main objective of this study was to investigate the optimal replacement of sand by Coffee Husk in the production of light weight and low-cost hollow concrete block. Depending on the type and amount, the lab-make the hollow concrete block had been fulfill the requirements of Ethiopian, American, Indian and European standards with respect to general use in dry conditions and partly in humid conditions of 7^th^, 14^th^, and 28^th^ days.

Specifically this experimental study was conducted by preparing two types of HCB test samples. The test sample of HCB was produced by using mix proportion 1:6 of cement and sand. Out of the six parts of aggregate, the aggregate was replaced with 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% and 100% amounts of coffee husk by volume.

Based on the result, the HCB without coffee husk achieved 3.82Mpa mean compressive strength and the HCB with 30% coffee husk achieved 3.64Mpa mean compressive strength. The optimum replacement was obtained at 30% coffee husk. The production cost of all HCBs with coffee husk was found lower than the HCB without coffee husk. The weight comparison made, the HCBs with coffee husk were found lighter than HCB without coffee husk.

The hollow concrete block with coffee husk in this study has achieved a better cost reduction in production cost, higher reduction in weight with 45.63% and a smaller reduction in compressive strength with 4.95% than hollow concrete blocks without coffee husk. The study further recommended to the micro and small HCB producers to increase the production of HCB with coffee husk, for the contractors and clients of Jimma Town to use this product instead of importing HCB.

Keywords: Coffee Husk, Compressive Strengths, Crushed Aggregate, Hollow Concrete Block and Sand

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ACRONYMS

ACI	American Concrete Institute
ASTM	American Society for Testing and Materials
BMTPC	Building Materials and Technology Promotion Council
BS	British Standard
CCI	Cement and Concrete Institute
CEM	Construction Engineering and Management
CH	Coffee Husk
CMU	Concrete Masonry Units
EBCS	Ethiopian Building Code Standard
ES	Ethiopian Standard
ETB	Ethiopian Birr
GB	Giga Bit
G_s	Specific Gravity
HCB	Hollow Concrete Block
Ib	Pound
IS	Indian Standard
JIT	Jimma Institute of Technology
kg	Kilo gram
MPa	Mega Pascal
OPC	Ordinary Portland cement
PPC	Portland Pozzolana Cement
SRCCD	Swiss Resource Center and Consultancy for Development

CHAPTER ONE

INTRODUCTION

1.1. Background

Sustainable development of the built environment in developing countries is a major challenge in the 21st century. The use of local materials in construction of buildings is one of the potential ways to support sustainable development in both urban and rural areas. The demand for low cost sustainable building materials is growing as social, economic, and environmental issues involve in today's society [24]. The urgent need to develop suitable and affordable housing is born as a consequence of the fact that over one billion people in the world, most of who live in developing nations, are either homeless or live in very poor housing. For that reason to satisfy and give a house for those who are homeless we must build low cost house. However for those houses walling materials are take the largest credit or cover large area than other housing materials like roof, door window [38].

The monetary cost of low-cost walling in developing countries is greatly dependent on the expensive additives that are used to manufacture the building units and the cost of transportation of raw materials or finished products to the site of construction. Therefore to have low cost housing we must reduce the cost of the walling system or use walling material produced from locally available materials hence the cost can be reduced without jeopardizing the strength of the material beyond acceptable limits then this would be a significant advantage [24]

Hollow concrete block is an important addition to the types of walling units available to designer and engineer and its use in walling construction is constantly increasing due to the various advantages discussed above. It is a multipurpose and most popular construction material in the world. It is produced by mixing fine aggregates (sand), cement and water and additives in a certain prescribed proportion. It is well known that a fine aggregate plays an important role in hollow concrete block. Research indicates that changes in aggregate can change the strength and fracture properties of concrete. The compressive strength of hollow concrete block depends on the water to cement ratio, degree of compaction, ratio of cement to aggregate, bond between mortars and aggregate [32]. To make hollow concrete block with recommended strength it needs proper proportioning of the ingredients and the right selections of materials to ensure a long-lasting structure that does not require excessive maintenance in the future.

The main natural lightweight aggregates are diatomite, pumice, scoria, volcanic cinder, and tuff. Except for diatomite, all are volcanic in origin. Pumice and scoria are most widely used for hollow and solid concrete block production in Ethiopia [1]. But no one try and approve that coffee husk is used for light weight and low cost hollow concrete block production from this ground this research is show using of Coffee Husk in production of HCB.

This study was conducted laboratory experiment on reducing, minimizing hollow concrete block making ingredients mainly sand and aggregate through substitute with coffee husk (CH) which helps to know the weight and production cost reduction and compressive strength of normal hollow concrete block. From analyzing the laboratory results, it was found that addition of coffee husk (CH) to the HCB production generally reduced the weight and the compressive strength.

1.2. Statements of the problem

Making hollow concrete block is not an easy task, especially to achieve the desired strength of concrete with light weight. Many scholar's and researchers are conduct to find out suitable ingredients to produce different types of hollow concrete block with acceptable strength.

The strength developed by a hollow concrete block made with given materials and given proportions increases for many months under favorable conditions, but in the majority of specifications the strength is specified at an age of 28 days. It is known that the strength of hollow concrete block in depending on the quality of ingredient used.

Among those ingredients the major portions are taken by fine aggregate (sand) and cement. In this study the researcher has investigated the possible or suitable ingredient for the production of hollow concrete block in the study area. Coffee in Jimma zone is one of main cash crop but its husk is abundant, waste material and environmental pollutant problem and the fine aggregates are come from another place; which means that the cost of sand is much expensive compare to other place.

Since hollow concrete blocks need to be light in weight, the use of light weight aggregates in production plays an important role in weight reduction. Around the study area, the only available light weight as aggregate is coffee husk which is not used for construction. Most contractors buy import light weight HCB from Addis Ababa to produce by using pumice. They only consider the light weight aspect and the quality is in question. Buying HCB from Addis Ababa instead of using coffee husk for HCB production is resulting extra cost in construction due to high cost of transportation.

1.3. Research Questions

The research questions that this study will go to explain; are as follows:

1. What are the Engineering properties and characteristics of hollow concrete block with coffee husk?
2. What are the potential effects of using coffee husk on the Compressive Strength of Normal hollow concrete block within the study area?
3. What is the optimum coffee husk replacement that will give maximum compressive strength?
4. How much the cost different of production of each HCB type?

1.4. Objectives

1.4.1. General objective

The main objective of study is to investigate alternative construction material by using coffee husk to produce HCB around Jimma zone.

1.4.2. Specific Objectives

- ✓ To determine the weight and compressive strength of both hollow blocks with Coffee Husk and without Coffee Husk.
- ✓ To determine the optimal replacement amount of coffee husk.
- ✓ To compare the cost of production between the two types of blocks.

1.5. Scope and Limitation of Study

The research conducted in Oromia National Regional state around Jimma zone to alternative construction material by using Coffee Husk to produce low cost HCB. And addressed the objective and tried to compare the weight, compressive strength and production costs of HCB with and without Coffee Husk in Jimma town. The two types of blocks used in this study are hollow concrete blocks without Coffee Husk (cement, sand, gravel 00 and crushed aggregate 01) and hollow concrete blocks with Coffee Husk (cement, Coffee Husk and crushed aggregate). The mix proportion for both hollow concrete blocks was taken from the trend of the micro and small enterprise in Jimma town. The production cost used for comparison is only the direct unit cost of production due to lack of data on the indirect production costs.

In this study, only the physical and chemical properties of the Coffee Husk used were determined from the reference. But not determined due to the lack of laboratory for such tests in Jimma University and ERA.

1.6. Significance of the Study

- This study is to investigate alternative construction material by using Coffee Husk To Produce HCB around Jimma zone provide helpful information to various stake holders as follows;
- Our country Ethiopia benefit from the study as a source of information and foundation for the construction industry that can help to improve environmentally friend construction material.
- Owners, contractors and consultants will benefit from the study as a source of information for building low cost construction projects, in case of Jimma city.
- The availability of ingredients nearly or locally for any construction materials makes the material cost lower than other ingredients which are not available. Since coffee husk is nearly and abundantly available to Jimma town, this study contributes to the use of coffee husk in the production of HCB both in terms of weight and cost without jeopardizing strength in the study area. This study will also use as a baseline data in those areas in Ethiopia where red ash is available. And also this study will contribute information about using coffee husk in HCB production for further studies to be conducted in the future.
- Other researchers will use the findings as a reference for further research on engineering property of concrete.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1. Theoretical review

Concrete blocks are also known as concrete masonry units and have become increasingly important as a construction material. Technological developments in the manufacture and utilization of the units have accompanied the increase in their use. Concrete masonry walls, correctly designed and constructed, will satisfy a variety of building requirements including fire resistance, durability, aesthetics and acoustics [33].

Dense concrete blocks, which may be hollow, cellular or solid in form, are manufactured from natural dense aggregates including crushed granite, limestone and gravel. Medium and lightweight concrete blocks are manufactured incorporating a wide range of aggregates Including expanded clay, expanded blast furnace slag, sintered ash and pumice [31]. But they did not use any by product or waste material to reduce the weight like coffee husk, rice husk.

According to Ethiopian standard HCB is an alternative wall and floor making material in the building construction having one or more large holes with the solid material between 50%- 75% of the total volume of the block calculated from the overall dimensions [20]. On the other hand according to concrete block association blocks which contains one or more formed voids which are fully penetrate the block, decrease in density, thus decreasing the end-product weight [15].

Figure 1: Hollow concrete blocks (source: - SRCCD, 2008)

2.1.1. Types of hollow concrete blocks

In Ethiopia, during the low cost housing project, different types of hollow concrete blocks were introduced [17].

a) Full HCB: the full hollow block has a size of L*W*H=32cm*16cm*19cm. The size of the HCB is reduced in comparison to the usual sizes used in Ethiopia. The new size of hollow blocks reduces the production materials and makes the HCB easier to handle, this reduces labor and material costs.

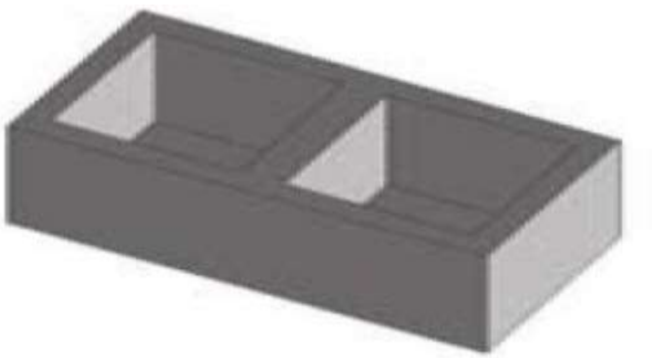

Figure 2(a): Full HCB (source: - GTZ Low cost Housing Technical Manual Volume I).

b) Half HCB: it has a size of L*W*H=16cm*16cm*19cm and represents exactly half of one full HCB.

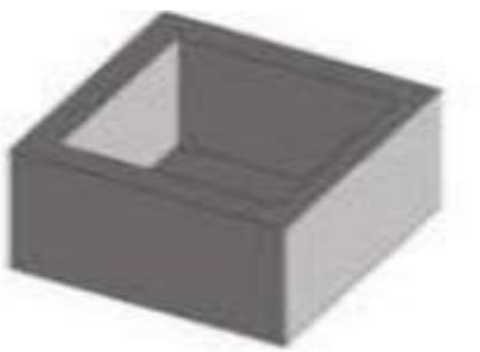

Figure 3: Half HCB (source: - GTZ Low cost Housing Technical Manual Volume I)

c) U- Shaped HCB: the u-shaped HCB has the same size as the full HCB, L*W*H=32cm*16cm*19cm. it is used as a formwork for ring beams and lintels and at the same time as a part of the wall.

Figure 4: U-shaped HCB (source: - GTZ Low cost Housing Technical Manual Volume I)

d) Column HCB: the column HCB has a size of L*W*H=32cm*16cm*19cm. It is used as a formwork for columns and at the same time as part of the wall.

Figure 5: Column HCB (source: - GTZ Low cost Housing Technical Manual Volume I)

e) Slab HCB: this slab construction system, introduced by the low-cost housing project, avoids formwork, reduces requirements of skilled manpower and time. The slab HCB is done in the same way as production of wall HCB.

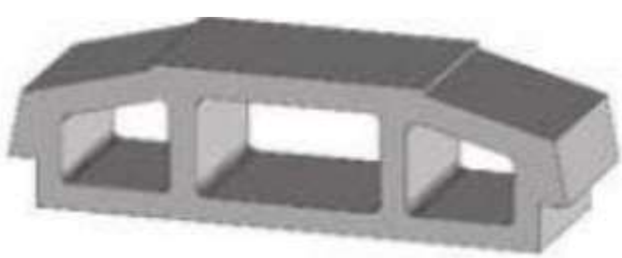

Figure 6: Slab HCB (source: - GTZ Low cost Housing Technical Manual Volume I).

2.1.2. Classification of hollow concrete blocks in different standards

A) Based on Ethiopian standard

According to Ethiopian standards hollow concrete blocks shall meet four classes depending on their compressive strength, as class A, class B, and class C

- **Class A:** are load bearings 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 60 range of 900 – 1200 kg/m^3 [20]. On the other hand Indian standard part I recommended minimum density 1500 kg/m^3 [25].

- **Class B:** are also load bearings are used for load bearing wall construction above ground level in damp proof course in exterior walls that are treated with suitable weather-protective coating and their density should be between 900 – 1200 kg/m^3 [20]. On the other hand Indian standard part I recommended minimum density within the range of 1000-1500 kg/m^3 [25].

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

Their minimum compressive strength is listed in **Table 1.** The minimum compressive strength in the table is to classify the blocks in each class is listed for both individual units and for average of 6 units in N/mm^2**.**

Table 1: Compressive strength of hollow concrete blocks at 28th days (source: - ES C.D3. 301)

Type of hollow concrete block	Class	Minimum compressive strength (N/mm^2)	
		Average of 6 unit	**Individual units**
Load bearing	**A**	**5.5**	**5.0**
	B	**4.0**	**3.2**
Non Load bearing	**C**	**2.0**	**1.8**

Table 2: Nominal dimensions of hollow concrete blocks (source: - ES 569:2001)

Length(L) mm	Breadth(B) mm	Height(H) mm
400	100 150 200	200
500	100 120 150 200	100 150 200 250
600	100 120 150 200	100 150 200 250

The standard also list nominal size of hollow concrete blocks in terms of length, breadth and height as shown below in **Table 2**. For each length class the standard list possible breadth and heights. Among the listed dimensions the length class 400 mm is only considered as modular with different breadth (100 mm, 150 mm and 200 mm) and a height of 200 mm.

B) Based on American Society for Testing and Materials hollow concrete blocks are mainly classified as load bearing and non- load bearing in terms of compressive strength. The classification is listed in **Table 3** as shown below.

Table 3: Compressive strength of hollow concrete blocks (source: - ASTM C90-70 and 129-70)

Type of HCB	Grade	Minimum compressive strength (N/mm2)	
		Average of 3 units	Individual units
Load bearing	Type N (I & II)	6.9	5.5
	Type S (I & II)	4.8	4.1
Non Load bearing	Type I & type II	Average of 5 units	Individual units
		3.5	3.0

As shown in **Table 3,** ASTM classifies hollow concrete blocks as load bearing and non-load bearing. There are two grades under load bearing these are type N and type S. grade N are used for general use such as in exterior walls below and above grade level. Grade S are used only above grade level. Both grades have two types such as moisture controlled units known as Type I and non moisture controlled units known as type II. The non-load bearings are also grouped under type I and type II [5].

2.2. Materials for hollow concrete block

Since the ingredients of concrete can be of very different types and qualities, not only depending on their local availability but also on the desired properties of blocks, equipment and production method. It is not possible to give detailed recommendation on materials and mix proportions, other than very general guidelines. It is up to the manufacturer to select the most suitable materials and design of mixes by trial and error [20].

1. Cement

Cement paste is the binder in concrete or mortar that holds the fine aggregate, coarse aggregate or other constituent's together in a hardened mass. The properties of concrete depend on the quantities and qualities of its constituents. Because cement is the most active component of concrete and usually has the greatest unit cost, its selection and proper use are important in obtaining most economically the balance of properties desired for a particular concrete mixture. Most cement will provide adequate levels of strength and durability for general use. It is usually satisfactory and advisable to use general-purpose cement that is readily obtainable locally. When such cement is manufactured and used in large quantity, it is likely to be uniform and its performance under local conditions will be known.

- ✓ **Type I, or ordinary cement**, is used where extended curing periods are no handicap, or where blocks can be yarded for 7 to 28 days, allowing time for the blocks to attain specification strength. Different brands may vary somewhat in colour, ranging from yellowish to slate gray, and may affect slightly the colour of the finished products when various brands are used.

- ✓ **Type II cement** is generally darker than Type I. It is therefore preferred in some localities where darker units are more popular. It may set and harden somewhat slower than Type I.
- ✓ **Type III (high early strength) cement** is being used more and more for concrete products. This cement is ground to greater fineness and produces a paste of greater coating capacity. The mix is reported to be able to carry more water, and responds more under vibration or compaction, forming denser units. This cement hardens rapidly so normal curing and storage periods are reduced and units are ready for marketing sooner. Some plants use this type of cement exclusively, finding that the small extra cost is offset by the advantages it offers [28].

2. Aggregates

The type and source of the aggregate has a considerable influence on the compressive strength of concrete. As a general rule, an uncrushed coarse aggregate (generally smooth and rounded) makes a concrete with a lower strength than one with crushed coarse aggregate. Other factors such as the type of fine aggregate, the maximum size of aggregate, the overall grading, and particle shape and surface texture, have little direct effect on the compressive strength and are ignored for the purposes of this publication.

The aggregates used will consist of sand, gravel, crushed stone, slag, cinders or other inert materials or combinations of them. They must be free from excessive amounts of dust, soft flaky particles or shale, or other deleterious materials [28]. All the aggregates also should be free from frost or lumps of frozen materials. The maximum and minimum sizes of aggregate used will be governed by the process of manufacture, the desired surface effects and the type and dimensions of the manufactured units [28].

- ✓ **Fine aggregates: -** According to ASTM fine aggregates are aggregates passing the 9.5mm sieve and almost entirely passing 4.75-mm (No. 4) sieve and predominantly retained on the 75-µm (No.200) [4].
- ✓ **Coarse aggregates: -** According to ASTM, aggregate predominantly retained on the 4.75-mm (N0.4) sieve or portion of an aggregate retained on the 4.75-mm (No.4) sieve [4]. The maximum size will be limited by the dimensions of the unit to be produced. The

largest pieces should not exceed one-third the thickness of the thinnest web of the units. The maximum size of aggregate should be 10 mm [35]. Gravel, since it occurs widely, is largely used. It must, of course, be clean and durable and free from soft, flat or elongated pieces and should be evenly graded from the minimum to the maximum sizes [24].

Well-graded sand, ***gravel*** and ***crushed stone*** are used to manufacture normal–weight units and they are called normal weight aggregates. Whereas lightweight aggregates such as ***pumice***, **scoria**, ***cinder***, ***expanded clay*** and ***expanded shale*** are used to manufacture light weight units [29].

Classıficatıon of Aggregates [35].

- ✓ **According to Source:**
  - Natural aggregate: sand, gravel, crush stone
  - Artificial aggregates: blast furnace slag, expanded perlite
- ✓ **According to Petrological Characteristics:**
  - Igneous rocks: granite
  - Sedimentary rocks: limestone
  - Metamorphic rocks: marble
- ✓ **According to Unit Weight:**
  - Heavy weight agg.: Hematite, Magnetite Specific Gravity, $G_s > 2.8$
  - Normal weight agg.:Gravel, sand, crushed stone $2.8 < G_s < 2.4$
  - Light weight agg.:Expanded perlite, burned clay $G_s < 2.4$

Cement- aggregate ratio:

- ✓ Suitable proportion of aggregate to cement must be found by testing
- ✓ Common ratios are 1:6 and 1:8
- ✓ Test the quality of block produced [33].

3. Coffee Husk

In the processing from the coffee fruit to the exposed bean, called green coffee beans, there are two methods primarily used: the dry or the wet method. In the dry method, the coffee fruits are spread out on terraces or bars in the sun until dried and the beans are separated from the pulp by shrinking from the parchment layer. A dehulling machine is used to separate the sundried coffee husks, the parchment and the beans from each other [10].

In the wet method, the skin and pulp are removed leaving the bean with the silver skin, the parchment and a mucilage layer. The beans are washed in water, drained and fermented for 12-48 hours. The dry method is generally used for *Robusta* and the wet method for *Arabica*.

Coffee husk has been considered a waste material and has generally been disposed-off by damping or burning. The bean is the main crop. Currently experimental work briefly describes that the suitability of the locally available coffee husk (CH) is environmentally friendly and present important attributes, such as light weight, low cost, high tensile strength.

Figure 7: By-product of coffee (source: - Coffee husk)

Generally it is low cost even it is disposed material and has color, light weight, abundant, good water absorption, low cohesive behavior, compressive strength in addition to that the physical and chemical property of coffee husks are listed below within those listed two tables [8].

Table 4: Physical property of coffee husk (source: - A.R.Vinod et al/Int.J.ChemTech Res.2013, 5(3))

Properties	**Coffee husk**
Length (mm)	0.3mm
Diameter	20μm
Designation	Short, fine

Table 5: Chemical property of coffee husk (source: - A.R.Vinod et al/Int.J.ChemTech Res.2013, 5(3))

Properties	**Coffee husk**
Cellulose	24.5%
Hemi cellulose	29.7%
Lignin (total)	23.7%
Ash	0.6%

Its uses

- **Coffee husk Solids to Silage:**

Coffee husk is really a very versatile substance, but the presence of caffeine has up to now been seen as a negative factor making it unusable as an animal foodstuff. By a slight dewatering of the pulp, inoculation with commercial silage additives and packing it into plastic liners within Recycling container, or one tone flexible bulk containers, within 3-4 months an excellent foodstuff suitable for cattle feedlots is achievable, bringing extra cash flow during the off season period [8].

- **Coffee Husk as a fuel:**

Coffee husk is practically pure lignocelluloses and has no fertilizer value at all. It is normally burnt in crude furnaces to dry our coffee parchment. If most of the parchment is partially sun dried for quality reasons then, even with today's crude single pass hot air driers, it is still possible to have a surplus of fuel after a finish drying operation. Burn the husk in a gas producer, and then run an engine on that producer gas to produce electricity. Once again as with biogas, the waste heat from the gas producer and the engine can be used to heat a clean air stream, and that can still be used to dry even more coffee than before [8].

- **Coffee pulp solids as Compost:**

Coffee pulp solids contain only one fifth of the nutrients taken out of the soil by export of the green bean. However, it is a good source of humus and organic soil carbon. If coffee pulp is turned over every few days in a heap preserved for a few years as in conventional compost making, it will compost in three weeks into one fifth of the original volume of a stable earthy smelling material which does not attract flies. Left to mature for three months under cover, it will reduce further to become very nice dry earthy compost which is a good soil improver and conditioning agent [8].

4. Water for hollow concrete blocks

As regards water content, the various states in which an aggregate may exist are: (1) Oven dry (2) Air dry (3) Saturated surface dry and (4) Damp, or wet. In proportioning the materials for HCB, it is always taken for granted that the aggregates are saturated and surface dry. It should be noted that if the aggregates are dry they absorb water from the mixing water and there by affect the workability and, on the other hand, if the aggregates contain surface moisture they contribute extra water to the mix and thereby increase the water/cement ratio [19]. Both these conditions are harmful for the quality of Hollow concrete block. In making quality concrete, it is very essential that corrective measures should be taken both for absorption and free moisture so that the water/cement ratio is kept as exactly as per the design. Therefore, in calculating or measuring quantities for mix it is important to know the state at which the aggregate is used.

The mixing water should be free from injurious amounts of oils, acids, strong alkalies, organic matter or factory wastes. Water that is fit to drink is usually satisfactory. The water is used not only to make the mixture plastic and easy to mold, but is essential in the hydration of the cement. Any impurities present may seriously lower the strength of the concrete units and may cause undesirable acceleration or retardation of the setting time of the cement. It should not be colder than 600 F. Since temperatures much lower than this tend to retard the setting time and early hardening of the block and, unless it is clean, stains on the finished units may result [29]. Water cements ratio. Accordingly recommended water- cement ratio is 0.49-0.55 [19].

2.3. Hollow concrete block (HCB) production process

The production process is carried out in three steps: batching and mixing, molding, and curing [20].

- **Batching and mixing:** Aggregates can be batch by volume or by weight, but the latter is more accurate. For this reason, cement should only be batch by weight, or preferably by using only whole bags of 50 kg. The objective of thorough mixing of aggregates, cement and water is to ensure that the cement-water paste completely covers the surface of the aggregates. All the raw materials including water are collected in a concrete mixer, which is rotated for about 1 ½ minutes. The prepared mix is discharged from the mixer and consumed within 30 minutes. In hot climates, the fresh mix must be shaded from the sun to avoid premature setting. In case of hand mixing, it must be done on a level, smooth, hard surface (e.g. concrete slab or steel plate). Because of the relatively low cement content of the concrete and the need for a cohesive mix, thorough mixing is essential. Thus the best mixes are obtained with mechanically operated mixers. The quality of concrete blocks depends largely on the type of mixer and period of mixing. The free fall, revolving drum type mixers are not suitable, because of the semi -dry nature of the mix. Pan mixers have a quick moving action and are thus recommended.
- **Moulding:** Concrete blocks can be moulded by several methods, ranging from manually tamping the concrete in wooden or steel mould boxes to large scale production with "egg laying‟ mobile machine and fully automatic stationary machine. "Egg-laying" mobile machines are designed for medium-scale production, either on-site or in a factory. The name was given to these machines, because they leave the blocks to dry where they are produced on a flat production surface and move a short distance away to produce the next batch of blocks, and so on. The quality of blocks generally increases with the degree of mechanization, but medium standards are normally adequate for most construction purposes.
- **Curing:** The blocks are either left to set and harden where they were molded, or carried away on pallets to the curing place. In all cases it is important to keep the concrete moist, for example, by regularly spraying with water, until the concrete has obtained sufficient strength. However, in developing countries, steam curing is unlikely to be implemented, because of its high cost and sophistication. Keep the concrete blocks moist by keeping under water in tanks or by regularly spraying with water for 7 days and Store for 2 weeks before usage [35].

CHAPTER THREE

MATERIALS AND RESEARCH METHODOLOGY

3.1.Study Area

The study was conducted at Jimma zone, southwestern Ethiopia which is located 346km by road southwest of Addis Ababa. Its geographical coordinates are between 7° 13’- 8° 56N latitude and 35°49’-38°38’E longitude with an estimated area of 19,506.24. The town is found in an area of average altitude, of about 5400 ft. (1780 m) above sea level. It lies in the climatic zone locally known as Woynā Dagā which is considered ideal for agriculture as well as human settlement.

Figure 8 : Map of the study area; Jimma zone (source: - Google Map)

3.2.Study Population

The population of this experimental study was Investigation of alternative construction material by using coffee Husk to produce HCB around Jimma Town**.**

3.3.Study Period

This research study was carried out within the prescribed time frame as per attached work schedule/plan from Dec 2016 to Apr 2017.

3.4.Sample size and sampling procedure

The sampling procedure needs to be conducted in order to select samples that are representatives for the study. The sampling procedure used in this research was purposive sampling. The sample size was determined accordingly to the test specimen number required to conduct compressive strength test for HCB and to meet the objectives of the study. For compressive strength test, a total of 3 HCB was prepared. For HCB without coffee husk, a total of 9 samples were prepared which were tested at 7, 14 and 28 days of curing. For HCBs with coffee husk 10 different sample were prepared with different percentage of coffee husk. These samples are listed below in table.

Table 6: Different samples with different percentage of coffee husk

Sample ID	1	2	3	4	5	6	7	8	9	10
Coffee Husk (%)	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%

For each percentage replacement, 3 samples were selected for each testing days (7th, 14th and 28th). A total of **3 samples x 3days x 10 sample kinds = 90 samples** were prepared**.** For both HCB with and without coffee husk a total sample size selected was tabulated below in **Tables**

Table 7: Sample size for HCB with coffee husk

For HCB with coffee husk	Number of samples for			Total
	7th day	**14th day**	**28th day**	
0%	3	3	3	**9**
10%	3	3	3	**9**
20%	3	3	3	**9**
30%	3	3	3	**9**
40%	3	3	3	**9**
50%	3	3	3	**9**
60%	3	3	3	**9**
70%	3	3	3	**9**
80%	3	3	3	**9**
90%	3	3	3	**9**
100%	3	3	3	**9**
Total	30	30	30	**99**

Total sample size= total sample for HCB with coffee husk + total sample for HCB without coffee husk. Therefore total sample size for this study was **99** HCBs. These samples were used to conduct compressive strength test and analysis of production cost to meet the research objectives.

3.5.Study variables

- **Dependent variable: -** Hollow concrete blocks (HCB) with coffee husk- Weight – Compressive strength-Cost of production
- **Independent variable: -** Percentage of coffee husk

3.6.Research approach

In order to achieve the objective of the research, information was gathered through literature review, compressive strength test on the samples prepared and also reviewing the HCB producers cost data and analyzing the production costs of the samples produced.

a) Literature review: this part was carried out in order to have a clear idea and information on the materials used to produce hollow concrete blocks and also how to produce hollow concrete blocks. After conducting literature review the production of hollow blocks was carried out.
b) Compressive strength test on the samples: this test was carried out on the blocks prepared to compare the compressive strength of the hollow blocks with and without coffee husk. Compressive strength test of 7th, 14^{th} and ^{28th} days were conducted [21].
c) Reviewing the HCB producers cost data and analyzing the production costs: to compare the production cost of producing HCB with and without coffee husk the producers direct cost breakdowns were reviewed the direct cost of producing the blocks were calculated and analyzed.

Finally all the data from the study were analyzed based on the objectives and in ways that are relevant to draw conclusion and recommendations.

3.7.Research Design

The research design is based on a purposive sampling selection process in terms of which a representative sample of both fine aggregate and coffee husk materials will be surveyed and the research will be conducted by using both descriptive and analytical methods. Which mean that the methodology used in the research is laboratory analysis of sample data, and will be collected from the site. After comprehensively, organizing literature review of different previous published researches, designate the effects of using coffee husk for production HCB. In particular, for fine aggregate material, the ASTM & AASHTOT laboratory producer will be conducted.

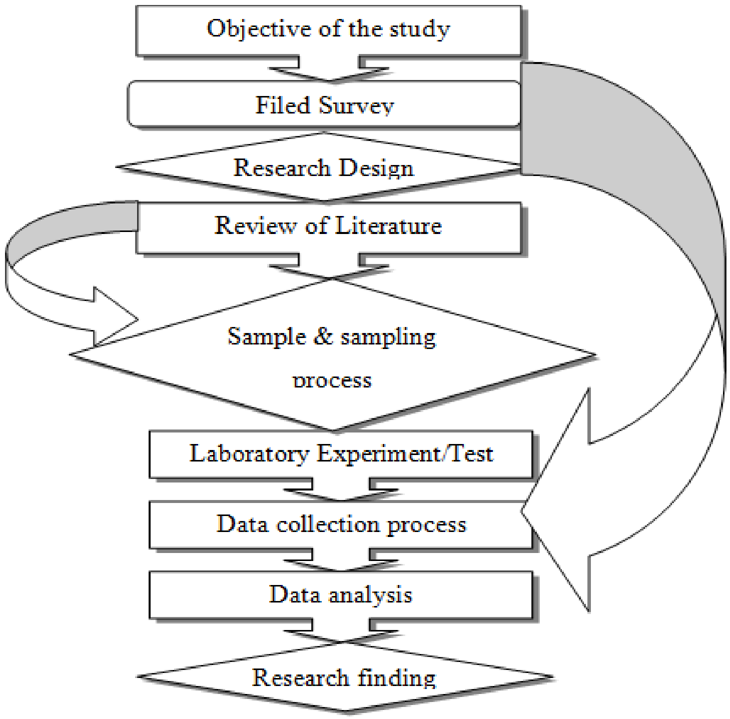

Figure 9: Research Design and Process

3.7.1. Material preparation

Generally Coffee husk, ordinary Portland cement, crushed aggregates, gravel 00 and sand were materials used in this study.

Materials for hollow concrete blocks without and with coffee husk

Materials used to produce HCB without Coffee husk were:

- DANGOTE Ordinary Portland cement(OPC)
- Crushed aggregate and
- Sand
- Medium aggregate (Gravel 00)
- Coffee husk

Sources of materials: a) Cement- local market

b) Crushed aggregate- local market

c) Medium aggregate (Gravel 00)- local market

d) Sand- local market

e) The coffee husk was extracted from Agaro and Tobba disposal site which is located at 45 km from Jimma town.

3.7.2. Determining engineering property of materials

The engineering property of all materials necessary for describing the type of materials used and also properties that can affect the production of HCB were determined prior to production. The test methods used for the aggregates are listed below in Table 8.

Table 8: Property tests and test methods

Property tests	Test methods
Sieve analysis (sand, medium & crushed aggregate and coffee husk)	ASTM C136,
Unit weight(sand, medium & crushed aggregate and coffee husk)	ASTM C29
Silt content(sand and medium Aggregate)	ASTM C117
Flakiness index (crushed aggregate)	BS 812-105.1: 1989
Specific gravity and absorption (sand, medium & crushed aggregate and coffee husk)	ASTM C127, BS 812:part 2:1995
Moisture content (sand, medium & crushed aggregate and coffee husk)	ASTM C 566

Test for cement was not conducted because DANGOTE standard cement with strength grade of 42.5 was used. The samples for the property test were taken from the production site by using quartering method. And the results for the tests are presented in the data sheets in Appendix one.

3.7.3. Production of different hollow blocks

Producing the hollow concrete blocks was conducted by following different production steps.

3.7.3.1. Proportioning the materials

The two most widely used cement to aggregate ratios are 1:6 and 1:8 for hollow concrete blocks production [35]. In the study area which is Jimma town the micro and small enterprises use cement to aggregate ratio of 1:6. Therefore the study was conducted by using 1:6 mix proportions for both type of HCB. The proportion 1:6 indicates 1 bag of cement to 6 boxes of aggregate. The proportioning box used was the box which is commonly used for HCB proportioning, which is 20cmx40cmx50cm (height, width and length). There was a need to prepare another box to measure the 10% incremental of coffee husk which is 10% of the volume of the six boxes.

The calculation conducted to prepare the box was:

V_{1box}=20cmx40cmx50cm=0.04 m^3.

For 6 boxes is V_{6box}=0.04x6=0.24 m^3.

Therefore, 10% of 0.24= 0.024 m^3, 0.024 m^3=20cmx30cmx40cm.

Therefore a box with 20cm height, 30 cm width and 40 cm length was prepared to measure the 10% coffee husk for the hollow blocks with coffee husk.

The study also separately conducted the proportioning for the two types of hollow concrete blocks as follows;

A. Proportioning for HCB without coffee husk

In Jimma town the micro and small HCB enterprises use 1:3:2:1 ratio of cement, sand, gravel 00 and crushed aggregate respectively for producing HCB without Coffee husk. The study was also conducted by using this proportion to produce the blocks.

B. Proportioning for HCB with Coffee husk

The proportion used by micro and small enterprise in Jimma to produce HCB with Coffee husk is 1:4:2. That is cement, Coffee husk and crushed aggregate proportion. But the study used 1:6 cement aggregate ratios. And out of the six part of aggregate it replaced the amount of crushed aggregate with different percentage of Coffee husk with a constant interval of 10% and increased up to 100%. This was done in order to determine the maximum replacement of Coffee husk for crushed aggregate.

The proportion for the HCB with Coffee husk was prepared by using the 20cmx30cmx40cm box as follows: 100% Coffee husk means 6 box of Coffee husk by using 20cmx40cmx50cm box. Since the volume of six boxes of 20c mx40cmx50cm is 6(0.04m^3) = 0.24 m^3 which is also equals to the volume of 10 boxes with 20cmx30cmx40cm (i.e. 10(0.024 m^3) = 0.24 m^3, 0.024 $m^3$is the volume of 20cmx30cmx40cm box). The different percentages of Coffee husk and crushed aggregates which were used are tabulated in Table 10.

Table 9: Different percentages of Coffee husks and crushed aggregates used

Sample ID	No. of(20cmx30cmx40cm) Box		No.of(20cmx40cmx50cm) Box		Percent	
	Coffee Husk	*Crushed Aggregate*	*Coffee Husk*	*Crushed Aggregate*	*Coffee Husk*	*Crushed Aggregate*
1	1	9	0.6	5.4	10%	90%
2	2	8	1.2	4.8	20%	80%
3	3	7	1.8	4.2	30%	70%
4	4	6	2.4	3.6	40%	60%
5	5	5	3	3	50%	50%
6	6	4	3.6	2.4	60%	40%
7	7	3	4.2	1.8	70%	30%
8	8	2	4.8	1.2	80%	20%
9	9	1	5.4	0.6	90%	10%
10	10	0	6	0	100%	-

After proportioning of the coffee husk and crushed aggregates, the materials were placed in bags and labeled with the % of coffee husk contents.

3.7.3.2.Mixing process

The mixing process was conducted in two steps. The first step was dry mix of aggregates and cement on the floor by hand and the second step was wet mixing of aggregates and cement inside electrically operated mixer. The first thing for mixing water determination was selecting water cement ratio. The selected water cement ratio for the HCB without coffee husk was 0.5, which is between (0.49-0.55) [19].

And the optimum mixing water was checked by rubbing a shovel against the mix and a ripple mark was observed at the back of the shovel [14]. The water amount added is 25 Kg. The next step was determining mixing water for the HCB with coffee husk. The first mix considered was 100% coffee husk and 25kg of water were added slowly by checking the optimum mixing water at some intervals. But due to absorption of the coffee husk the mix was very dry and the optimum mixing water checked and no ripple marks were observed. Then by continuously adding water and checking for the ripple marks, the water amount was determined and recorded as 27.5 kg. As going down to 90%-80%, the same amount of water was added by following the same procedure. For 70% -60% the water amount 26.5kg was found enough. But while determining the 50%-30% mixes, the mixes attained their optimum mixing water at 25kg. But the 20% and 10% coffee husk mixes at 24.5kg. The amount of water used and their water cement ratio were listed in Table below.

a) Mixing water for HCB with coffee husk

Since the coffee husk content for every mix is different the right moisture content was fixed based on the above method and the mixing water is listed below in table.

b) Mixing water for HCB without coffee husk

The same procedure was followed for the HCB without coffee husk. The mixing water fixed for HCB without coffee husk was 25kg with water-cement ratio of 0.5.

Table 10: Mixing water for HCB with coffee husk

Sample ID	Coffee husk (%)	Mixing water (lit)	w/c
1	10%	24.5kg	0.49
2	20%	24.5 kg	0.49
3	30%	25 kg	0.5
4	40%	25 kg	0.5
5	50%	25 kg	0.5
6	60%	26.5 kg	0.53
7	70%	26.5kg	0.53
8	80%	27.5kg	0.55
9	90%	27.5 kg	0.55
10	100%	27.5 kg	0.55

3.7.3.4. Molding process

After the preparation of the mix the mix was delivered to the electrically operated vibratory mold and the mix was placed inside the mold. Then after vibration was applied to compact the hollow blocks for about 50 seconds, for a free space inside the mold another mix was added to fill the mold and another vibration was applied for additionally 10 seconds. A total of 60 seconds vibration was conducted as specified by GTZ Low Cost Housing Manual volume I.

3.7.3.5.Curing process

Since molding was carried out under the shade, after molding the hollow concrete blocks were kept for 24 hours before starting spraying water. Just after 24 hours the concrete blocks were regularly cured by spraying water for 7 days [35].

3.7.4. Weight, Production cost calculation and Compressive strength test

Compressive strength test was carried out on the blocks prepared to compare the compressive strength of the hollow blocks with and without coffee husk. Compressive strength test of 7th, 14th and 28th days were conducted according to ES C.D4.001 after regularly cured by spraying water for 7 days. The production cost calculation was conducted based on direct unit production costs for both hollow concrete blocks with and without coffee husk in order to compare the production costs.

3.8.Data processing and analyzing

To meet the research objectives, this part was conducted in two steps: the first step was computing the compressive strength the second step was analyzing the direct cost of producing the hollow concrete blocks.

3.8.1. Analyzing the compressive strength

The compressive strength of both HCB without and with coffee husk was conducted by taking the mean of six HCBs as stated in the procedure of Ethiopian standard [21]. The mean compressive strengths of HCB without coffee husk were compared with each HCB with coffee husk. Further the data found were computed with different standards. According to ASTM average of 3 and 5 HCBs are required [3]. Therefore, the means were computed and compared according to Ethiopian standard and individually with ASTM. The results were analyzed and presented in tables and graphs.

3.8.2. Method of production cost analysis

The direct cost of producing both blocks was analyzed by considering only direct unit cost of production. This is due to lack of data and lack of a proper way of calculating the cost of production.

3.8.2.1.Direct unit cost of production

The direct unit cost of production analyzed in this study includes direct unit cost of materials, direct unit cost of labor and direct unit cost of equipment. Direct unit cost of materials: the materials cost data from the current market in Jimma town were analyzed by considering the quantity to produce one hollow concrete block as follow.

- ✓ One quintal of cement produces 40 hollow concrete blocks with 40x20x20 dimensions.
- ✓ To produce 40 blocks, quantities of aggregates used was obtained by using the ratio of cement to aggregate and by considering the dimension of gagging box(20x40x50cm). The cement aggregate ratio considered was 1:6. For the HCB without coffee husk the ratio considered was 1:3:2:1, 1bag cement, 3 $_{box}$ of sand, 2 $_{box}$ of medium Aggregate and 1 $_{box}$ of crushed aggregate.
- ✓ But this ratio is only with one bag cement. The analysis was conducted by considering 2 bags (1 quintal)

  Therefore 2*(1:3:2:1) = 2:6:4:2 and the ratio becomes 1 quintal cement: 6 $_{box}$ sand: 4 $_{box}$ medium Aggregate and 2 $_{box}$ crushed aggregate.
- ✓ Quantity of aggregates
  - For 40 blocks= No. of box $_{for\ each\ aggregates}$ * V $_{for\ one\ box}$.
- ✓ The box has a volume of 0.04m^3 quantity of sand
  - For 40 blocks would be 0.04x6=0.24m^3,
  - For gravel 0.04x4=0.16m^3 and for crushed aggregate 0.04m3x2=0.08m^3
- ✓ To analyze direct unit cost the quantities of each materials to produce 40 blocks were divided by 40. Therefore the quantities are listed in the table 12 below.

Type of materials	**Qunt. 40 HCB(A)**	**Qunt. For 1 HCB=A/40**
Sand	0.24	0.006
Medium aggregate (gravel 00)	0.16	0.004
crushed aggregate	0.08	0.002

Table 11 Quantities of materials for HCB without coffee husk

- ✓ For the HCB with Coffee husk the same procedure was followed except to incorporate the percentages the volume of six box was considered. If the block has 10% coffee husk it also means that it has 90% crushed aggregate.
- ✓ The volume of the 6 box=0.24m^3, which can be used with one bag of cement but for one quintal the volume was multiplied by 2. Quantity of coffee husk was determined for each percentage of coffee husks by multiplying % coffee husk with volume of the box. The same procedure was also followed for the crushed aggregate. The quantities of coffee husk and crushed aggregates for one block are listed below in Table 13.
- ✓ The quantity of cement for both types was 1 quintal but for one block = 1/40=0.02
- ✓ Direct material unit cost=quantity for 1 block*cost of materials

Coffee husk (%)	Crushed agg. (%)	Coffee husk Qty (m3)	Crushed agg. Qty (m3)
10%	90%	0.0012 m3	0.0108 m3
20%	80%	0.0024 m3	0.0096 m3
30%	70%	0.0036 m3	0.0084 m3
40%	60%	0.0048 m3	0.0072 m3
50%	50%	0.006 m3	0.006 m3
60%	40%	0.0072 m3	0.0048 m3
70%	30%	0.0084 m3	0.0036 m3
80%	20%	0.0096 m3	0.0024 m3
90%	10%	0.0108 m3	0.0012 m3
100%	0%	0.012 m3	0 m3

Table 12 Quantities of materials for HCB with coffee husk

Direct unit cost of labor: - The direct unit cost of labor was analyzed by considering utilization factor, daily wage and number of labor used to produce.

- ✓ Utilization factor (*uf*) = 1/crew daily production.
- ✓ The crew daily production in Jimma for producing HCB is 1200 blocks per day.
- ✓ Direct labor unit cost= number of labor * *uf**daily wage

3.8.2.2.Direct unit cost of equipment

The direct unit cost of equipment was analyzed by considering daily rental cost, number of equipment used and utilization factor.

- ✓ Utilization factor (uf) =1/machine daily production. The daily production considered is 1200 blocks per day.
- ✓ Direct unit cost of equipment= Number of equipment*uf *daily rental cost
- ✓ Direct unit cost of production was analyzed by using a format which is in appendix three part of this thesis.

Total unit cost of production= MDUC+LDUC+EDUC

Whereas,

- MDUC= material direct unit cost
- LDUC= labor direct unit cost
- EDUC= equipment direct unit cost.

3.9. Data quality assurance

The quality of the data will be assured through replicate the samples by using standard operating procedures. To check the accuracy and validity of data instrument calibration and verification will be checked. Laboratory test and field work manual will be prepared in order to avoid error of data. And also give attention during data collecting and recording carefully.

3.10. Plan for dissemination

The research mainly concentrates for academic purposes that are enrolled by the JU; the finding will be presented to Jimma Institute of Technology, Civil Engineering, Department, Construction Engineering and Management Stream. And disseminated to Jimma university Technology library, all concerned governmental and nongovernmental office.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1. Physical Properties of Materials

It is necessary and worthwhile to determine the engineering properties of material sources when assessing their quality, which gives us the chance to use those materials to their maximum potential. This chapter contains tabulations of all data recorded during the tests conducted, a discussion of all quality test, as well as outlines of the subsequent calculations needed to translate test results into the properties of aggregates.

To specify the type of materials used in this research and to check whether the materials used are recommended by available standards and documents regarding to hollow concrete blocks production, physical properties tests of materials were conducted and the detailed data sheets with results are attached on appendix one of this thesis.

4.1.1. Physical property tests on crushed aggregate, sand and gravel

The normal weight aggregates for making hollow concrete blocks needs to have property of concrete aggregate.

4.1.1.1. Sieve analysis

The objective is to see whether the samples satisfy the gradation requirement set by the Standard, gradation charts were prepared and their gradations were checked in light of the given requirement in the Standard and determination of particle size distribution of fine, coarse and all- in aggregates by sieving. Because it is important and indeed required to determine the characteristics of the aggregate which include among other things its gradation. The grading of particle size distribution of aggregate is usually determined by a sieve analysis.

It is used as an index to the fineness or coarseness and uniformity of aggregate supplied, but it is not an indication of grading since there could be an infinite number of gradings which will produce a given fineness modulus. Fine aggregates range from a FM of 2.00 to 4.00. Combinations of fine and coarse aggregates have intermediate values. And it suggests that the fineness modulus be kept between 2.3 and 3.1 [2].

A. **Crushed aggregate**: the maximum size of coarse aggregates used was 10mm.

Table 13: Sieve analysis for crushed aggregate versus ASTM limits

Sieve Size	M.retained (kg)(1)	M.retained (%)(2)	Cum.R. Pass (%)	Cum.P. Pass (%)	ASTM standard of P. pass	
					Max limit	Min limit
19mm	0	0	0	100%	100%	100%
12.5mm	0.045	0.91	0.91	99%	100%	90-100%
4.75mm	1.755	35.59	36.50	63.5%	70%	40-70%
1.18mm	1.520	30.83	67.33	32.67%	15%	15-40%
300µm	1.611	32.67	100.00	0.00%	5%	0%-5%
150µm	0	0	100.00	0.00%	0%	0%
Pan	-	-		-		
T.sample	4.985	100%	304.75%			
Fineness Modulus FM		304.75/100=3.04				

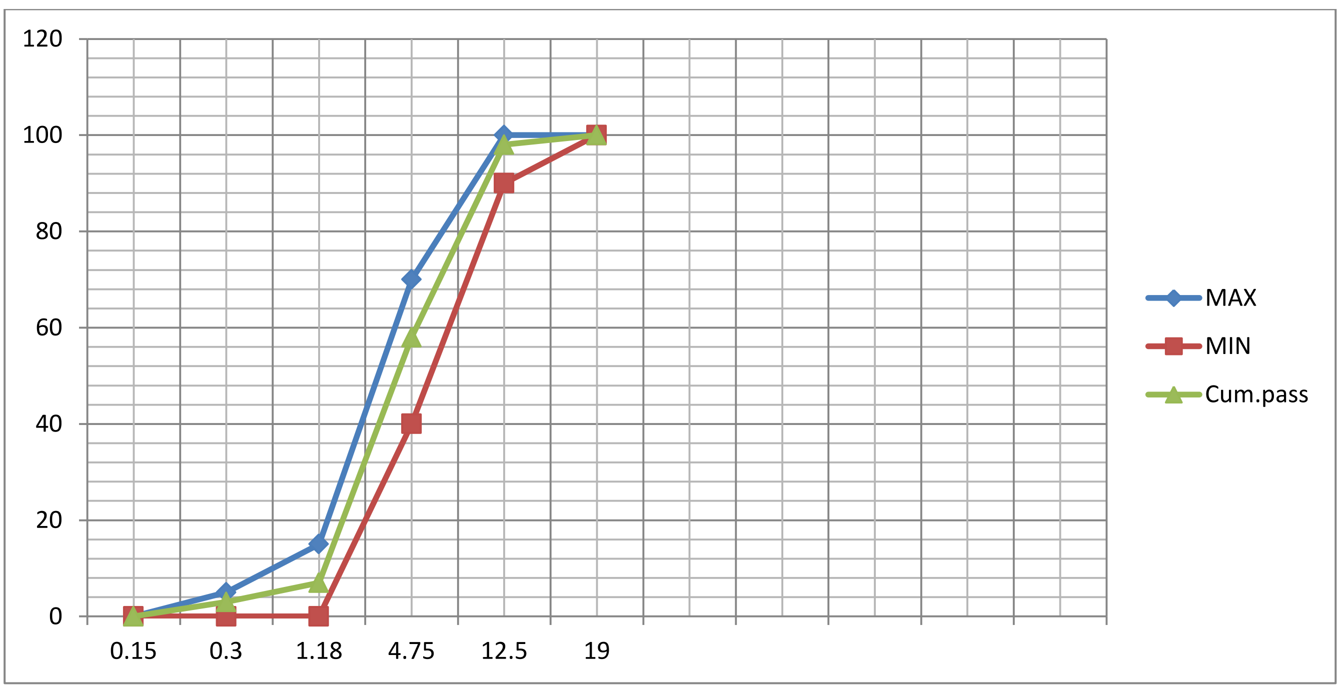

Figure 10: Gradation curve for crushed aggregate versus ASTM limits

B. Medium Aggregate

Table 14: Sieve analysis for gravel 00 versus ASTM limits

Sieve size	M.retained (gr)(1)	M.retained (%)(2)	Cum.P. Pass (%)	ASTM standard of P. pass		Remark
				Max limit	Min limit	
37.5mm	**0**	**0**	**100%**	**100%**	**100%**	**Ok!**
19mm	**0**	**0**	**100%**	**100%**	**100%**	**Ok!**
4.75mm	**177**	**3.26**	**96.37%**	**100%**	**95%**	**Ok!**
2.36mm	**490**	**12.72**	**86.33%**	**100%**	**80%**	**Ok!**
1.18mm	**770**	**14.20**	**70.56%**	**85%**	**50%**	**Ok!**
0.6µm	**990**	**18.53**	**50.28%**	**60%**	**25%**	**Ok!**
0.3µm	**1150**	**23.05**	**26.72%**	**30%**	**10%**	**Ok!**
0.15 µm	**931**	**19.01**	**7.64%**	**10%**	**2%**	**Ok!**
Pan	**373**	**-**	**-**	**-**	**-**	

Both from Table 14 and Figure 11, the gravel gradation is between the ASTM C33 limitations. Therefore, the aggregate can be used for concrete making. Since hollow concrete blocks are also concrete the aggregate is suitable for HCB in terms of gradation.

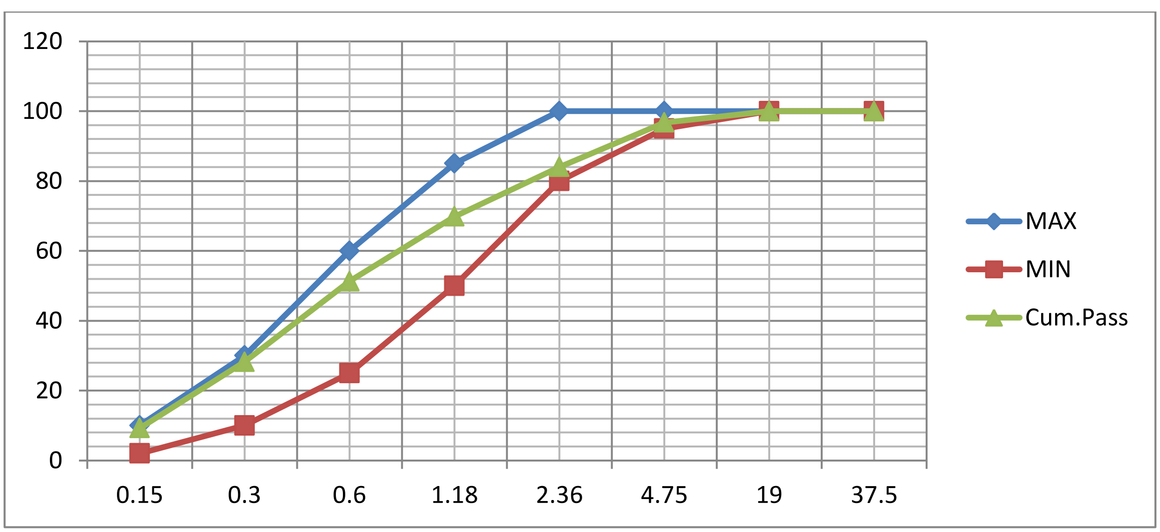

Figure 11: Gradation curve for medium gravel versus ASTM limits

C. Sand

Table 15: Sieve analysis for gravel 00 versus ASTM limits

Sieve size	M.retained (gr)(1)	M.retained (%)(2)	Cum.P. Pass (%)	ASTM standard of P. pass		Remark
				Max limit	Min limit	
19mm	**0**	**0**	**100%**	**100%**	**100%**	**Ok!**
4.75mm	**122**	**2.44%**	**97.56%**	**100%**	**95%**	**Ok!**
2.36mm	**650**	**13%**	**84.56%**	**100%**	**80%**	**Ok!**
1.18mm	**756**	**15.12%**	**69.44%**	**85%**	**50%**	**Ok!**
0.6µm	**1150**	**23%**	**46.44%**	**60%**	**25%**	**Ok!**
0.3µm	**1350**	**27%**	**19.44%**	**30%**	**10%**	**Ok!**
0.15 µm	**850**	**17%**	**2.44%**	**10%**	**2%**	**Ok!**
Pan	**122**	**-**	**-**	**-**	**-**	

According to **ASTM C33** fine aggregates should have fineness modules between 2.3 and 3.1; the sand used has fineness modules of 2.82, this means it is within the ASTM limits.

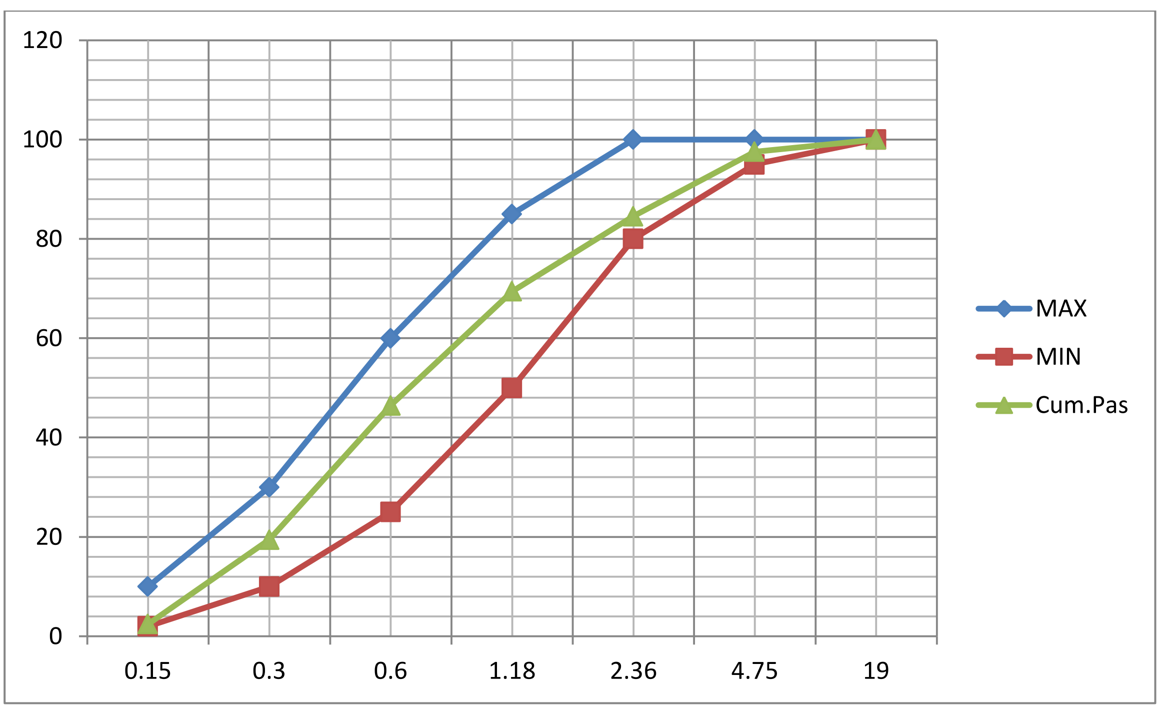

Figure 12: Gradation curve for Sand versus ASTM limits

Both from **Table 15** and **Figure 12** the sand gradation is between the **ASTM C33** limitations.

4.1.2.2. Bulk Unit weight

This test is used to determine the unit weight of coarse and fine aggregates within the weight of a given volume of graded aggregate or density measurement. Through placing three layers of oven-dry aggregate in a container of known volume, Roding each layer 25 times with a tamping rod, levelling off the surface, and determining the mass of the container and its contents. The mass of the container is subtracted to give the mass of the aggregate, and the bulk density is the aggregate mass divided by the volume of the container. The table showed the test results of unit weight of crushed aggregate, sand.

Table 16: Unit weight used aggregates

Description	**Measurements**		
	Sample 1	Sample 2	Sample 3
Weight of container (A) kg	18	18	18.00
Weight of container +Sample=(B) kg	65	62	67.34
Weight of sample(B-A)=(D) kg	47	44	49.34
Volume of container(C) m^3	0.03	0.03	0.03
Unit weight= D/C	1566.67kg/m^3	1466.67 kg/m^3	1644.67kg/m^3
Mean unit weight	**1,559.34 kg/m^3**		

Table 17: Unit weight used aggregates

Aggregates	**Bulk Unit weight**
Crushed aggregate	1,559.34 kg/m^3
sand	1,712.83 kg/m^3
Medium Aggregate (Gravel 00)	1,477.77kg/m^3

ASTM C33 limits the bulk unit weight from 1200-1760 kg/m^3, as it is shown from **Table 17**, the unit weights are within the limits. Therefore, the aggregates fulfill specification. Generally, the aggregates with bulk densities less than 1120 kg/m^3 are called lightweight and those weighing more than 2080 kg/m^3 are called heavy weight. Hence, our sample represents a medium weight aggregate.

4.1.2.3 Specific gravity and absorption

Specific gravity of a substance is the ratio between the weight of the substance and that of the same volume of water. Aggregates, however, have pores that are both preamble and impermeable, whose structure (size, number, and continuity pattern) affects water absorption, permeability and Specific gravity of aggregates.

Absorption represents the total water contained in the aggregate in the saturated surface-dry condition and the surface moisture (or free moisture) is the water in excess at the saturated surface-dry state. The total water content of a damp or moist aggregate is equal to the sum of absorption and surface moisture content. The surface or free moisture content is generally given in terms of percent of the weight of the saturated surface dry aggregates.

A. Test results of coarse aggregate

Table 18: Specific gravity and absorption of coarse aggregate

Description	**Var.**	**Weight in kg**		
Samples		S_1	S_2	S_3
Weight of oven dry sample in air	A	4.92	4.89	4.9
Weight of saturated-surface dry sample in air	B	5	5	5
Weight of wire in water C	C	0.35	0.35	0.35
Weight in water (of (SSD) sample +wire basket)	D	3.07	3.17	2.97
Weight in water of SSD=D-C	E	2.72	2.82	2.87
Bulk Sp.gr.(SSD)=	SG	*2.24*	*2.36*	*2.41*
Mean bulk sp. Gr.				**2.34**
Absorption=[(B-A)/A]*100%	Abs.	***1.63***	2.25	2.04
Mean absorption				**1.97**

Sample Calculation

- Bulk Specific gravity $=\frac{MD}{MD-Mw}=\frac{4.92}{4.92-2.72}=\boldsymbol{2.24}$
- Bulk Specific gravity (SSD basis) $=\frac{MSSD}{MSSD-Mw}=\frac{5}{5-2.72}=\boldsymbol{2.19}$
- Absorption capacity (%) $=\frac{MSSD-MD}{MD}=\frac{5-4.92}{4.92}*100=\boldsymbol{1.63\%}$

Where:

MD= weigh of oven dry sample in air

MSSD= weigh of saturated surface dry sample in air

Mw= weigh of Saturated sample in water

The Calculated value indicates that, type of the aggregate can be grouped under light weight coarse aggregate, because for light weight aggregate the specific gravity approximately equal to 2.5.

B. Test results of sand

Table 19: Specific gravity and absorption of sand

Description	**Var.**	**Weight in g**		
Samples		S_1	S_2	S_3
Weight of oven dry sample in air	A	497	492	494
Weight of Pycnometer filled with Water (Va)	B	1290	1290	1290
Weight of the Pycnometer+Sample+Water	C	1570	1608	1540
Weight of sample SSD	D	500	500	500
Bulk Sp.gr.(SSD)=	SG	*2.26*	*2.70*	*1.98*
Mean bulk sp. Gr.	**2.31**			
Absorption=[(B-A)/A]*100%	Abs.	0.60	1.63	1.21
Mean absorption	**1.15**			

Calculation

- Bulk Specific gravity $=\frac{A}{B+D-C}=\frac{497}{1290+500-1570}=2.26$
- Bulk Specific gravity (SSD basis) $=\frac{D}{B+D-C}=\frac{500}{1290+500-1570}=2.27$
- Apparent Specific gravity$=\frac{A}{B+A-C}=\frac{497}{1290+497-1570}=2.29$
- Absorption capacity (%) $=\frac{D-A}{A}*100=\frac{500-497}{497}*100=0.60\%$

Table 20: Test results of Bulk specific gravity (SSD) and absorption Vs ASTM limit

Aggregates	ASTM limit	Bulk specific g.(ssd)		ASTM limit	Absorption	
Coar.Aggt	2.4 to 3.0	2.34	Ok!	0.2% to 2%.	1.97%	Ok!
sand		2.31	Ok!		1.15%	Ok!
Gravel 00		2.7	Ok!		1.7%	Ok!

According to ASTM C33, the limitation for bulk specific gravity (SSD) is from 2.4 to 3.0. Accordingly the aggregates are within ASTM limitations and absorption from 0.2% to 4%, for coarse aggregates and 0.2 to 2% for fine aggregates. From **Table 20**, the crushed aggregate as coarse aggregate is between 0.2% and 4%. And both sand and medium aggregates (gravel 00) are within the limits of fine aggregates.

4.1.1.2. Moisture content and silt content

This test is conducted to determine the silt (finer than No.200 sieve) content in sand

Table 21: Test result of moisture content

Description	Var.	Weight in gm		
Samples		S_1	S_2	S_3
Weight of wet sample (tarred) M1	A	500	500	500
Weight of the oven dried sample (tarred) M2	B	492	489	495
Moisture content=([M1-M2]/M2)*100	C	1.63%	2.25%	1.01%
Mean moisture content				**1.63%**

Calculation

Moisture content (%) $=\frac{M1-M2}{M2}*100=\frac{500-492}{492}*100=1.63\%$

Table 22: Test result of silt moisture content

Description	Var.	Height in mm		
Samples		S_1	S_2	S_3
Amount of Silt	A	4	3	6
Amount of Silt + Sand	B	145	148	155
Silt content	C	2.76%	2.02%	3.87%
Mean silt content				**2.88%**

Silt content $=\frac{A}{B} * 100\% = \frac{4}{145} * 100\% = 2.76\%$

Table 23: Test result of moisture content and silt content

Aggregates	Moisture content (%)	Silt content (%)
Crushed agg.	1.63%	-
sand	1.21%	2.88%
Gravel 00	1.29%	2.1%

According to ASTM silt content should not be greater than 3%. Both gravel and sand fulfill this requirement. When we are referring our country Ethiopian code tell us if the silt content is greater than 6% it is not recommended for any construction. And the moisture contents should be within 0.5% to 2% [2]. All aggregates are within the limits.

4.1.2.5. Flakiness index of crushed aggregate

According to British standard the flakiness index of the combined coarse aggregate shall not exceed 50 for uncrushed gravel and 40 for crushed rock or crushed gravel. Since the used aggregate is crushed aggregate with a flakiness index of 30.82% [11].

4.2. Comparisons of Weight results

The American Society for Testing and Materials (ASTM) standards define characteristics of strength and quality Hollow Concrete Block. Which standard applies to a particular product may depend upon its configuration and/or use. Refer to product sections and the specification section for further discussions.

While when we see the weight standards applicable to HCB contain three classifications of weight, expressed in lbs/cu.ft. (Kg/m^3): normal weight, medium weight, and light weight.

- ***Normal weight*** is 2000kg/$m^3$and over.
- ***Medium weight*** is 1680kg/m^3-2000kg/m^3
- ***Lightweight*** is less than 1680kg/m^3

To meet the objectives of this research, the Weight of each blocks produced was conducted after regularly cured by spraying water for 7, 14 and 28days. The Weight test results for each sample are listed. In terms of comparing weight of the two kinds of HCBs produced mainly HCB with and without Coffee husk were computed. Since the HCB with Coffee husk samples were produced by considering different percentage amount of coffee husk, from 10% up to 100% each of them were compared with the HCB without coffee husk.

4.2.1. The determined Weight of HCB without Coffee husk

As shown in the **Table 27** the mean weight of The HCB which was produced by mix ratio of 1:3:2:1, one bag of cement, 3 box of sand, 2 box of gravel 00 and 1 box of crushed aggregate 01 was determined for 7th, 14th and 28th testing days and the average for each testing days or the mean weight were determined.

Table 24: Mean weight of HCB without coffee husk

Testing day	Weight of HCB without Coffee husk (kg)			The mean weight (kg)
7th day	18.9	19.0	18.4	**18.77**
14th day	17.4	18.2	16.7	**17.43**
28th day	15.1	15.3	14.9	**15.1**

A mean weight of **18.77 kg** for the 7th days, **17.43 kg** for the 14th and **15.1 kg** were obtained from the weight tests on each day samples. The incremental in weight from 7th up to 28th day is easily observed in the **Figure 13** below.

From the graph in the **Figure13**, it is easy to observe that, as the days increase the weight also increases this is mainly due to hydrating of concrete.

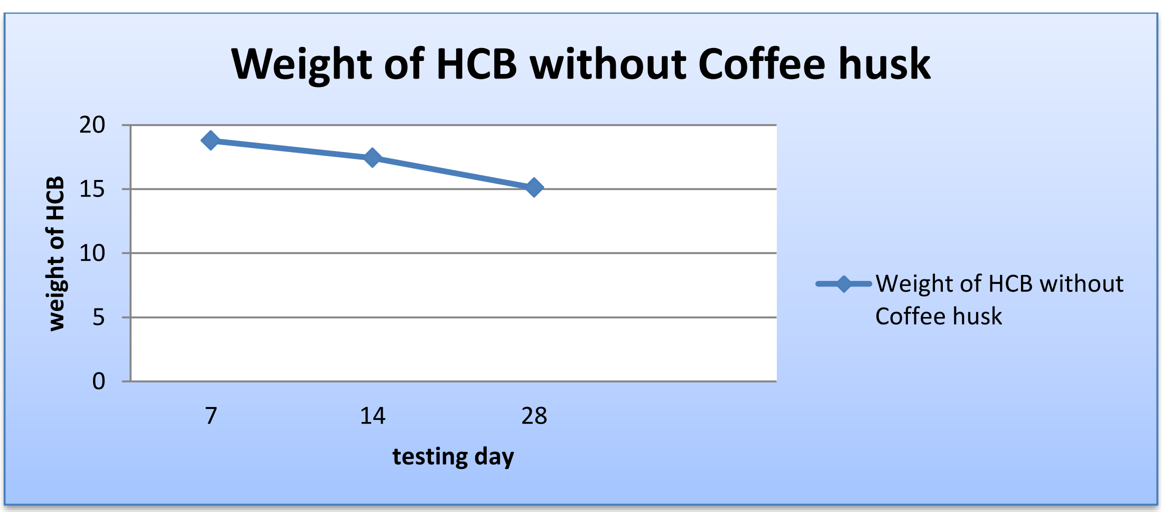

Figure 13: Weight graph for HCB without coffee husk

4.2.2. Comparison of compressive strength of HCB with and without coffee husk

For the HCB with coffee husk the weight was determined for all samples with different coffee husk contents and they are discussed prior to comparison with HCB without coffee husk here.

4.2.2.1. HCB without coffee husk and 10% coffee husk HCB

The determined weight of the 10 % coffee husk HCB is listed below in **Table 28.** From **Table 28** the mean weight of the 7^{th}, 14^{th} and 28^{th} day weight 18.57, 17.2 and 14.57Kg are respectively. And the comparison of weight with HCB without coffee husk is plotted on the graph in **Figure 14**

Table 25: Mean weight of 10% coffee husk HCB

Testing day	**Weight of HCB Kg**			**Mean weight *10%* Coffee Husk in Kg**	**Mean weight *without* Coffee Husk in Kg**
7th day	18.7	18.8	18.2	**18.57**	**18.77**
14th day	17.3	17.9	16.4	**17.2**	**17.43**
28th day	14.8	14.9	14.6	**14.57**	**15.1**

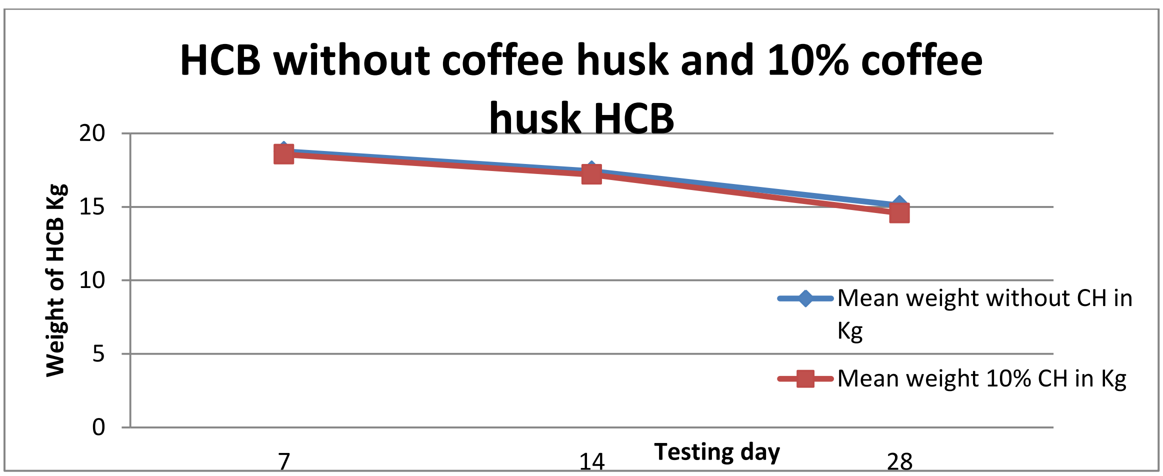

Figure 14: comparison graph of HCB without coffee husk and 10% coffee husk HCB

From Figure 14, the upper line indicates the mean compressive strength of the HCB without coffee husk. The percent increase was calculated by using $\frac{(Max-Min)}{Min} * 100$. The weight when compared with 10% coffee husk HCB, the 7th day reduced with 1.08%, the 14th day reduced with 1.34% and the 28th day reduced with 3.64% when compared with the respective days of the 10% Coffee husk HCB. This means the 7th day weight of HCB without Coffee husk is 1.08% larger than the 7th day of 10% Coffee husk HCB; the 14th day is 1.34% and 28th day is 3.64% larger than the respective days of 10% Coffee husk HCB. From weight result the HCB with 10%coffee husk has lighter than the HCB without Coffee husk.

4.2.2.2. HCB without coffee husk and 20% coffee husk HCB

The determined weight of the 20 % coffee husk HCB is listed below in **Table 29.** From **Table 29** the mean weight of the 7th, 14th and 28th day weight 18.13, 16.5 and 14.3Kg are respectively. And the comparison of weight with HCB without coffee husk is plotted on the graph in **Figure 26**

Table 26: Mean weight of 20% coffee husk HCB

Testing day	Weight of HCB Kg			Mean weight *20%* CH in Kg	Mean weight *without* CH in Kg
7th day	18.1	18.4	17.9	**18.13**	**18.77**
14th day	16.3	17.3	15.9	**16.5**	**17.43**
28th day	14.4	14.6	13.9	**14.3**	**15.1**

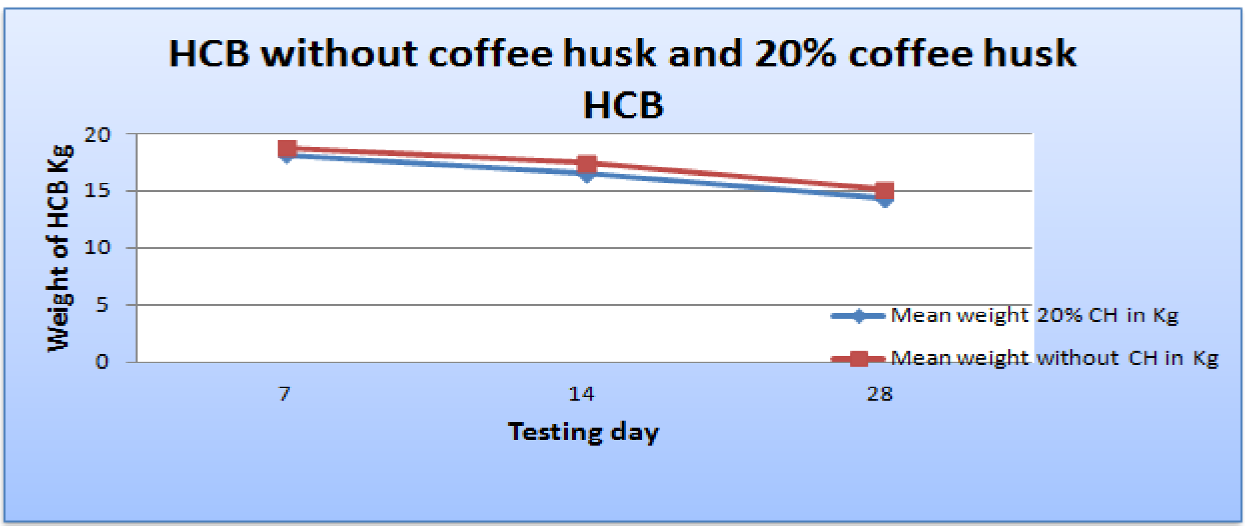

Figure 15: Comparison graph of HCB without coffee husk and 20% coffee husk HCB

From Figure 15, the upper line indicates the mean compressive strength of the HCB without coffee husk. The percent increase was calculated by using $\frac{(Max-Min)}{Min} * 100$. The weight when compared with 20% coffee husk HCB, the 7th day reduced with 3.53%, the 14th day reduced with 5.64% and the 28th day reduced with 5.59% when compared with the respective days of the 20% Coffee husk HCB. This means the 7th day weight of HCB without Coffee husk is 3.53% larger than the 7th day of 20% Coffee husk HCB; the 14th day is 5.64% and 28th day is 5.59% larger than the respective days of 20% Coffee husk HCB. From weight result the HCB with 20% coffee husk has lighter than the HCB without Coffee husk.

4.2.2.3. HCB without coffee husk and 30% coffee husk HCB

The determined weight of the 30 % coffee husk HCB is listed below in **Table 30.** From **Table 30** the mean weight of the 7th, 14th and 28th day weight 17.23, 15.37 and 12.97kg are respectively. And the comparison of weight with HCB without coffee husk is plotted on the graph in **Figure 27**

Table 27: Mean weight of 30% coffee husk HCB

Testing day	**Weight of HCB kg**			**Mean weight *30%* CH in kg**	**Mean weight *without* CH in kg**
7th day	17.2	17.6	16.9	**17.23**	**18.77**
14th day	16.2	15.7	14.2	**15.37**	**17.43**
28th day	12.8	13.4	12.7	**12.97**	**15.1**

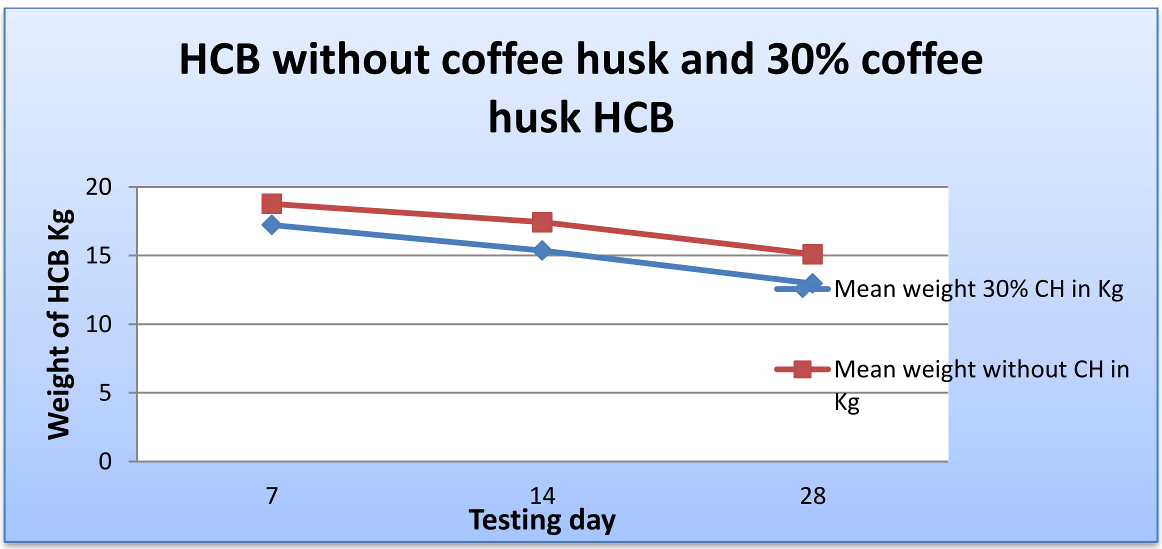

Figure 16: Comparison graph of HCB without coffee husk and 30% coffee husk HCB

From Figure16, the upper line indicates the mean compressive strength of the HCB without coffee husk. The percent increase was calculated by using $\frac{(Max-Min)}{Min} * 100$. The weight when compared with 30% coffee husk HCB, the 7th day reduced with 8.94%, the 14th day reduced with 13.40% and the 28th day reduced with 16.42% when compared with the respective days of the 30% Coffee husk HCB. This means the 7th day weight of HCB without Coffee husk is 8.94% larger than the 7th day of 30% Coffee husk HCB; the 14th day is 13.40% and 28th day is 16.42% larger than the respective days of 30% Coffee husk HCB. From weight result the HCB with 30% coffee husk has lighter than the HCB without Coffee husk.

4.2.2.4. HCB without coffee husk and 40% coffee husk HCB

The determined weight of the 40 % coffee husk HCB is listed below in **Table 28.** From **Table 28** the mean weight of the 7th, 14th and 28th day weight 16.67, 14.9 and 12.37kg are respectively. And the comparison of weight with HCB without coffee husk is plotted on the graph in **Figure 17**

Table 28: Mean weight of 40% coffee husk HCB

Testing day	Weight of HCB kg			Mean weight *40%* CH in kg	Mean weight *without* CH in kg
7th day	16.7	17.2	16.1	**16.67**	**18.77**
14th day	15.8	15.1	13.8	**14.9**	**17.43**
28th day	12.2	12.8	12.1	**12.37**	**15.1**

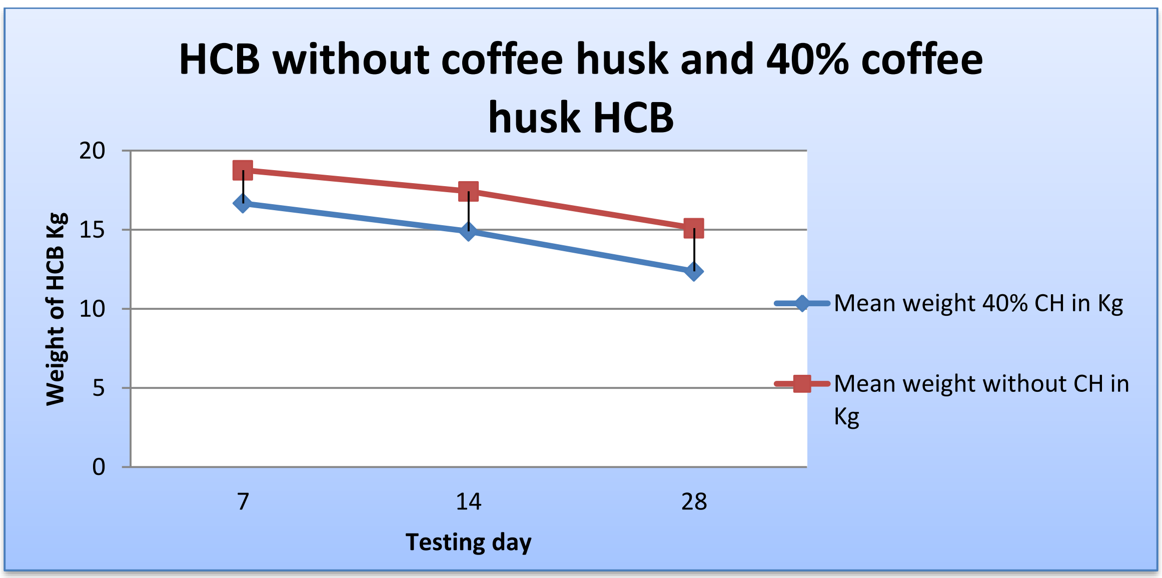

Figure 17: Comparison graph of HCB without coffee husk and 40% coffee husk HCB

From Figure 17, the upper line indicates the mean compressive strength of the HCB without coffee husk. The percent increase was calculated by using $\frac{(Max-Min)}{Min} * 100$. The weight when compared with 40% coffee husk HCB, the 7th day reduced with 12.60%, the 14th day reduced with 16.98% and the 28th day reduced with 22.07% when compared with the respective days of the 40% Coffee husk HCB. This means the 7th day weight of HCB without Coffee husk is 12.60% larger than the 7th day of 40% Coffee husk HCB; the 14th day is 16.98% and 28th day is 22.07% larger than the respective days of

40% Coffee husk HCB. From weight result the HCB with 40% coffee husk has lighter than the HCB without Coffee husk.

4.2.2.5. HCB without coffee husk and 50% coffee husk HCB

The determined weight of the 50 % coffee husk HCB is listed below in **Table 32.** From **Table 32** the mean weight of the 7th, 14th and 28th day weight 16.17, 14.4 and 11.7kg are respectively. And the comparison of weight with HCB without coffee husk is plotted on the graph in **Figure 18**

Table 29: Mean weight of 50% coffee husk HCB

Testing day	Weight of HCB kg			Mean weight *50%* CH in kg	Mean weight *without* CH in kg
7th day	16.1	16.7	15.7	**16.17**	**18.77**
14th day	15.2	14.7	13.3	**14.4**	**17.43**
28th day	11.5	12.2	11.4	**11.7**	**15.1**

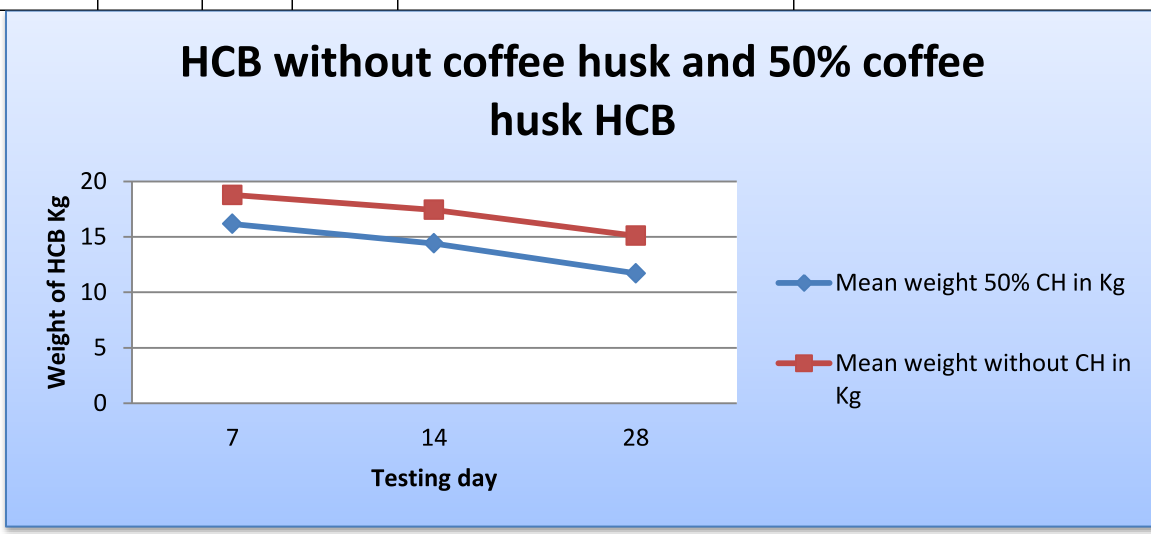

Figure 18: Comparison graph of HCB without coffee husk and 50% coffee husk HCB

From Figure 18, the upper line indicates the mean compressive strength of the HCB without coffee husk. The percent increase was calculated by using $\frac{(Max-Min)}{Min} * 100$. The weight when compared with 50% coffee husk HCB, the 7th day reduced with 16.10%, the 14th day reduced with 21.04% and the 28th day reduced with 29.06% when compared with the respective days of the 50% Coffee husk HCB. This means the 7th day weight of HCB without Coffee husk is 16.10% larger than the 7th day of 50% Coffee husk HCB; the 14th day is 21.04% and 28th day is 29.06% larger than the respective days of

50% Coffee husk HCB. From weight result the HCB with 50% coffee husk has lighter than the HCB without Coffee husk.

4.2.2.6. HCB without coffee husk and 60% coffee husk HCB

The determined weight of the 60 % coffee husk HCB is listed below in **Table 30.** From **Table 30** the mean weight of the 7^{th}, 14^{th} and 28^{th} day weight 15.63, 13.87 and 11.2kg are respectively. And the comparison of weight with HCB without coffee husk is plotted on the graph in **Figure 19**

Table 30: Mean weight of 60% coffee husk HCB

Testing day	**Weight of HCB kg**			**Mean weight *60%* CH in kg**	**Mean weight *without* CH in kg**
7th day	10.85	10.34	10.49	**10.56**	**18.77**
14th day	7.18	7.62	6.89	**7.23**	**17.43**
28th day	4.52	5.14	5.7	**5.12**	**15.1**

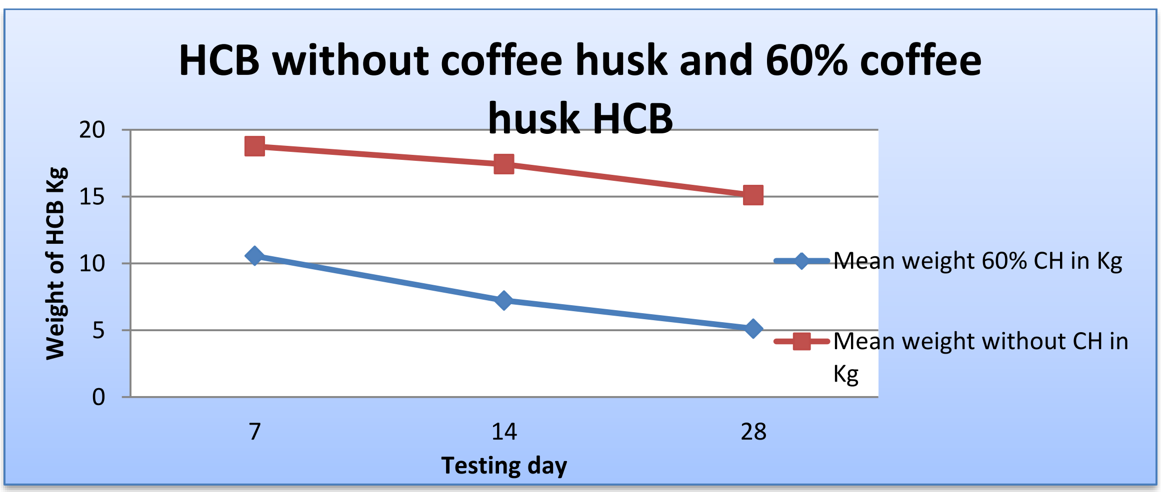

Figure 19: Comparison graph of HCB without coffee husk and 60% coffee husk HCB

From Figure19, the upper line indicates the mean compressive strength of the HCB without coffee husk. The percent increase was calculated by using $\frac{(Max-Min)}{Min} * 100$. The weight when compared with 60% coffee husk HCB, the 7th day reduced with 78%, the 14th day reduced with 141% and the 28th day reduced with 195% when compared with the respective days of the 60% Coffee husk HCB. This means the 7th day weight of HCB without Coffee husk is 78% larger than the 7th day of 60% Coffee husk HCB; the 14th day is 141% and 28th day is 195% larger than the respective days of 60% Coffee husk HCB. From weight result the HCB with 60% coffee husk has lighter than the HCB without Coffee husk.

The comparison of HCB without coffee husk and 70%, 80%, 90% and 100% coffee husk HCB for this research was cancels out because of those tests after the 7th day (i.e. 14th day and 28th day) progress they didn't attain or have good capability reach for testing. But during the first week (i.e. 7th day) result they have (i.e. 70%, 80%, 90% and 100% coffee husk HCB) too light weight.

4.3. The determined compressive strength of HCB without coffee husk

A mean strength of 2.18 MPa for the 7th days, 3.25MPa for the 14th and 3.82 MPa for the 28th were obtained from the compressive strength tests on each day samples. The incremental in compressive strength from 7th up to 28th day is easily observed in the Figure 20 below.

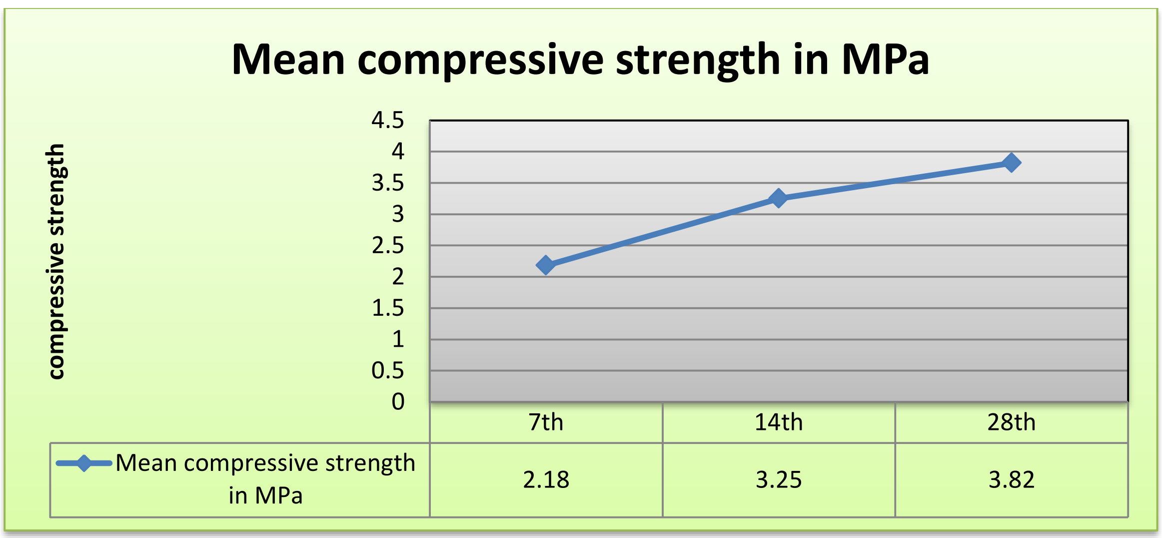

Figure 20: Mean compressive strength of HCB

From the graph in the Figure 20, it is easy to observe that, as the days increase the compressive strength also increases due to curing of concrete. The hollow concrete blocks attained a compressive strength 3.82 MPa at 28th day which is the maximum compressive strength from the rest days. This indicate that there is a 45.87% increase as the curing date increases from the 7th day to 14th day and a 30.77% increase in compressive strength as the curing date increases from 14th day to 28th day.

4.3.1. Comparison of compressive strength of HCB with and without coffee husk

For the HCB with coffee husk the compressive strength was determined for all samples with different coffee husk contents and they are discussed prior to comparison with HCB without coffee husk here.

4.3.1.1. HCB without coffee husk and 10% coffee husk HCB

A mean strength of 1.98 MPa for the 7th days, 2.97 MPa for the 14th and 3.58 MPa for the 28th were obtained from the compressive strength tests on each day samples.

Table 31: Mean compressive strength of 10% coffee husk HCB

Testing day	**Mean compressive strength with 10% coffee husk in MPa**	**Mean compressive strength without coffee husk in MPa**
7th day	**1.98**	**2.18**
14th day	**2.97**	**3.25**
28th day	**3.58**	**3.82**

The compressive strength when compared with 10% coffee husk HCB, the day decreased with 10.10%, the 14th day decreased with 9.43% and the 28th with 6.70% when compared with the respective days of the 10% coffee husk HCB. This means the 7th day compressive strength of HCB without coffee husk is 10.10% larger than the 7th day of 10% coffee husk HCB; the 14th day is 9.43% and 28th day is 6.70% larger than the respective days of 10% coffee husk HCB.

4.3.1.2. HCB without coffee husk and 20% coffee husk HCB

A mean strength of 1.78 MPa for the 7th days, 2.74 for the 14th and 3.58 MPa for the 28th were obtained from the compressive strength tests on each day samples.

Table 32: Mean compressive strength of 20% coffee husk HCB

Testing day	**Mean compressive strength with 20% coffee husk in MPa**	**Mean compressive strength without coffee husk in MPa**
7th day	**1.78**	**2.18**
14th day	**2.74**	**3.25**
28th day	**3.59**	**3.82**

The compressive strength when compared with 20% coffee husk HCB, the 7th day decreased with 22.47%, the 14th day decreased with 18.61% and the 28th with 6.41% when compared with the respective days of the 20% coffee husk HCB. This means the 7th day compressive strength of HCB without coffee husk is 22.47% larger than the 7th day of 20% coffee husk HCB; the 14th day is 18.61% and 28th day is 6.41% larger than the respective days of 20% coffee husk HCB.

4.3.1.3. HCB without coffee husk and 30% coffee husk HCB

A mean strength of 1.54 MPa for the 7th days, 2.71 for the 14th and 3.64 MPa for the 28th were obtained from the compressive strength tests on each day samples.

Table 33: Mean compressive strength of 30% coffee husk HCB

Testing day	Mean compressive strength with 30% coffee husk in MPa	Mean compressive strength without coffee husk in MPa
7th day	**1.54**	**2.18**
14th day	**2.71**	**3.25**
28th day	**3.64**	**3.82**

The compressive strength when compared with 30% coffee husk HCB, the 7th day decreased with 41.56%, the 14th day decreased with 19.93% and the 28th with 4.95% when compared with the respective days of the 30% coffee husk HCB. This means the 7th day compressive strength of HCB without coffee husk is 41.56% larger than the 7th day of 30% coffee husk HCB; the 14th day is 19.93% and 28th day is 4.95% larger than the respective days of 30% coffee husk HCB.

4.3.1.4. HCB without coffee husk and 40% coffee husk HCB

A mean strength of 1.4 MPa for the 7th days, 2.11 for the 14th and 3.04 for the 28th were obtained from the compressive strength tests on each day samples.

Table 34: Mean compressive strength of 40% coffee husk HCB

Testing day	Mean compressive strength with 40% coffee husk in MPa	Mean compressive strength without coffee husk in MPa
7th day	**1.4**	**2.18**
14th day	**2.11**	**3.25**
28th day	**3.04**	**3.82**

The compressive strength when compared with 40% coffee husk HCB, the 7th day decreased with 55.71%, the 14th day decreased with 54.03% and the 28th with 25.66% when compared with the respective days of the 40% coffee husk HCB. This means the 7th day compressive strength of HCB without coffee husk is 55.71% larger than the 7th day of 40% coffee husk HCB; the 14th day is 54.03% and 28th day is 25.66% larger than the respective days of 40% coffee husk HCB.

4.3.1.5. HCB without coffee husk and 50% coffee husk HCB

A mean strength of 0.97MPa for the 7th days, 1.51 MPa for the 14th and 2.44 MPa for the 28th were obtained from the compressive strength tests on each day samples.

Table 35: Mean compressive strength of 50% coffee husk HCB

Testing day	Mean compressive strength with 50% coffee husk in MPa	Mean compressive strength without coffee husk in MPa
7th day	**0.97**	**2.18**
14th day	**1.51**	**3.25**
28th day	**2.44**	**3.82**

The compressive strength when compared with 50% coffee husk HCB, the 7th day decreased with 124.74%, the 14th day decreased with 115.23% and the 28th with 56.56% when compared with the respective days of the 50% coffee husk HCB. This means the 7th day compressive strength of HCB without coffee husk is 124.74% larger than the 7th day of 50% coffee husk HCB; the 14th day is 115.23% and 28th day is 56.56% larger than the respective days of 50% coffee husk HCB.

4.3.1.6. HCB without coffee husk and 60% coffee husk HCB

A mean strength of 0.27MPa for the 7th days, 0.58 MPa for the 14th and 0.98 MPa for the 28th were obtained from the compressive strength tests on each day samples.

Table 36: Mean compressive strength of 60% coffee husk HCB

Testing day	Mean compressive strength with 60% coffee husk in MPa	Mean compressive strength without coffee husk in MPa
7th day	**0.27**	**2.18**
14th day	**0.58**	**3.25**
28th day	**0.98**	**3.82**

The compressive strength when compared with 60% coffee husk HCB, the 7th day decreased with 707.41%, the 14th day decreased with 460.34% and the 28th with 289.80% when compared with the respective days of the 60% coffee husk HCB. This means the 7th day compressive strength of HCB without coffee husk is 707.41% larger than the 7th day of 60% coffee husk HCB; the 14th day 460.34% and 28th day is 289.80% larger than the respective days of 60% coffee husk HCB.

4.4. Determination of the Optimum coffee husk replacement

The study was carried out to investigate the effects of coffee Husk in improving the engineering properties of light weight HCB. The optimum coffee husk content for this study is the coffee husk content that gives the light weight with maximum compressive strength with its weight up to that content and any further increase in the content results a decrease in compressive strength. The optimum content was determined on the 28th day light weight and mean compressive strength and clearly plotted in the **Figure 21**.

Table 37: The 28th days mean weight and mean compressive strength of HCB with coffee husk

Coffee Husk content (%)	10%	20%	30%	40%	50%	60%
28th Mean Weight (kg)	14.57	14.3	12.97	12.37	11.7	11.2
28th Comp.Stre (Mpa)	3.59	3.58	3.64	3.04	2.44	0.98

In the **Table37**, the mean compressive strength of the different coffee husk content HCBs are listed. From the above **Table37,** the maximum compressive strength is 3.64MPa which is obtained from the 30% coffee husk content and the minimum compressive strength is 0.98MPa which is obtained from 60% coffee husk content. The graph in **Figure 21** shows, the mean compressive strength versus coffee husk content in percent. As shown in the **Figure21**, as the coffee husk amount in the hollow concrete blocks increases up to 30% the compressive strength also increases from 3.59MPa to 3.64MPa. But after 30% to 60% the compressive strength decreases from 3.64MPa to 0.98MPa. The decrease in compressive strength is due to further replacement of crushed aggregates with relatively weak coffee husk aggregate. But the research for compressive strength and mean weight of 70%-100% not presents a result because it fails easily and even it cannot reach to the laboratory easily, that mean above 60% coffee husk replacement the HCB become loss it strength to attain the 14^{th} and 28^{th} days test due to that it does not show the results. From this the research cancels out the test result of 70%-100% replacement of coffee husk.

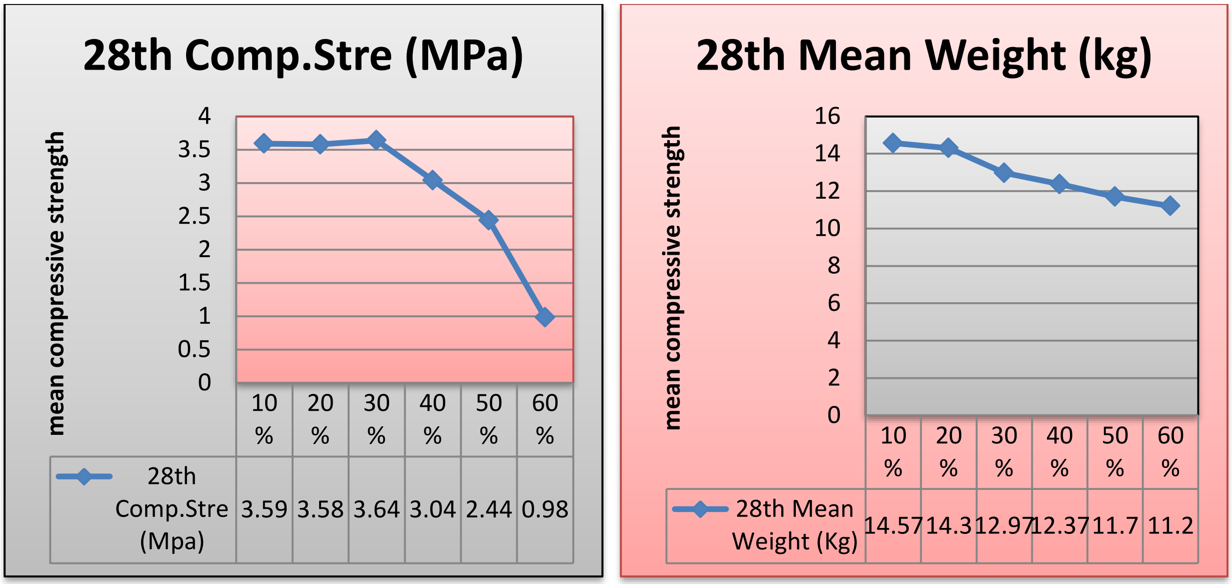

Figure 21: 28th mean compressive strength & mean weight versus coffee husk content (%)

But up to 30% the relative weakness of aggregate was compensated by the formation of dense zone and also the hollow concrete blocks need for fine aggregate was decreased because coffee husk used was a combined aggregate.

4.4.1. Comparison of HCB without coffee husk and the optimum coffee husk HCB

While collecting the results of the test samples for this research it was observed that the following findings were made there was a significant increase in the compressive strength value and weight change from heavy to light of the hollow concrete block with addition of coffee husk. The comparison was in terms of the 28th day mean compressive strength results of the two blocks. From the result, the compressive strength of HCB without coffee husk only increased with 0.18MPa, this means 4.95% increment in compressive strength but the weight of HCB with 30% coffee husk decrease with 2.13kg, this means 16.42% decrement in weight. HCB without coffee husk compressive strength is 4.95% larger than the 30% coffee husk HCB. This show that the 30% coffee husks HCB has achieved a compressive strength that is close to the HCB without coffee husk. Even the crushed aggregate and coffee husk which has weaker strength was used for the 30% coffee husk HCB, the difference in compressive strength was smaller than the difference between the other coffee husk HCB and HCB without coffee husk. This is mainly due to at 30% coffee husk content the relative weakness of coffee husk was highly compensated by the formation of dense mass due to cement paste penetration in the pores of coffee husk.

4.5. Comparison of produced HCBs with different standards

Since the compressive strength was conducted according to Ethiopian standard (ES C.D4.001) and (ES C.D3.301) the mean compressive strength was determined by considering three HCBs. But ASTM uses average of 5 blocks and 3 blocks. Therefore the mean compressive strengths were compared with Ethiopian standard and individually with ASTM only.

4.5.1. With Ethiopian standards (ES C.D3.301)

According to the data listed below, 5.5, 4.0 and 2.0 are the minimum compressive strength for Class A, B and C respectively. According to Ethiopian Standards (ES C.D3. 301), Class A and Class B type of hollow concrete blocks are load-bearing whereas Class C hollow concretes are non-load bearings according to the minimum compressive requirements.

- ✓ **Load bearing:** class A (Average of 6 unit=5.5N/mm2 and Individual units=5.0N/mm2) and class B (Average of 6 unit =4.0 N/mm2 and Individual units=3.2N/mm2)
- ✓ **Non Load bearing:** class C (Average of 6 unit =2.0 N/mm2 & Individual units=1.8 N/mm2)

Accordingly all the produced hollow concrete blocks were Class C except 70%, 80%, 90% and 100% coffee husk HCB. The 70%, 80%, 90% and 100% coffee husks HCB were found to be out of the Class requirements of Ethiopian Standard. This shown that, According to the study and Ethiopian standard, coffee husk can replace up to 60% of crushed aggregate in the production of HCB with coffee husk.

Table 38: Classes of the produced HCB according to the Ethiopian standard (ES C.D3. 301)

Type of HCB produced	**28th day's Mea.comp.str (MPa)**	**Class of HCB according to ES**
HCB without coffee husk	3.82MPa	Class C
10% coffee husk HCB	3.58 MPa	Class C
20% coffee husk HCB	3.59 MPa	Class C
30% coffee husk HCB	3.64 MPa	Class C
40% coffee husk HCB	3.04 MPa	Class C
50% coffee husk HCB	2.44 MPa	Class C
60% coffee husk HCB	0.98 MPa	Class C

4.5.2. With ASTM, (ASTM C90-70) and (ASTM C-129-70)

The ASTM classification of HCB with minimum compressive strength requirements in terms of average and individual units are listed in **Table 43**. ASTM classifies HCB as load bearing and non-load bearing types and with grades as type N and type S. Since the blocks mean compressive strength was determined by using average of six units, and ASTM recommends only 3 for load bearing and 5 for non -load bearing, it is better to consider individual compressive strength of blocks. From the compressive strength test results, the individual compressive strengths that full fill ASTM are 30% coffee husk HCB and HCB without coffee husk only.

Table 39: Compressive strength of HCB (ASTM C90-70) & (ASTM C-129-70)

Sample no.	**the 28th day individual compressive strength (N/mm^2)**	
	30% coffee husk HCB	**HCB without coffee husk**
1	3.61	3.91
2	3.72	3.70
3	3.59	3.85

According to **Table 39,** the 30% coffee husk HCB and HCB without coffee husk are non-load bearing hollow concrete blocks.

4.6. Unit weight comparisons of the hollow concrete blocks

The unit weights of each sample in **Table 44** were calculated by dividing the weight by the volume of each hollow concrete blocks. Their weight is listed in **appendix two** with their corresponding compressive strengths.

As shown from **Table 44**, the average unit weights of the HCB without coffee husk and the 30% coffee husk HCB there is 810.625Kg/m^3 unit weight difference this indicates that 30% coffee husk HCB in this study are 16.42% lighter than the HCB without coffee husk.

Table 40: Unit weight of 30% coffee husk HCBs and HCBs without coffee husk

Sample no.	the 28th day unit weight of the HCBs	
	30% coffee husk HCB (Kg/m^3)	**HCB without coffee husk (Kg/m^3)**
1	835.29	955.15
2	790.45	893.45
3	806.14	982.65
Average	**810.63 Kg/m^3**	**943.75Kg/m^3**

Since 10% up to 60% coffee husk HCBs are Class C according to Ethiopian standard **(ES C.D3.301)**, if they are to be used there will be a maximum unit weight reduction at 60% coffee husk which is 34.82%. This was due to the fact that the heavier crushed aggregate was only 40% and the light weight aggregate coffee husk takes the majority section of the HCB.

4.7. Analysis sheet for direct & indirect unit costs

4.7.1. Unit costs of HCB without coffee husk

Project Cost estimation is the process of valuing on monetary expression, including the cost of all possible entrants necessary for the planning, implementing and monitoring stages of the proposed project under consideration.

a) **Direct material unit cost:** a format as shown in **table 41** was used to calculate the direct material unit cost.

Table 41: Direct material unit cost without coffee husk

Material Cost (1:01)				
Type of Material	**Unit**	**Qty**	**Rate**	**Cost /Unit**
Medium Aggregate (Gravel 00)	*(m3)*	0.00286	1150	3.289
Crushed agg.	*(m3)*	0.00143	650	0.9295
Sand	*(m3)*	0.00429	950	4.08
Coffee husk	*(m3)*	0	150	0
Cement	*Qnt*	0.04	260	10.4
Total materials cost/block				**18.6985**

Materials required for 1:3:2:1

(i.e. 1bag of cement, 3 box of sand, 2 box of gravel 00 and 1 box of crushed aggregate 01)

Quantity for dry base analysis=**0.01m^3** Water …………..= **0.06 m^3**

Volume of cement=$\frac{1}{7}$*0.01=0.00143m^3 =$\frac{0.00143m3}{0.035m3/bag}$= **0.04bags of cement**

Volume of Sand= $\frac{3}{7} * \mathbf{0.01}$=**0.00429 m^3**

Volume of Gravel 00=$\frac{2}{7} * 0.01$=**0.00286 m^3**

Volume of Crushed Agg.t=$\frac{1}{7} * \mathbf{0.01}$=**0.00143 m^3**

B). direct labour unit cost: a format as shown in **Table 46** was used to calculate the direct labour unit cost.

Table 42: Direct labour unit cost of HCB without coffee husk

Labour Cost (1:02)				
Labour by Grade	**No.**	**UF**	**Indexed Hourly Cost**	**Hourly Cost**
Forman	1	0.00087	170	0.148
Orator	2	0.00087	100	0.174
D/L	11	0.00087	60	0.574
Total labour cost/block				**0.896**

C) Direct equipment unit cost: the direct cost of equipment is also calculated using the same format.

Table 43: Direct equipment unit cost of HCB without coffee husk

Equipment Cost (1:03)				
Type of Equipment	**No.**	**Hourly Rental**	**Hourly Cost**	**Cost/unit**
Mechanical mixer	1	0.000833	300	0.2499
HCB machine	1	0.000833	350	0.292
Total Equipment cost/block				**0.5419**

Total unit cost of production= DMUC+DLUC+DEUC.

Where, DMUC= direct material unit cost,

DEUC= direct equipment unit cost and

DLUC= direct labour unit cost.

The direct cost of producing without coffee husk HCB

= **18.6985+0.896+0.5419**

=**20.14birr**

4.7.2. Unit costs of HCB with 10% coffee husk

a) **Direct material unit cost:** a format as shown in table 48 was used to calculate the direct material unit cost.

Table 44: Direct material unit cost of HCB with 10% coffee husk

Material Cost (1:01)				
Type of Material	**Unit**	**Qty**	**Rate**	**Cost /Unit**
Medium Aggregate (Gravel 00)	*(m3)*	0.0	1150	0.00
Crushed agg.	*(m3)*	0.00143	650	0.9295
Sand	*(m3)*	0.0	950	0.00
Coffee husk	*(m3)*	0.0026	150	0.39
Cement	*Qnt*	0.044	260	11.4
Total materials cost/block				**12.76**

B). direct labour unit cost: a format as shown in **Table 49** was used to calculate the DLUC.

Table 45: Direct labour unit cost of HCB 10% coffee husk

Labour Cost (1:02)				
Labour by Grade	**No.**	**UF**	**Daily wage**	**Hourly Cost**
Forman	1	0.00087	170	0.148
Orator	2	0.00087	100	0.174
D/L	11	0.00087	60	0.574
Total labour cost/block				**0.896**

Direct equipment unit cost: the direct cost of equipment is also calculated using the same format.

Table 46: Direct equipment unit cost of HCB 10% coffee husk

Equipment Cost (1:03)				
Type of Equipment	**No.**	**UF**	**Rent/day**	**Cost/unit**
Mechanical mixer	1	0.000833	300	0.2499
HCB machine	1	0.000833	350	0.292
Total Equipment cost/block				**0.5419**

Total unit cost of production= DMUC+DLUC+DEUC.

Where, DMUC= direct material unit cost,

DEUC= direct equipment unit cost and

DLUC= direct labour unit cost.

The direct cost of producing without coffee husk HCB= **12.76+0.896+0.5419=14.20birr**

For all HCBs with 10% coffee husk the direct unit production costs were calculated by using the same format and are attached in **appendix** of this paper.

Table 46 below shows the summarized direct unit costs for all percentage of coffee husks HCB. As shown in **Tables 46**, the direct material cost is very high comparing to the other costs of production. The cost of labour and equipment are constant as observed in **Tables 46**. They also have less cost than cost of materials. From this one can conclude that in producing hollow concrete blocks majority of the cost goes to materials.

Type of HCB with coffee husk	**DMUC(bir)**	**DLUC(bir)**	**DEUC(bir)**	**Total cost/block(bir)**
10% coffee husk	12.759	0.896	0.5419	14.20
20% coffee husk	12.672	0.896	0.5419	14.11
30% coffee husk	12.393	0.896	0.5419	13.83
40% coffee husk	11.743	0.896	0.5419	13.18
50% coffee husk	11.414	0.896	0.5419	12.85
60% coffee husk	10.952	0.896	0.5419	12.39

Table 47: summarized direct unit costs of HCB with coffee husk

4.7.3. Comparison of production costs

Generally the production cost of HCB with coffee husk decreases from 14.20birr to 9.69birr as the coffee husk percentage increases from 10% to 100%. And the HCB that have a good compressive strength or 3.64MPa is HCB with 30% coffee husk decrease from 20.14birr to 13.83 birr, that mean 45.63% decrement from normal HCB or HCB without coffee husk. This is mainly due to the cost of materials and the amount used.

In Jimma Town, 1m3 coffee husk costs 150 birr and 1m3 crushed aggregate costs 650birr. Therefore, as the content of cheapest material which is coffee husk increases the content of crushed aggregate decreases this intern reduces the production cost.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

Coffee husk is a rich with fibbers and organic agricultural waste that have potable size for construction and light weight to reduce the weight of construction and give strength through minimizing the uniformity of aggregate. From this the research carried out has shown some of the comparison of the compressive strength, weight and production cost of HCB without and with Coffee Husk in Jimma town. The following conclusions and recommendations are drawn out from the investigation undertaken on the hollow concrete block production projects.

5.1.Conclusion

During conducting this study it is concluded that the compressive strength of the HCB without coffee husk was greater than the HCB with coffee husk. But the weight and cost wise the HCB without coffee husk incurred very higher weight and direct cost of production than the HCB with coffee husk.

While meeting the specific objectives of the study, the coffee husk amount which gives a higher strength was achieved at 30% coffee husk content, which is the optimum replacement of coffee husk for crushed aggregate that gives a higher compressive strength than the rest coffee husk replacement contents.

During The replacement of different percentage of coffee husk, the 30% coffee husk hollow concrete blocks have achieved a 28th day mean compressive strength which is only 4.95% smaller than that of HCB without coffee husk. On the other aspects of production cost and self-weight, the 30% coffee husk HCB has achieved 45.63% of cost and 16.42% of weight reductions. Therefore the 30% coffee husk HCB can be used in place of HCB without coffee husk.

According to the 28th day mean compressive strength test results, hollow concrete blocks produced without coffee husk and with coffee husk except 70%, 80%, 90% and 100% coffee husk HCBs, all were Class C according to Ethiopian standards. The 70%, 80%, 90% and 100% coffee husk HCBs were out of Class according to Ethiopian Standard. According to ASTM, the 30% coffee husks HCBs and HCB without coffee husk in terms of individual requirements, were non-load bearing hollow concrete blocks.

Generally it is concluded that, by using coffee husk as an aggregate a higher reduction in cost of production, higher reduction in weight and a small reduction in compressive strength than the HCB without coffee husk were achieved.

5.2.Recommendation

According to the study conducted on the comparison of compressive strength and production costs of HCB with and without coffee husk, the following recommendations were made for concerned bodies.

a) For Jimma Town Administration Office

The construction units of Jimma Town Administration should create awareness to the users of HCB about the use of coffee husk HCB. The construction unit should also encourage the micro and small HCB production enterprises for their contribution in production of cost effective hollow concrete blocks.

b) For contractors and micro and small HCB production enterprises

If it is properly produced, with a small difference in compressive strength but with large amount of cost and weight reduction HCB can be produced from coffee husk. Therefore, it is recommended that the micro and small producers of hollow concrete blocks in Jimma town should increase the production of HCB with coffee husk and crushed aggregate. Since other lightweight aggregates are not available around Jimma, it is recommended that producers of HCB use coffee husk as light weight aggregate alone with crushed aggregates in the production of HCB. The contractors shall produce or buy HCB with coffee husk instead of using HCB without coffee husk, which has higher cost of production and self-weight than the coffee husk HCB. They are also recommended to use coffee husk HCB instead of importing HCB from other town to reduce the cost of construction.

c) For other Towns in Ethiopia where coffee husk is abundantly available

For other Towns in Ethiopia where is coffee husk abundantly available, it is recommended that HCB producers should adopt the use of coffee husk alone with crushed aggregate in HCB production.

d) For construction materials research centers

The governmental and non-governmental materials research centers are recommended to conduct further studies on coffee husk as a hollow concrete block production material, in areas where coffee husk is abundantly available.

Further research is proposed in the following areas.

1. The effects that have on digging for natural sand on environment shall be studied.

2. More research and investigations need to be carried out to assess the scope for saving through optimization of both natural and manufactured sand.

3. Guide lines, mix design proposals and specifications shall be prepared using manufactured sand to establish acceptable mixes for concrete producers, contractors and their clients.

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APPENDIX ONE

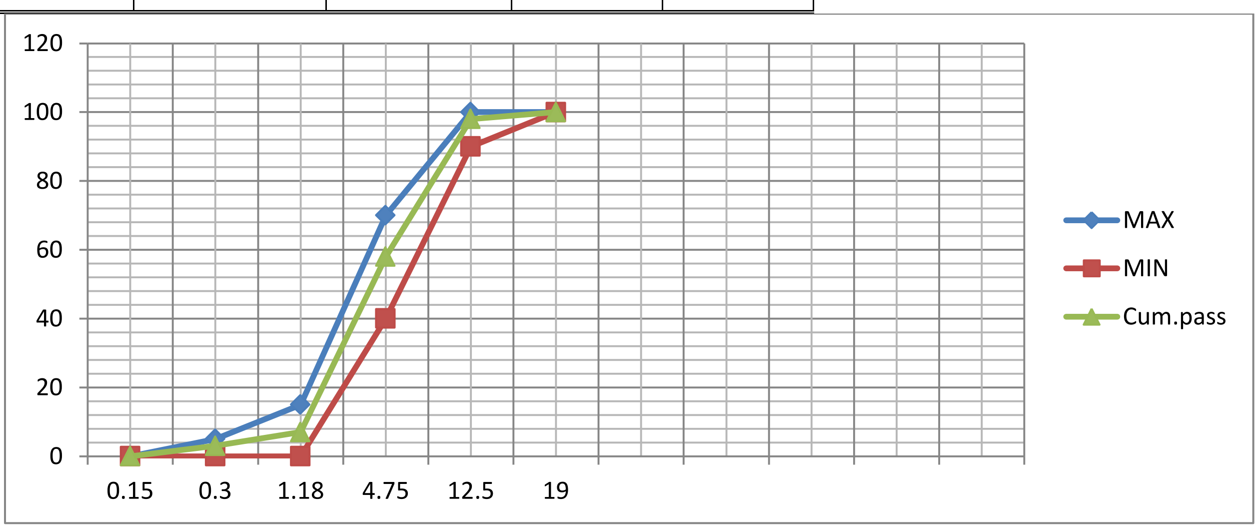
Laboratory Data Sheets for physical properties

PLACE	**Jimma university**
DEPARTMENT	**Civil engineering department**
LABORATORY	**Construction materials laboratory**

Sample description: Crushed aggregate 01

1. **Test method: ASTM C136, Sieve analysis**

Sieve size	M.retained (Kg)(1)	M.retained (%)(2)	Cum.R. Pass (%)	Cum.P. Pass (%)	ASTM standard of P. pass		Remark
					Max	Min	
19mm	0	0	0	100%	100%	100%	Ok!
12.5mm	0.045	0.91	0.91	99%	100%	90-100%	Ok!
4.75mm	1.755	35.59	36.50	63.5%	70%	40-70%	Ok!
1.18mm	1.520	30.83	67.33	32.67%	15%	15-40%	Ok!
300µm	1.611	32.67	100.00	0.00%	5%	0%-5%	Ok!
150µm	0	0	100.00	0.00%	0%	0%	Ok!
pan	-	-	-	-			



Sample description: crushed aggregate 01

2. Test method: ASTM C29 , Unit weight

Description	Measurements		
	Sample 1	Sample 2	Sample 3
Weight of container (A)	18	18	18
Weight of container +Sample=(B)	65	62	67.34
Weight of sample(B-A)=(D)	47	44	14.8
Volume of container(C)	0.03	0.03	0.03
Unit weight= D/C	1566.67kg/m3	1466.67 kg/m3	1644.67kg/m3
Mean unit weight	**1,559.34 kg/m3**		

Sample description: crushed aggregate 01

3. Test method: ASTM C127, Specific gravity and absorption

Description	Var.	Weight in kg		
Samples		S_1	S_2	S_3
Weight of oven dry sample in air	A	4.92	4.89	4.9
Weight of saturated-surface dry sample in air	B	5	5	5
Weight of wire in water C	C	0.35	0.35	0.35
Weight in water (of (SSD) sample +wire basket)	D	3.07	3.17	2.97
Weight in water of SSD=D-C	E	2.72	2.82	2.87
Bulk Sp.gr.(SSD)=	SG	*2.24*	*2.36*	*2.41*
Mean bulk sp. Gr.				**2.34**

Absorption

Absorption=[(B-A)/A]*100%	Abs.	***1.63***	2.25	2.04
Mean absorption				**1.97**

Sample description: crushed aggregate 01

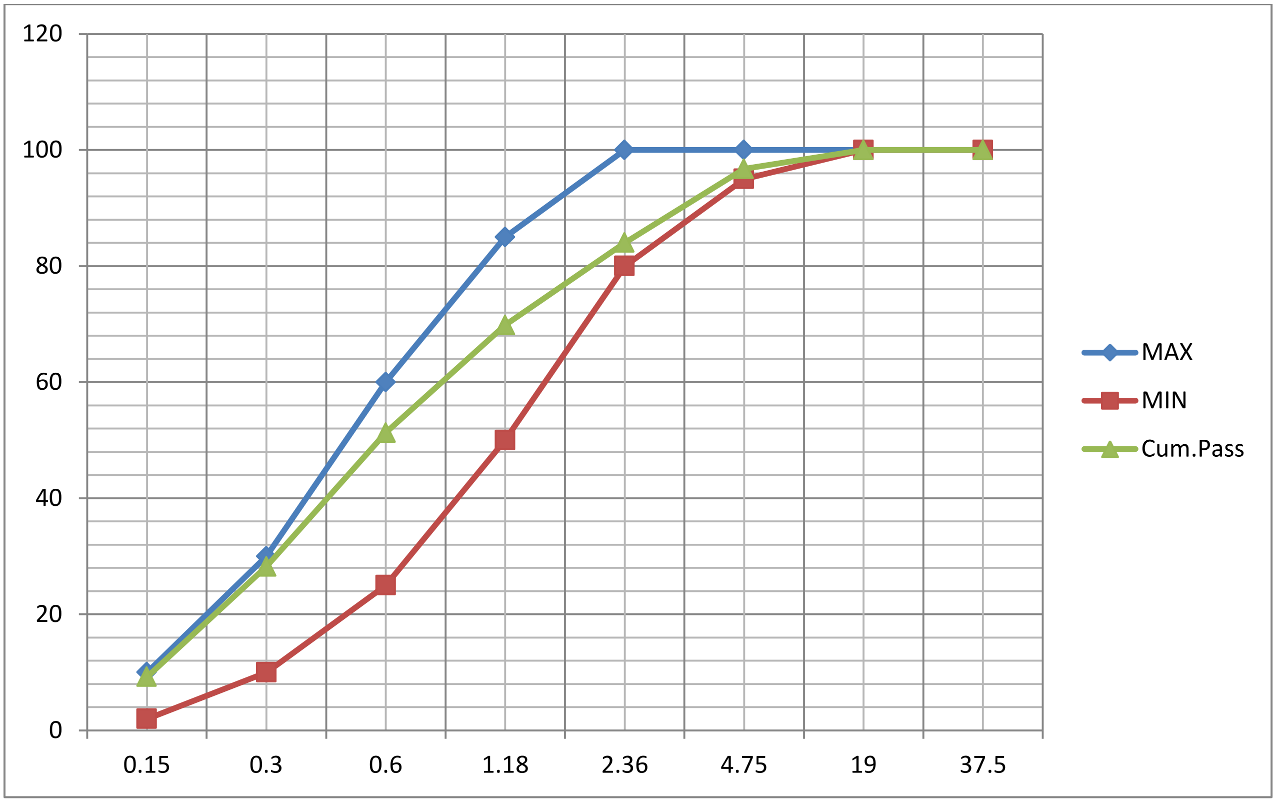
4. **Test method: ASTM C 566, Moisture content**

Description	Var.	Weight in gm		
Samples		S_1	S_2	S_3
Weight of wet sample (tarred) M1	A	500	500	500
Weight of the oven dried sample (tarred) M2	B	492	489	495
Moisture content=[M1-M2]/M2	C	1.63%	2.25%	1.01%
Mean moisture content				**1.63%**

Sample description: Medium Aggregate (Gravel 00)

1. **Test method: ASTM C136, Sieve analysis**

Sieve size	M.retained (Kg)(1)	M.retained (%)(2)	Cum.P. Pass (%)	ASTM standard of P. pass		Remark
				Max	Min	
19mm	**0**	**0**	**100%**	**100%**	**100%**	**Ok!**
4.75mm	**177**	**3.26**	**96.37%**	**100%**	**95%**	**Ok!**
2.36mm	**490**	**12.72**	**86.33%**	**100%**	**80%**	**Ok!**
1.18mm	**770**	**14.20**	**70.56%**	**85%**	**50%**	**Ok!**
600 µm	**990**	**18.53**	**50.28%**	**60%**	**25%**	**Ok!**
300µm	**1150**	**23.05**	**26.72%**	**30%**	**10%**	**Ok!**
150µm	**931**	**19.01**	**7.64%**	**10%**	**2%**	**Ok!**
Pan	-	-	-			



Sample description: gravel 00

2. **Test method: ASTM C29 , Unit weight**

Description	**Measurements**		
	Sample 1	Sample 2	Sample 3
Weight of container (A)	18	18	18
Weight of container +Sample=(B)	60	63	64
Weight of sample(B-A)=(D)	42	45	46
Volume of container(C)	0.03	0.03	0.03
Unit weight= D/C	1400kg/m3	1500 kg/m3	1533.33kg/m3
Mean unit weight	**1,477.77 kg/m3**		

Sample description: gravel 00

3. Test method: ASTM C127, Specific gravity and absorption

Description	**Var.**	**Weight in kg**		
Samples		S_1	S_2	S_3
Weight of oven dry sample in air	A	4.89	4.97	4.85
Weight of saturated-surface dry sample in air	B	5	5	5
Weight of wire in water C	C	0.35	0.35	0.35
Weight in water (of (SSD) sample +wire basket)	D	2.97	3.01	2.87
Weight in water of SSD=D-C	E	2.62	2.66	2.52
Bulk Sp.gr.(SSD)=	SG	*2.15*	*2.25*	*2.08*
Mean bulk sp. Gr.				2.16

Absorption=[(B-A)/A]*100%	Abs.	*2.25*	0.604	3.09
Mean absorption				1.98

Sample description:

4. Test method: ASTM C 566, Moisture content and silt content

Description	**Var.**	**Weight in gm**		
Samples		S_1	S_2	S_3
Weight of wet sample (tarred) M1	A	500	500	500
Weight of the oven dried sample (tarred) M2	B	494	485	491
Moisture content=[M1-M2]/M2	C	1.21%	1.03%	1.63%
Mean moisture content				1.29%

Silt content determination

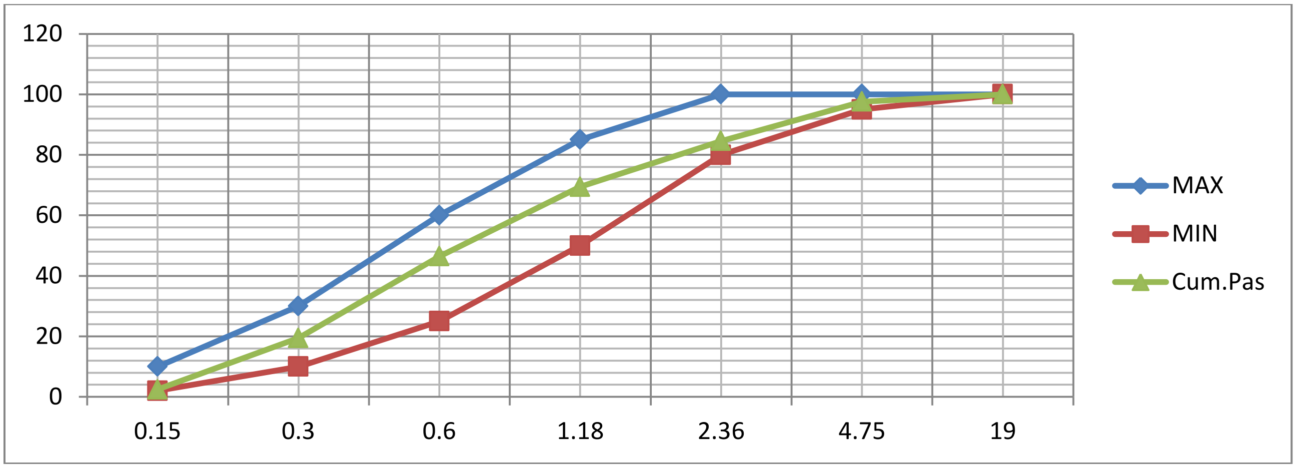
Description	**Var.**	**Height in mm**		
Samples		S_1	S_2	S_3
Amount of Silt	A	2	2.5	4.5
Amount of Silt + Sand	B	145	148	157
Silt content	C	1.38%	1.69%	2.87%
Mean moisture content				**2.88%**

SAND

Sample description:

1. **Test method: ASTM C136, Sieve analysis**

Sieve size	**M.retained (gr)(1)**	**M.retained (%)(2)**	**Cum.P. Pass (%)**	**ASTM standard of P. pass**		**Remark**
				Max limit	**Min limit**	
19mm	**0**	**0**	**100%**	**100%**	**100%**	**Ok!**
4.75mm	**122**	**2.44%**	**97.56%**	**100%**	**95%**	**Ok!**
2.36mm	**650**	**13%**	**84.56%**	**100%**	**80%**	**Ok!**
1.18mm	**756**	**15.12%**	**69.44%**	**85%**	**50%**	**Ok!**
0.6µm	**1150**	**23%**	**46.44%**	**60%**	**25%**	**Ok!**
0.3µm	**1350**	**27%**	**19.44%**	**30%**	**10%**	**Ok!**
0.15 µm	**850**	**17%**	**2.44%**	**10%**	**2%**	**Ok!**
Pan	**122**	**-**	**-**	**-**	**-**	



Sample description: Sand

2. **Test method: ASTM C29 , Unit weight**

Description	Measurements		
	Sample 1	Sample 2	Sample 3
Volume of cylinder (A)	2lit	2lit	2lit
Weight of cylinder +Sample=(B)	4.35	4.25	4.30
Weight of cylinder (C)	0.875	0.875	0.873
Weight of sample(B-C)=(D)	3.475	3.375	3.427
Unit weight= D/A	1737.5Kg/m3	1687.5Kg/m3	1713.5Kg/m3
Mean unit weight			1712.83Kg/m3

Sample description: Sand

3. **Test method: ASTM C 566, Specific gravity and Absorption**

Description	Var.	Weight in g		
Samples		S_1	S_2	S_3
Weight of oven dry sample in air	A	497	492	494
Weight of Pycnometer filled with Water (Va)	B	1290	1290	1290

Weight of the Pycnometer+Sample+Water	C	1570	1608	1540
Weight of sample SSD	D	500	500	500
Bulk Sp.gr.(SSD)	SG	*2.26*	*2.70*	*1.98*
Mean bulk sp. Gr.	**2.31**			

Absorption=[(B-A)/A]*100%	Abs.	0.60	1.63	1.21
Mean absorption	**1.15**			

Sample description: Sand

4. **Test method: ASTM C 566, Moisture content and silt content**

Description	**Var.**	**Weight in gm**		
Samples		S_1	S_2	S_3
Weight of wet sample (tarred) M1	A	500	500	500
Weight of the oven dried sample (tarred) M2	B	492	489	495
Moisture content=([M1-M2]/M2)*100	C	1.63%	2.25%	1.01%
Mean moisture content				**1.63%**

Silt content determination

Description	**Var.**	**Height in mm**		
Samples		S_1	S_2	S_3
Amount of Silt	A	4	3	6
Amount of Silt + Sand	B	145	148	155
Silt content	C	2.76%	2.02%	3.87%
Mean silt content				**2.88%**

APPENDIX TWO

Weight and Compressive strength test results of HCB

The seventh day (___7th) compressive strength of HCB without coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	18.9	174.7	2.18
2	40	20	20	0.08	19.0	178.6	2.23
3	40	20	20	0.08	18.4	171.1	2.14
					MEAN		2.18

The seventh day (___14th) compressive strength of HCB without coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	17.4	253.6	3.17
2	40	20	20	0.08	18.2	267.2	3.34
3	40	20	20	0.08	16.7	259.2	3.24
					MEAN		3.25

The seventh day (___28th) compressive strength of HCB without coffee husk

Sample casting date:						**No. Testing date:**	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	15.1	301.60	3.77
2	40	20	20	0.08	15.3	320.80	4.01
3	40	20	20	0.08	14.9	294.40	3.68
MEAN							3.82

The seventh day (___7th) compressive strength of HCB with 10% coffee husk

Sample casting date:						**No. Testing date:**	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	18.7	108.8	1.36
2	40	20	20	0.08	18.8	205.6	2.57
3	40	20	20	0.08	18.2	160.8	2.01
MEAN							1.98

The seventh day (___7th) compressive strength of HCB with 20% coffee husk

Sample casting date:						**No. Testing date:**	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	18.1	124.8	1.56
2	40	20	20	0.08	18.4	131.2	1.64
3	40	20	20	0.08	17.9	171.2	2.14
					MEAN		1.78

The seventh day (___7th) compressive strength of HCB with 30% coffee husk

Sample casting date:						**No. Testing date:**	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	17.2	102.4	1.28
2	40	20	20	0.08	17.6	116	1.45
3	40	20	20	0.08	16.9	151.2	1.89
					MEAN		1.54

The seventh day (___7th) compressive strength of HCB with 40% coffee husk

Sample casting date:					No. Testing date:	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	16.7	121.6	1.52
2	40	20	20	0.08	17.2	110.4	1.38
3	40	20	20	0.08	16.1	104.0	1.30
					MEAN		1.40

The seventh day (___7th) compressive strength of HCB with 50% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	16.1	88.80	1.11
2	40	20	20	0.08	16.7	71.20	0.89
3	40	20	20	0.08	15.7	72.80	0.91
					MEAN		0.97

The seventh day (___7th) compressive strength of HCB with 60% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	10.85	20	0.25
2	40	20	20	0.08	10.34	26.4	0.33
3	40	20	20	0.08	10.49	18.4	0.23
					MEAN		0.27

The fourteenth day (14th) compressive strength of HCB with 10% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	17.3	244.0	3.05
2	40	20	20	0.08	17.9	253.6	3.17
3	40	20	20	0.08	16.4	215.2	2.69
					MEAN		2.97

The fourteenth day (14th) compressive strength of HCB with 20% coffee husk

Sample casting date:					No. Testing date:		
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	16.3	238.4	2.98
2	40	20	20	0.08	17.3	240.0	3.00
3	40	20	20	0.08	15.9	179.2	2.24
					MEAN		2.74

The fourteenth day (14th) compressive strength of HCB with 30% coffee husk

Sample casting date:					No. Testing date:		
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	16.2	210.4	2.63
2	40	20	20	0.08	15.7	188.0	2.35
3	40	20	20	0.08	14.2	252.0	3.15
					MEAN		2.71

The fourteenth day (14th) compressive strength of HCB with 40% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	15.8	157.6	1.97
2	40	20	20	0.08	15.1	178.4	2.23
3	40	20	20	0.08	13.8	170.4	2.13
					MEAN		2.11

The fourteenth day (14th) compressive strength of HCB with 50% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	15.2	112.8	1.41
2	40	20	20	0.08	14.7	123.2	1.54
3	40	20	20	0.08	13.3	126.4	1.58
					MEAN		1.51

The fourteenth day (14th) compressive strength of HCB with 60% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	7.18	49.6	0.62
2	40	20	20	0.08	7.62	39.2	0.49
3	40	20	20	0.08	6.89	50.4	0.63
					MEAN		0.58

The fourteenth day (28th) compressive strength of HCB with 10% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			**Area(m2)**	**Weight(kg)**	**Failure Load(KN)**	**Compre.Strength(KN/M2)**
	L	W	H				
1	40	20	20	0.08	14.8	300.8	3.76
2	40	20	20	0.08	14.9	276.0	3.45
3	40	20	20	0.08	14.6	282.4	3.53
					MEAN		3.58

The twenty eighth day (28th) compressive strength of HCB with 20% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	14.4	292.0	3.65
2	40	20	20	0.08	14.6	283.4	3.54
3	40	20	20	0.08	13.9	286.4	3.58
MEAN							3.59

The twenty eighth day (28th) compressive strength of HCB with 30% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	12.8	305.6	3.82
2	40	20	20	0.08	13.4	277.6	3.47
3	40	20	20	0.08	12.7	290.4	3.63
MEAN							3.64

The twenty eighth day (____28th) compressive strength of HCB with 40% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	12.2	229.6	2.87
2	40	20	20	0.08	12.8	254.4	3.18
3	40	20	20	0.08	12.1	245.6	3.07
					MEAN		3.04

The twenty eighth day (____28th) compressive strength of HCB with 50% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	11.5	191.2	2.39
2	40	20	20	0.08	12.2	200.8	2.51
3	40	20	20	0.08	11.4	193.6	2.42
					MEAN		2.44

The twenty eighth day (____28th) compressive strength of HCB with 60% coffee husk

Sample casting date:						No. Testing date:	
	Dimension(cm)			Area(m2)	Weight(kg)	Failure Load(KN)	Compre.Strength(KN/M2)
	L	W	H				
1	40	20	20	0.08	4.52	83.2	1.04
2	40	20	20	0.08	5.14	76.8	0.96
3	40	20	20	0.08	5.7	75.2	0.94
					MEAN		0.98

APPENDIX THREE

Analysis sheet for direct & indirect unit costs

Analysis sheet for direct & indirect unit costs without coffee husk

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost Per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	Cost/ unit
Gravel 00	*(m3)*	0.00286	1150	3.289	Forman	1	0.00087	170	0.148	Mechanical mixer	1	0.000833	300	0.249
Crushed agg.	*(m3)*	0.00143	650	0.9295	Orator	2	0.00087	100	0.174	HCB machine	1	0.000833	350	0.292
Sand	*(m3)*	0.00429	950	4.08	D/L	11	0.00087	60	0.574					
Coffee husk	*(m3)*	0	150	0										
Cement	*Qnt*	0.04	260	10.4										
Total materials cost/block (A)				**18.6985**	**Total labour cost/block (B)**				**0.896**	**Total Equipment cost/block (C)**				**0.542**
Direct Cost of Work Item				**A+B+C=18.6985+0.896+0.542**										**20.14**
Indirect Cost of Work Item (10%)				**20.14*.10**										**2.014**
														22.114

Analysis sheet for direct & indirect unit costs with 10% coffee husk

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost Per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	Cost/ unit
Gravel 00	*(m3)*	0.00	1150	0.00	Forman	1	0.00087	170	0.148	Mechanical mixer	1	0.000833	300	0.249
Crushed agg.	*(m3)*	0.00143	650	0.9295	Orator	2	0.00087	100	0.174	HCB machine	1	0.000833	350	0.292
Sand	*(m3)*	0.00	950	0.00	D/L	11	0.00087	60	0.574					
Coffee husk	*(m3)*	0.0026	150	0.39										
Cement	*Qnt*	0.044	260	11.4										
Total materials cost/block (A)				**12.7195**	**Total labour cost/block (B)**				**0.896**	**Total Equipment cost/block (C)**				**0.542**
Direct Cost of Work Item				**A+B+C=12.7195+0.896+0.542**										**14.1575**
Indirect Cost of Work Item (10%)				**14.1575*.10**										**1.41575**
														15.5733

Analysis sheet for direct & indirect unit costs with 20% coffee husk

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost Per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	Cost/ unit
Gravel 00	*(m3)*	0.00	1150	0.00	Forman	1	0.00087	170	0.148	Mechanical mixer	1	0.000833	300	0.249
Crushed agg.	*(m3)*	0.00143	650	0.869	Orator	2	0.00087	100	0.174	HCB machine	1	0.000833	350	0.292
Sand	*(m3)*	0.00	950	0.00	D/L	11	0.00087	60	0.574					
Coffee husk	*(m3)*	0.0026	150	0.403										
Cement	*Qnt*	0.044	260	11.4										
Total materials cost/block (A)				**12.672**	**Total labour cost/block (B)**				**0.896**	**Total Equipment cost/block (C)**				**0.542**
Direct Cost of Work Item				**A+B+C=12.672+0.896+0.542**										**14.11**
Indirect Cost of Work Item (10%)				**14.11*.10**										**1.411**
														15.521

Analysis sheet for direct & indirect unit costs with 30% coffee husk

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost Per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	Cost/ unit
Gravel 00	*(m3)*	0.00	1150	0.00	Forman	1	0.00087	170	0.148	Mechanical mixer	1	0.000833	300	0.249
Crushed agg.	*(m3)*	0.00143	650	0.587	Orator	2	0.00087	100	0.174	HCB machine	1	0.000833	350	0.292
Sand	*(m3)*	0.00	950	0.00	D/L	11	0.00087	60	0.574					
Coffee husk	*(m3)*	0.0026	150	0.406										
Cement	*Qnt*	0.044	260	11.4										
Total materials cost/block (A)				**12.393**	**Total labour cost/block (B)**				**0.896**	**Total Equipment cost/block (C)**				**0.542**
Direct Cost of Work Item				**A+B+C=12.393+0.896+0.542**										**13.83**
Indirect Cost of Work Item (10%)				**13.83*.10**										**1.383**
														15.213

Analysis sheet for direct & indirect unit costs with 40% coffee husk

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost Per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	Cost/ unit
Gravel 00	*(m3)*	0.00	1150	0.00	Forman	1	0.00087	170	0.148	Mechanical mixer	1	0.000833	300	0.249
Crushed agg.	*(m3)*	0.00143	650	0.422	Orator	2	0.00087	100	0.174	HCB machine	1	0.000833	350	0.292
Sand	*(m3)*	0.00	950	0.00	D/L	11	0.00087	60	0.574					
Coffee husk	*(m3)*	0.0026	150	0.421										
Cement	*Qnt*	0.044	260	10.9										
Total materials cost/block (A)				**11.743**	**Total labour cost/block (B)**				**0.896**	**Total Equipment cost/block (C)**				**0.542**
Direct Cost of Work Item				**A+B+C=11.743+0.896+0.542**										**13.18**
Indirect Cost of Work Item (10%)				**13.18*.10**										**1.318**
														14.498

Analysis sheet for direct & indirect unit costs with 50% coffee husk

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost Per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	Cost/ unit
Gravel 00	*(m3)*	0.00	1150	0.00	Forman	1	0.00087	170	0.148	Mechanical mixer	1	0.000833	300	0.249
Crushed agg.	*(m3)*	0.00143	650	0.087	Orator	2	0.00087	100	0.174	HCB machine	1	0.000833	350	0.292
Sand	*(m3)*	0.00	950	0.00	D/L	11	0.00087	60	0.574					
Coffee husk	*(m3)*	0.0026	150	0.427										
Cement	*Qnt*	0.044	260	10.9										
Total materials cost/block (A)				**11.414**	**Total labour cost/block (B)**				**0.896**	**Total Equipment cost/block (C)**				**0.542**
Direct Cost of Work Item				**A+B+C=11.414+0.896+0.542**										**12.85**
Indirect Cost of Work Item (10%)				**12.85*.10**										**1.285**
														14.135

Analysis sheet for direct & indirect unit costs with 60% coffee husk

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty	Rate	Cost Per Unit	Labour by Grade	No.	UF	Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	Cost/ unit
Gravel 00	*(m3)*	0.00	1150	0.00	Forman	1	0.00087	170	0.148	Mechanical mixer	1	0.000833	300	0.249
Crushed agg.	*(m3)*	0.00143	650	0.061	Orator	2	0.00087	100	0.174	HCB machine	1	0.000833	350	0.292
Sand	*(m3)*	0.00	950	0.00	D/L	11	0.00087	60	0.574					
Coffee husk	*(m3)*	0.0026	150	0.441										
Cement	*Qnt*	0.044	260	10.45										
Total materials cost/block (A)				**10.952**	**Total labour cost/block (B)**				**0.896**	**Total Equipment cost/block (C)**				**0.542**
Direct Cost of Work Item				**A+B+C=10.952+0.896+0.542**										**12.39**
Indirect Cost of Work Item (10%)				**12.39*.10**										**1.239**
														13.629