JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

(Construction Engineering and ManagementChair)

STUDY ON THE PROPERTIES OF AGGREGATES USED FOR PRODUCTION OF RIBBED SLAB HCB IN ETHIOPIA

A thesis submitted to the school of postgraduate studies of jimma institute of technology, school of civil and Environmental Engineering in partial fulfillment of the requirements for the degree of masters in construction Engineering and management

By: Hiwot Daniel

November 2017

Jimma, Ethiopia

JIMMA UNIVERSITY
SCHOOL OF GRADUATE STUDIES
JIMMA INSTITUTE OF TECHNOLOGY
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
Department of Civil Engineering
(Construction engineering and management)

STUDY ON THE PROPERTIES OF AGGREGATES USED FOR PRODUCTION OF RIBBED SLAB HCB IN ETHIOPIA

A thesis submitted to the school of postgraduate studies of jimma institute of technology, school of civil and Environmental Engineering in partial fulfillment of the requirements for the degree of masters in construction Engineering and management

By: Hiwot Daniel
Main Advisor: Dr. TameneAdugna(PhD)
Co-Advisor: Engr. Sinatyehu Assefa (MSc.)

November 2017
Jimma, Ethiopia

DECLARATION

I, the undersigned, declare that this thesis entitled "study on the properties of aggregates used for production of ribbed slab HCB in 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 materials used for the thesis have been duly acknowledged.

Candidate:

Name: Hiwot Daniel

Signature:

Date: ___________________________

As Master research Advisors, we hereby certify that we have read and evaluate this MSc research prepared under our guidance, by Hiwot Daniel entitled: study on the properties of aggregates used for production of ribbed slab in HCB in Ethiopia

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

Main Advisor:

Dr. - Ing. TameneAdugna

Signature:

Date: ___________________________

Co-Advisor:

Engr.Sinatyehu Assefa (MSc.)

Signature:

Date: ___________________________

ABSTRACT

Concrete can found everywhere around the world. It has dominated world multi-story commercial and residential building. Slabs take the highest cost Percentage of the total volume over the other structural load bearing Members. Nowadays, one of the most common floor systems is ribbed slab concrete. The conventional available hollow concrete block size results its limitation on the concrete slab thickness. Hollow blocks construction provides facilities for electrical conduit, water and soil pipes. It saves cement in construction work, bringing down cost of construction considerably.

The objectives were study on properties of aggregates used for production of ribbed slab HCB in Ethiopia.To identify the physical property of aggregates and compare the result with different standards. The other objective were to find out effect of each different aggregates property on production of ribbed slab HCB .The effects are expressed by using compressive strength, density of the block and dry shrinkage tests and compare the result with ES. The aggregates are classified based on density: pumice, red ash (scoria)and crushed (01) aggregates.The HCB used in this study are casted using prelisted aggregates and combination of those three aggregates..

The studywas conducted in terms of quantitative methods. The study designs used for this research were comparative and lab based study. The laboratory test was conducted compressive strength of HCB agefor 7, 14 and 28 day.

From the result crushed aggregate had highest specific gravity than pumice and red ash aggregate.It indicates low porosity therefore high durability and high strength had gainThe water observation of Crushed aggregate was lowest value .Which indicated that during mix design, water cement ratio would depended on this value.Mixed of three aggregate had largest compressive strength relative to crushed ,red ash and pumice HCB. Their Compressive strength respectivelyare 2.3, 2.13, 2 and 1.95 Mpa.

Keywords;-HCB**,** compressive strength,ribbed slab,crushed aggregate, pimce and red ash dinsity

ACKNOWLEDGEMENT

First of all I would like to gratefully acknowledge the almighty **Trinity**to get the chance of this program. My deepest gratitude goes to my advisorDr.Ing TameneAdugna and my Co-Advisor Ingr Sinatyehu Assefa for all theirsuggestions, kind support, and limitless efforts in guiding me through my work and for providing me useful reference materials. .

I take this chance to express my appreciation to ERA, Jimma University and Addis Ababa University/EiABC, Ethiopian for providing me the research material, data and for their support.

My deepest appreciation goes to Jimma University, School of Graduate Studies, Jimma Institute of Technology, School of Civil and Environmental Engineering, Construction Engineering and Management Stream.

Lastly, Special thanks are due to my Mother,Meslech Semign Reta , all my families and friend, Almesged Gudu, for their endless patience, encouragement, continuous support and help during my study.

TABLE CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATIONS

ACI	American Concrete Institute
ACV	Aggregate Crushing Value
ACV	Aggregate Crushing Value
AD	Air-Dry
ASTM	American Society Testing and Materials Codes
B.C	Before Christ
CCAA	Cement and Concrete Association of Australia
DL	Daily Labor
EBCS	Ethiopian Building Code Standard
EiABC	Ethiopia Institute of Architectural Building and City Construction
ES	Ethiopian Standard
ETB	Ethiopian Birr
F.M	Fineness Modules
G.C	Gregorian Calendar
G_s	Specific Gravıty
HCB	Hallow Concrete Block
Hr	Hour
HSC	High Strength Concrete.
Ib	Pound
IS	Indian Standard
JU	Jimma University
LWC	Light Weight Concrete
OD	Oven-Dry
OPC	Ordinary Portland Cement
SSD	Saturated Surface Dry
U.S	United State

CHAPTER ONE

INTRODUCTION

1.1.Background

Concrete can found everywhere around the world. Its versatilityand ready availability have ensured that it hasbeen and will continue to be a great importance for all types of construction throughoutthe world.A simple definition of concrete is that it is amixture of cement, water and aggregates in whichthe cement and water combine to bind the aggregateparticles together to form a monolithic whole. It canbe found above the ground, in housing, industrial, commercial buildingsand bridges. On the ground it also found in roads, airport runways, under the ground infoundations, tunnels, drainage systems, sewers and in water or in river. Many structures have concrete astheir principal structural material, either in a plain or mass form.However, even in those structures where other materialssuch as steel or timber form the principal structuralelements, concrete will normally still have animportant role, for example in foundations.Not surprisingly, concrete has been described as theessential construction material (Peter D andJohn I ,2010).

Concrete structures have dominated world multi-storey commercial and residential building scene. Landmark projects are among the tallest reinforced concrete buildings in the world and testify to the skills of designers, builders and tradesmen.Traditionally, column spacing and floor spans in buildings have been in the range of 6 to 9 meters .However, recently there is an increasing preference bybuilding owners and tenants for large floor areas withcolumn-free space and spans from 9 to 16 meters.This has focused the interest of designers andbuilders on methods of reducing costs and speedingconstruction of long-span floors (CCAA, 2003).

The table shows slabs take the highest cost over the other structural load bearing Members Percentage of the total concrete volume used for the realization of the main load bearing structural elements in buildings (James K, 2009).

Table 1.1: Cost of structural part of building

Structural element or load bearing Member	Percentage of total volume of concrete
Foundations and ground supported slabs	22%
Bearing walls	4%
Columns	5%
Slabs (elevated or framed slabs)	59%
Others	10%

Nowadays, one of the most common floor systems for mid-rise to high-rise building construction in Addis Ababa and other regional cities is ribbed slab system (Mohammed A, 2006). Ribbed slab construction possesses some advantages over conventional slab-beam-column construction. This type of construction has architectural flexibility, more clear space, less building height, lack of sharp corners and affords simple construction by using standard modular and reusable formwork. The conventional available hollow concrete block size results its limitation on the concrete slab thickness. This slab column frame system is also susceptible to significant reduction in stiffness as a consequence of slab cracking that arises from construction loads, service gravity load and lateral loads. Even the punching failure is prevented by introducing adequate reinforcement at slab column connection. The serious problem in this slab-column frame system is its low lateral stiffness.

Hollow Concrete Blocks are blocks manufactured from concrete and processed into moulds, to achieve the required physical strength and dimensions to requirements and standards**.**

Masonry may be constructed mainly with the following units:

1. Hollow Concrete Blocks
2. Dressed (natural) stones
3. Burnt or clay bricks

While comparing with others, HCB masonry is a cost and time efficient and economical solution in construction(GZT, 2008).

Building Materials and Technology Promotion Council Ministry of Housing and Urban Poverty has defined and historical back ground of HCB .A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. Most concrete blocks have one or more hollow cavities and their sides may be cast smooth or with a design. Concrete blocks are stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall**.** Concrete mortar was used by the Romans as early as 200 B.C. To bind shaped stones together in the construction of buildings.Small blocks of precast concrete were used as a construction material in the region around present-day Naples, Italy .Much of the concrete technology developed by the Romans was lost after the fall of the Roman Empire in the fifth century. Hollow concrete blocks and bricks are becoming very popular. These blocks are being widely used in construction of residential buildings, factories and multi-storied buildings.

The main advantage of HCB for slab is minimizing the cost of form work. The primary use of structural lightweight concrete is to reduce the dead load of concrete structure, which then allows the structural designer to reduce the size of columns, footings and other load bearing elements (Hossain K, 2007).The use of lightweight concrete is usually preferred for lower overall cost of structures. Although lightweight concrete may cost higher per cubic meter than normal weight concrete, the structure may cost less as a result of reduced dead weight and lower foundation cost (Mikyas A,1970).

In order to produce hollow concrete blocks based on specified standard specification, proper care and control have to be done during proportioning of ingredients which contains two parts: these are selection of suitable ingredients and determining relative quantities and production processes such as batching, mixing, transporting, placing, compaction and curing(Tesfaalem K , 2014).

Following Italy, Chile, and Ecuador; Ethiopia is the 4^{th} leading producer of pumice and scoria aggregates in the world .The use of these abundantly produced natural lightweight materials, in the construction industry has been studied in Ethiopia (Hossain K, 2007).

The study had carried out the property of HCB. It is expressed by compressive strength, block density and dry shrinkage test. It also presents the results of experimental investigation on physical property of aggregate: - Sieve analysis of fine aggregate, specific gravity and water absorption, silt content, organic impurity, moisture content of aggregates and unit weight of aggregate. After the laboratory conclusion the effects of aggregates properties on production of ribbed slab HCB.

1.2. Statements of the problem

Ribbed slabs are in-situ concrete ribs with hollow blocks or voids. These types of structural plate systems can minimize formwork complexity by using standard modular, reusable formwork (Mohammed A, 2006).Building Materials and Technology Promotion Council Ministryof Housing and Urban Poverty state that,these hollow blocks are more useful due to its lightweight and ease of ventilation. Hollow blocks construction provides facilities for concealing electrical conduit, water and soil pipes. It saves cement in masonry work, bringing down cost of construction considerably. Different kind of aggregate properties have different engineering property like Compressive strength, water content, cost of material and production, density of block, water absorption, Unit weight and specific gravity.

The main characteristics of aggregate that affect the performance of fresh and hardened concrete are; Shape and texture, Grading, Absorption, , Strength and stiffness, Maximum size, Specific gravity or relative density, Soundness and Toughness. (Pedro N,2003).Aggregate is the main ingredient for the production of hallow concrete block. It has significant effect on the compressive strength.Abebe Dinku (2005 G.C) and Melese yohannes (2010 G.C)conducted study to find out suitable ingredients to produce different types of concrete with acceptable strength and used different type of aggregates in the production of concrete in Ethiopia.The study has shown the effect of aggregates property for the production of HCB relates to acceptable standard and cost in the study area. Therefore, the effectiveness has studied. The laboratory tests focus on HCB compressive strength depending on it different type of aggregate properties. The ingredients used in this researchare crushed aggregate (01), pumice and red ash in Addis Ababa, Ethiopia.

In order to minimize the cost of form work for ribbed slab construction HCB should be used. The primary use of structural lightweight concrete is to reduce the dead load of concrete structure (Mikayes A,1970).Since building slab cover more percentage of cost consuming, considering the above cases HCB directly affect the over a building slab cost . Contractors and small enterprise can chose from the above aggregate for production of HCB according to strengths and cost, help them to decade to chose appropriate aggregate for their work.

Now days on of slab system build in Ethiopia is ribbed slab system .the quality of construction has been issued by researches and medias. One o to control the quality of construction is used appropriate proportion of ingredient ,understand the property of aggregate for the production of HCB and used right class of HCB for used in ribbed slab.

1.3. Objective

1.3.1. General objective

- This study was to conduct on properties of aggregates used for production of ribbed slab HCB in Ethiopia

1.3.2. Specific objective

- To identify the physical property of aggregates and compare the result with different standards
- To find out each different aggregates property effect on production of ribbed slab HCB compressive strength, density of the block and dry shrinkage and compare the result with ES
- To make cost comparison of those aggregate to produce HCB

1.4. Research Questions

- What are the physical propertiesof those aggregate according to standards?
- What are the potential effects of using different aggregate properties on the Compressive Strength,density of the block and dry shrinkage of production of HCB according to standards?
- How much is cost different between those aggregate for production of HCB?

1.5. Significant of the study

This study is to compare the compressive strength of HCB for ribbed slab using crush, pumice, red ash and combined of those three aggregates. It will provide helpful information to various stakeholders.The Administration of different Ethiopian cities will benefit from the study as a source of information and foundation for the construction industry that can help to improve of the materials regarding to standards and specifications. And also different Ethiopia cities will product HCB, chose the material from around city to minimize cost of transport of marital.

Owners, contractors and consultants will benefit from the study as a source of information for building construction projects.It provide lessons that will help the concerned body can come up with appropriate production of HCB for ribbed slab measures to address problems resulting from using crushed, pumice and red ash aggregate on the strength of concrete.Other researchers will use the findings as a reference for further research on compressive strength of HCB for ribbed slab.Small enterprise will benefit from the study as a source of information for production of HCB. This study will help students to understand the value HCB on ribbed slab and using as a reference.

1.6. Scope and limitation of Study

This study has limited to use aggregate classification based on their density: crush, pumice and red ash for the production of HCB to ribbed slab. The test that has been conducted are compressive strength, dry shrinkage and density of the block.Even if other parameters affects the engineering property of HCB like: chemical property, sound insulation and effects of quality of water, different kinds of cementand so on, the research studied on only at pre mentioned ingredients and tests.

CHAPTER TWO

LITERATURE REVIEW

2.1. General

Concrete is a composite man-made material is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as lime or cement, well graded fine and coarse aggregates, water and admixtures (to produce concrete with special properties). The simple reason for its extensive use in the construction of almost all civil engineering works is that the properties can be controlled within a wide range by using appropriate ingredients and by special mechanical, physical and chemical processing techniques (Duggal S, 2008).

The process of selecting a floor system can be complex, covering architectural, structural and construction considerations and generally will involve several iterations or progressive refinements until the final choice is made and the detailed design can be undertaken (CCAA, 2003)

2.1.1. Slab type

Slabs are classified based on many aspectsBased of shape: Square, rectangular, circular and polygonal in shape. Based on type of support: Slab supported on walls, Slab supported on beams, Slab Supported on columns (Flat slabs). Based on support or boundary condition: - Simply supported, Cantilever slab, Overhanging slab, Fixedor Continues slab. Based on use: - Roof slab, Floor slab, Foundation slab, Water tank slab. Basis of cross section or sectional configuration: Ribbed slab or Grid slab, Solid slab,Filler slab, folded plate.Basis of spanning directions:One-way slab - Spanning in one direction and two-way slab - Spanning in two directions.In general, slabs are classified as being one way or two ways. Slabs that primarily deflect in onedirection are referred to as one-way slabswhen slabs are supported by columns arranged generally in rows so that the slabs can deflect in two directions, they are usually referred to as two-way slabs. Two-way slabs can be strengthened by the addition of beams between the columns, by thickening the slabs around the columns (drop panels), and by flaring the columns under the slabs (column capitals) (James K, 2014).

I. Solid Slabs

Solid precast prestressed floor slabs are typicallywet-cast on long-line beds in unit moulds or byhollowcore equipment using slipform or extrusionmethods. The hollowcore equipment will set the widthdimension, usually at 1200 mm. It is also possible tocast them on separate casting beds. A convenientmodule to suit the building layout may be selectedwhen using unit moulds. The cross-section has similarshear key details to hollowcore planks. Thickness isusually 150, 200 and 250 mm. Units over 250 mmdeep are likely to be too heavy for normal buildingpurposes. Slabs are chosen where:the loading results in high shear or there areheavy point loads; when the environment is aggressive and high cover or special concrete is required (CCAA, 2003).

The features of solid plate floors are easy to build, since lightening items are removed, either filler blocks, blocks and caissons recoverable. In the absence of nerves, forming operations, formwork, rebar, and concrete vibrated and, in general, the execution controls are less expensive and can be reduced execution times.The existence of less contact surface with the environment, as well as the elimination of reduced thickness ,greatly reduces the risks of attack on the durability of the slab.The existence of a flat bottom formwork and complete work provides a comfortableplatform, which together with the absence of manipulation of parts that can break or fallas arches or beams, reduces the risk of accident (Soraya S ,2011).

II. Flat Slab

For heavy industrial loads, the flat slabsystem may be used.Here, the shear transfer to the column is accomplished by thickening the slab near the columnwith drop panelsor by flaring the top of the column to form a column capital. It used for loads in excess of 100 psf and for spans of20 to 30 ft. Capitals of the types are less common today than they werein the first half of the Twentieth Century, due to the cost of forming them. Slab systemsmay incorporate beams between some or all of the columns. If the resulting panels areroughly square, the structure is referred to as a two-way slab with beams(James K ,2012).

A flat slab is a one-way or two-way system with thickenings in the slab at the columns and load bearing walls called 'drop panels'. Drop panels act as T-beams over the supports. They increase the shear capacity and the stiffness of the floor system under vertical loads, thus increasing the economical span range. The main advantage of flat slab is No beams, simplifying under-floor services outside the drops and usually does not require shear reinforcement at the columns. The principal features of a flat slab floor are a flat soffit, simple formwork and easy construction. Disadvantages of flat slab isthe size of the slab isMedium spans .it is not suitable for supporting brittle (masonry) partitions and also Drop panels may interfere with larger mechanical ducting Vertical penetrations need to avoid area around columns. For reinforced flat slabs, deflection at the middle strip may be critical(CCAA, 2003).

III. Ribbed (Waffle) Slab

Ribbed floors consisting of equally spaced ribs are usually supported directly by columns. They are either one-way spanning systems known as ribbed slab or a two-way ribbed system known as a waffle slab. This form of construction is not very common because of the formwork costs and the low fire rating. Ribbed slabs are suitable for medium to heavy loads, can span reasonable distances are very stiff and particularly suitable where the soffit is exposed (CCAA, 2003).

IV. Flat Plate

Flat plates,are solid concrete slabs of uniform depths that transfer loadsdirectly to the supporting columns without the aid of beams or capitals or drop panels. Flatplates can be constructed quickly because of their simple formwork and reinforcing bar arrangements.They need the smallest overall story heights to provide specified headroom requirements,and they give the most flexibility in the arrangement of columns and partitions. They also providelittle obstruction to light and have high fire resistance because there are few sharp corners. Flat plates are probably the most commonly usedslab system today for multistory reinforced concrete hotels, motels, apartment houses, hospitals,and dormitories.Flat plates present a possible problem in transferring the shear at the perimeter of thecolumns. In other words, there is a danger that the columns may punch through the slabs.As a result, it is frequently necessary to increase column sizes or slab thicknesses or to useshear heads. Shearheads consist of steel I or channel shapes placed in the slab over the columns. Although such procedures may seem expensive,the simple formwork required for flat plates will usually result in such economical constructionthat the extra costs required for shearheads are more than canceled. For heavy industrial loadsor long spans, however, some other type of floor system may be required (James K, 2014)

Advantages of Flat Plate areSimple formwork and suitable for direct fix orsprayed ceiling. No beamssimplifying under-floor services and minimum structural depth and reduced floor-tofloorheight.On the other hand its disadvantagesare medium spansLimited lateral load capacity as part of a momentframe may need shear heads or shear reinforcement atthe columns or larger columns for shear. Long-term deflection may be controlling factor,maynot be suitable for supporting brittle(masonry) partitionsand may not be suitable for heavy loads (CCAA2003).

2.2. Ribbed (Waffle)Slab

Waffle slabs have the shape of a set of crossing joists with a thin plate on the upper side.The meaning of this system is to increase the effective depth keeping a relatively low self-weight of the structure. Such slabs can be designed to work either as flat slab or two wayslabs and are applied when long span, up to 10 Meter are needed.Waffle slab floors are commonly used when buildings are subjected to heavy imposedloading. They are very efficient in the use of materials and provide very economical longspans. But the additional complexity of formwork can often slow the construction. For largespans, the thickness required to transmit the vertical loads to the column exceeds thethickness required for bending. As a result the concrete at the middle of the panel is notefficiently used(Mohammed A, 2006).

The Features of waffle slab it is belongs to the family of reinforced concrete slabs, no uniform, lightweight and reinforced in two orthogonal directions forming a ribbed plate. In the reticular and about the pillars of the blocks is dispensed with lightening and the plate becomes solid ribs disappearing as such. This defines the abacus, which is the area of a plate around a support or capital that is highlighted, or if it is a lightweight plate is solid with or without shoulder. Solid plates may not exist, and if present, may be accompanied by capital. And lightened plates (grid), their existence is mandatory and may be accompanied or not of capital. To resist the punching head is usually widen the pillar is the capital. The structure thus formed admits that bends can be broken down and analyzed according to two e-armed. Form with supporting a structural assembly capable of withstanding the vertical spread and timely actions very well, and the horizontal reasonably well but in a much smaller extent than the first (Soraya S,2011).

For longer spans, the thickness required for the shear transfer of vertical loads to the columns exceeds that required for flexural strength. As a result, the concrete at the middle of the panel is not used efficiently. To lighten the slab, reduce the slab moments, and savematerial, the slab at midspan can be replaced by intersecting ribs. Note that, near the columns, the full depth is retained for shear transfer of loads from the slab to the columns (James k, 2012).

Slab depths typically vary from 75 to 125 mm and rib widths from 125 to 200 mm. Rib spacing of 600 to1500 mm can be used. The overall depth of the floor typically varies from 300 to 600 mm with overall spans of up to 15 m if reinforced, longer if post-tensioned. The use of ribs to the soffit of the slab reduces the quantity of concrete and reinforcement and also the weight of the floor. (CCAA, 2003).

2.3.1 History and Development of ribbed slab

The use of the floor began to be necessary with the first urban settlements, to save and fill in thegaps that the man needed to live. In the city of Iraq around 2000 B.C, there were already some two-story houses, as at Thebes (Egypt) 1500 B.C. The more robust method used was to simply supported beams and vaults on load-bearing walls, which will be later replaced by reinforced and pre stressed concrete flat slabs shaped. Since Roman times to the twentieth century vernacular architecture was characterized by basically using load-bearing walls and slabs of wood, except for some unique construction met with vaulted stone slabs or bricks (Soraya S, 2011).

Already in the nineteenth century, in parallel with the development of steel structures, reinforcedconcrete was born. In the U.S., development of reinforced concrete catapulted after the construction of the PacificCoast Borax stores. Floors were constructed of solid slabs supported on bearing walls, steel beams andthen concrete beams, which were not based on any structural analysis, simply load tests. No one knewhow to calculate the slabs or that standards applied to assemble them (Soraya S ,2011).

Looking to the future expects the ultimate evolution of flat slabs due to the economic and functional benefits they provide. Charged beams and pre stressed concrete and structural steel will maintain its field of application in special buildings, industrial buildings and commercial buildings, where lights and make loads impractical flat slabs .The pre stressed hollow core slab is prime basic solutions where speed and strength capacity. The slabs of concrete decking is not expected to have a more than occasional because of the cost and sensitivity to fire, although some types are currently seeking to compete with concrete floors(Matthew, P.W 1990).

2.3.2 Ribbed slab in Ethiopia

Ribbed slab are in-situ concrete ribs with hollow blocks or voids. These types of structural plate systems can minimize formwork complexity. Ribbed slab floors are very adaptable for accommodating a range of service openings. This type of ribbed slab constructions is frequently built in Addis Ababa and other regions(Mohammed A, 2006).

Figure 2.1:Formwork for ribbed slabFigure 2.2:Ribbed slab under construction

2.3.3 Classification of ribbed slab

In general, ribbed slab structural systems can categorize :-

1) **Structural topping**: contributes to structural strength.The clear distance between ribs should not be more than 500mm. The width ofthe rib will be determined by consideration of cover, bar spacing and firerequirements. But the depth of the rib excluding the topping should not exceedfour times the width. If the blocks are suitably manufactured and have adequatestrength they can be considered to contribute to the strength of the slab in the design calculations, but in many designs no such allowance is made. Thesepermanent blocks which are capable of contributing to the structural strength ifit can be jointed with cement -sand mortar. During construction the hollow tilesshould be well soaked in water prior to placing the concrete,

otherwise shrinkageracking of the top concrete flange is liable to occur. This probably developsstrength for topping.

2) **Non-structural topping**: where topping does not contribute to the structuralstrength. In addition to this, the slabs can be divided as slabs with permanentblocks and those without permanent blocks for the purpose of thickness oftopping.In this case the spacing of the ribs can be increased above 500mm clear but thecenter of the ribs must not exceed 1500 mm. The depth of the rib should notexceed four times its width. The minimum thickness of topping should be thegreater of 40 mm or one tenth of the clear distance between the ribs.

2.3.4 Ribbed slab with HCB

Ribbed slabs are in-situ concrete ribs with hollow blocks or voids. These types of structuralplate systems can minimize formwork complexity by using standard modular and reusable formwork. When panels are used, the ribs should be positioned away from thecolumn lines. Ribbed slab floors are very adaptable for accommodating a range of serviceopenings. This type of ribbed slab constructions is frequently built in Addis Ababa andother regions. According to EBCS, ribs shall not be less than 70 mm in width and shallhave a depth, excluding any topping of not more than 4 times the minimum width of ribs.The rib spacing shall not exceed 1.0m. If the rib spacing exceeds 1.0m, the topping shallbe designed as slab resting on the ribs considering load concentration, if any. Thethickness of topping shall not be less than 40mm, nor less than 10/1of the clear distancebetween the ribs. If the span of the ribbed slab exceeds 6.0m, transverse ribs shall beprovided. When these ribs are provided, the center to center distance shall not exceed 20 times the overall depth of the ribbed slab. The transverse ribs shall be designed for atleast half of the value of maximum moments and shear force in the longitudinal ribs(Mohammed A, 2006).Theconcrete filled in situ to fill and the upper slab (layer compression) which has the mission to transmit the loads to the joists.Reinforcement:Active and passive reinforcements (rebar rods) and Welded steel mesh that are placed on top of the slab, embedded in the compression layer and serves as a distribution of loads and prevent shrinkage of the concrete.The tie-beams, which can be:Resistant or autoresistant’s (pre-stressed beams) and Semi-resistant’s (pre-stressed beams).


Figure 2.3: Pre-stressed tie beamFigure 2.4: Reinforced tie beam

filled block are based on: it's Lightening the weight of the slab serving as permanent formwork to the concrete slab above, developing a cross-bracing the joists, encouraging the thermal insulation of the floors acting as air chambers, serving as a support element for the lower covering and they are made of ceramic, lightweight concrete or Styrofoam (Soraya S,2011).

2.3. Concrete Production

Concrete is a composite material composed of coarse granular material (the aggregate or filler) embedded in hard matrix of material (the cement of binder) that fills the space between the aggregate particles and glue them together (Sydney M, 2003). In concrete the binder or matrix is a combinationof cement and water; it is commonly called the cement paste. Aggregates are essentially fillermaterials that can be separated into fine and coarse aggregates. In addition to aggregates andbinders, there is another material called additive which may be used in concretes to improvecertain of its properties (AbebeD, 2005).

Light weight concrete (LWC)

Conventional cement concrete is a heavy building material. For structures such as multi storeybuildings it is desirable to reduce the dead loads. Light weight concrete (LWC) is most suitablefor such construction works. Lightweight aggregate concrete is particularly suitable for usewhere low density, good thermal insulation or fire protection are required but not all of theavailable aggregate are equally suitable for any particular application. It is best produced by entraining air in the cement concrete and can be obtained by anyone of the following methods:Due to light weight and high strength to mass ratio, the cellular products are quiteeconomical.

The basic economy of LWC can be demonstrated by the savings achieved in associated reinforcement requirement. LWC has superior resistance of shear elements to earthquake loadingsince seismic forces are largely a direct function of deal weight of a structure, is also one amongthe other advantages of LWC. Due to lower handling transportation, the construction cost, thelight weight concrete is ideally suited for the production of precast concrete elements andprefabricated elements.

Advantage of LWC areLow density cellular concrete is used for precast floor and roofing units, as load bearing walls using cellular concrete blocks and As insulation cladding to exterior walls of structures (Duggal S ,2008).

High strength concrete (HSC)

Most cements used to produce HSC have finenessin the range of 300–400 m2/kg with an exception of high early strength cement for whichfineness should be at least 450 m2/kg. For HSC a smaller maximum size of coarse aggregateleads to higher strength. Fine aggregate should have a F.M >3.Because of the high density of aggregate particles, segregation of fresh concrete is one of theprincipal concerns in mix proportioning. From the standpoints of high unit weight and lesstendency for segregation, it is desirable that both fine and coarse aggregates be produced fromhigh-density rocks (Duggal K,2008).

2.4 The production of Ribbed slab Hollow Concrete Blocks (HCB)

2.4.1 Classification of HCB

Indian standard recommended classes of hollow concrete blocks as A, B, C and D but class.

Class A used for load bearing wall construction above or below ground level in damp proof course, in exterior walls that may or may not be treated with weather- protective coating and for interior walls and density of Class A blocks must conform between the range of 900 – 1200 kg/m3 on the other hand Indian standard IS: 2185 (Part I) – 1979 recommended minimum density 1500 kg/m3.

Class B and C are used for load bearing wall construction above ground level in damp proof course in exterior walls that are treated with suitable weather- protective coating and their density should be between 900 – 1200 kg/m3 on the other hand Indian standard IS: 2185 (Part I) – 1979 recommended minimum density within the range of 1000-1500 kg/m3 but class C is recommended for non-load bearing wall.

Class 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/m3

2.4.2Aggregates

Aggregates, i.e. Sand, Gravel, and Red Ash: should be clean, stored separately close to the mixing plant. All aggregates used for production have to be approved by an independent concrete laboratory(GZT, 2008).

Aggregates are the materials basically used as filler with binding material in the production ofmortar and concrete. They are derived from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag. Aggregates form the body of the concrete, reduce the shrinkage and effect economy. They occupy 70-80 per cent of the volume and have considerable influence on the properties of the concrete (Duggal K, 2008).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 (Marsh B, 1997).

There are three general types or groups of aggregatedepending on their source:

- *Primary*: which are specifically produced for use in concrete.
- *secondary*: which are by-products of other industrial processes not previously used in construction In principle, any by-product from other processes or waste material that is inert and has properties that conform to the requirements for primary aggregates strength and particle size ,are suitable for use in concrete.
- *Recycled*: from previously used construction materials e.g. from demolition. (Peter D, 2010)

A. Classification of aggregate

I. Based on unit weight

Aggregates are classified as normal-weight, heavy-weight and light-weight aggregate dependingon weight and specific gravity as given in table 2.1

Table 2.1: Weight of aggregate

Aggregate	Sp.gr	Unit weight KN/m³	Bulk density Kg/m³	Example
Normal weight	2.5-2.7	23-26	1520-1680	Sand ,gravel, limestone
Heavy weight	2.8-2.9	25-29	>2080	Magnetite ,scrap iron
Light weight		12	<1120	Clay, pumice red ash

II. On the basis of geological origin

a) **Natural Aggregate;-**For the most part, concrete aggregates are comprised of sand, gravel, and crushed rock derived from natural sources, and are therefore referred to as natural mineralaggregates.

b) **Synthetic aggregates**.Thermally processed materials such as expanded clay and shale, which are used for making lightweight concrete, are called synthetic aggregates Municipal wastes and recycled concrete from demolished buildings and pavements have also been investigated for use as aggregates (Metha P,2001)

III. On the basis of size

a) **Coarse Aggregate**;-Aggregate retained on 4.75 mm sieve are identified as coarse. They are obtained by natural disintegration or by artificial crushing of rocks. The maximum size of aggregate can be 80 mm. The size is governed by the thickness of section, spacing of reinforcement, clear cover, mixing, handling and placing methods. For economy the maximum size should be as large as possible but not more than one-fourth of the minimum thickness of the member.

b) **All in Aggregate**; -Naturally available aggregates of different fractions of fine and coarse sizes are known as all-in-aggregate. The deficiency of any particular fraction can be corrected for use in the mix but they are not recommended for quality concrete.

c) **Graded Aggregate**;-Aggregate most of which passes through a particular size of sieve are known as graded aggregate. For example, a graded aggregate of nominal size 20 mm means an aggregate most of which passes IS sieve 20 mm.

d) **Fine Aggregate**;-Aggregate passing through 4.75 mm sieve are defined as fine. They may be natural sand—deposited by rivers, crushed stone sand—obtained by crushing stones and crushed gravel sand. The smallest size of fine aggregate (sand) is 0.06 mm. depending upon the particle size, fine aggregates are described as fine, medium and coarse sands.

IV. On the basis of shape

a) **Rounded Aggregate**:-These are generally obtained from river or seashore and produceminimum voids (about 32 per cent) in the concrete. They have minimum ratio of surface area to the volume, and the cement paste required is minimum. Poor interlocking bond makes it unsuitable for high strength concrete and pavements.

b) **Irregular Aggregate:-**They have voids about 36 per cent and require more cement paste as compared to rounded aggregate. Because of irregularity in shape they develop good bond and are suitable for making ordinary concrete.

c) **Angular Aggregate**: **-**They have sharp, angular and rough particles having maximum voids (about 40 per cent). Angular aggregate provide very good bond than the earlier two, are most suitable for high strength concrete and pavements; the requirement of cement paste is relatively more.

d) **Flaky Aggregate:-**These are sometimes wrongly called as elongated aggregate. However, bothof these influence the concrete properties adversely. The least lateral dimension of flaky aggregate (thickness) should be less than 0.6 times the mean dimension. Elongated aggregate are those aggregate whose length is 1.8 times its mean dimension.

Flaky aggregate generally orient in one plane with water and air voids underneath. They adversely affect durability and are restricted to maximum of 15 per cent.

B .**Properties of Aggregate**

The physical properties like specific gravity, porosity, thermal behavior, and the chemical properties of an aggregate are attributed to the parent material. The shape, size and surface texture which are essential for concrete workability and bond characteristics between the aggregate and cement paste are, however, attributes of the mode of production. It is, therefore, essential to understand the mechanical, physical and chemical properties of aggregate and its modes of production in an effort to produce the required quality of concrete at a minimum price (Abebe D,2004).

I. Mechanical property

The behavior of solids is of particularinterest to construction engineers for the obviousreason that these are used to produce load-bearingstructures (Peter D, 2010). Generally, flexural strength is more affected than compressive strength. Rougher texture results in a greater adhesion or bond between theparticles and cement matrix. The required information about the aggregate particles has to be obtained from indirect tests, such as crushing strength of prepared rock samples, crushing value of bulk aggregate and performance of aggregate in concrete. The aggregate crushing value (ACV) test is prescribed by different standards and is a useful guide when dealing with aggregates of unknown performance(Abebe D, 2005).

A. **Bond**;-both the shapes and the surface texture of aggregate influence considerably the strength of concrete, especially so for high strength concretes; flexural strength is more affected than compressive strength. A rougher adhesion or bond between the particles and the cement matrix (Neville A, 2010).

B. **Strength**; -is a measure of the amount of stress required to fail a material. The working stress theory for concrete design considers concrete as mostly suitable forbearing compressive load (Metha P, 2001).The compressive strength of concrete cannot significantly exceed that of the major part of the aggregate contained there in, although it is not easy to determine the crushing strength of the aggregate itself. A few weak particles can certainly be tolerated; after all, air voids can be viewed as aggregate particles of zero strength (Neville A,2010).

C. **Elasticity**;-is the ability of a material to restore its initial form and dimensions after the load isremoved. Within the limits of elasticity of solid bodies, the deformation is proportional to the stress. Ratio of unit stress to unit deformation is termed as modulus of elasticity. A large value ofit represents a material with very small deformation (Duggal S,2008).

D. **Toughness**;- can be defined as the resistance of aggregate to failure by impact, and it is usual to determine the aggregate impact value of bulk aggregate (Neville A,2010) .The term toughness issued as a measure of this energy. The contrast between toughness andstrength should be noted; the former is a measure of energy, whereas the latter is a measure of the stress required to fracture the material (Metha P,2001).

E. **Hardness**;-Hardness, or resistance to wear, is an important property of concrete used in roads and in floor surfaces Subjected to heavy traffic (Neville A, 2010).

II. Physical properties

The physical properties of aggregates include specific gravity, porosity, absorption capacity, moisture content, unsoundness due to volume changes and thermal properties and need a close scrutiny(Abebe D, 2005).

1. **Specific gravity**;-According to ASTM C 127-04, specific gravity is defined as the ratio of the density of material to the density of a material to the density of distilled water at a started temperature: hence, specific gravity is dimensionless. The absolute specific gravity and the particle density refer to the volume of the solid material excluding all pores(Neville A,2010).It is used in certain computations for mixture proportioning and control, such as the volume occupied by the aggregate in the absolute volume method of mix design(Steven H,2003).

   For the purpose of proportioning concrete mixtures it is not necessary to determine the true specific gravity of an aggregate. Natural aggregates are porous; porosity values up to 2 percent are common for intrusive igneous rocks, up to 5 percent for dense sedimentary rocks, and 10 to 40 percent for very porous sandstones and limestone. For the purpose of mix proportioning, it is desired to know the space occupied by the aggregate particles, inclusive of the pores existing within the particles. Therefore determination of the apparent specific gravity, which is defined as the density of the material including the internal pores, is sufficient. The apparent specific gravity for many commonly used rocks ranges between 2.6 and 2.7; typical values for granite, sandstone, and dense limestone are 2.69, 2.65, and 2.60, respectively (Metha P, 2001)

2. **Bulk density;** - The bulk density or unit weight of an aggregate is the mass or weight of the aggregate required to fill a container of a specified unit volume. The volume referred to here is that occupied by both aggregates and the voids between aggregate particles (Neville A, 2010).For mix proportioning, in addition to the apparent specific gravity, data are usually needed on bulk density, which is defined as the weight of the aggregate fragments that would fill a unit volume (Metha P, 2001).

3. **Porosity and absorption;-**The porosity, permeability and absorption of aggregate influence the bond between it and the cement paste, the resistance of concrete to freezing and thawing. As well as chemical stability, resistance to abrasion andspecific gravity (Neville A, 2010).

4. **Moisture content;-**Since absorption represents the water contained in the aggregate in a saturated, surface-dry condition, we can define the moisture content as the water in excess of the saturated and surface-dry condition. Thus, the total water content of a moist aggregate is equal to the sum of absorption and moisture content (Neville A, 2010).

Aggregates can hold water in two ways: Absorbed within the aggregate porosity or held on theparticle surface as moisture content.Thus, depending on the relative humidity, recent weather conditions, and location within the aggregate stockpile, aggregate particles can have variable moisture content

i. ***Oven-dry (OD):***All moisture is removed by heating the aggregates in an oven at 105°C to constant weight.

ii. ***Air-dry (AD):***No surface moisture is present, but the pores may be partially full.

iii. ***Saturated surface dry (SSD***):All pores are full, but the surface is completely dry.

iv. ***Wet***: All pores are full and a water film is on the surface ofthese four states, only two (OD and SSD) correspond to well-defined moisture conditions;eitherone can be used as a reference point for calculating the moisture contents (EdwardG, 2008).

5. **Water permeability: -**is the capacity of a material to allow water to penetrate under pressure .Materials like glass, steel and bitumen are impervious (S.K. Duggal, 2008).
6. **Weathering resistance; -**isthe ability of a material to endure alternate wet and dry conditionsfor a long period without considerable deformation and loss of mechanical strength (Duggal K, 2008).

C. Aggregate characteristics and their significance

Aggregate properties are discussed in two parts on the basis of properties affecting (1) mix proportions and (2) the behavior of fresh and hardened concrete. Due to a considerable overlap between the two, it is more appropriate to divide the properties into the following groups, which are based on microstructure and processing factors

1. Characteristics dependent on porosity: density, moisture absorption, strength, hardness, elastic modulus, and soundness

2. Characteristics dependent on prior exposure and processing factors: particle size, shape, and texture

3. Characteristics dependent on chemical and mineralogical composition: strength, hardness, elastic modulus, and deleterious substances present (Metha P, 2001).

D. Effects of Using Different Type of Aggregates on Concrete Strength

Since up to approximately 80 percent of the total volume of concrete consists of aggregate, aggregate characteristics significantly affect the performance of fresh and hardened concrete and have an impact on the cost effectiveness of concrete (Hudson B, 1999). Aggregate characteristics of shape, texture, and grading influence workability, finish-ability, bleeding, pump-ability, and segregation of fresh concrete and affect strength, stiffness, shrinkage, creep, density, permeability, and durability of hardened concrete. Construction and durability problems have been reported due to poor mixture proportioning and variation on grading(Lafrenz J, 1997).

Maximum size, Specific gravity or relative density, Soundness and Toughness.An excess of poorly shaped particles could reduce the strength of concrete through the increase of water demand. In addition,flat particles can be oriented in such a way that they could impair the strength and the durability of concrete (Pedro N, 2003).

The properties of aggregates and their processing and handling influence the properties of both plastic and hardened concrete. The effectiveness of processing, stockpiling, and aggregate quality control procedures will have an effect on batch-to-batch and day-to-day variation in the properties of concrete ASTM,So that to proportion suitable concrete mixes, certain properties of aggregate which influence the paste requirement of fresh concrete such as shape and texture, size graduation, moisture content, specific gravity and bulk unit weight must be known(Steven H, 2003).

Aggregates shall be stockpiled on clear hard surface to prevent contamination by other material and to avoid segregation. Different grades of aggregate shall be stocked independently, sufficient distance being maintained, to avoid mixing during unloading and use (BACTON).

E. Lightweight Aggregates

Natural lightweight aggregates include pumice, scoria, and tuff; however, most lightweight aggregates are synthetically produced. The most common such lightweight aggregates are made from expanded clay, shale, or slate. The raw material is both crushed to the desired size or ground and then pelletized; it is then heated to 1000 to 1200°C (Edward G,2008).

i. Pumice

Pumice is a very light, porous igneous rock that is formed during volcanic eruptions. It isan excessively cellular, glassy lava, usually rhyolite or dacite in composition. It is usuallywhite-gray to yellow in color, but may be red, brown or sometimes black according to themineral oxides or impurities it contains. Pumice is bubble rich and therefore has very lowdensity. Due to this low density, pumice is very light and can even float in water. It has abulk density of 500-900kg/m3. The varieties of pumice, which are not too weakstructurally, make a satisfactory concrete with a density of 700 to 1400kg/m^3 and withgood insulating characteristics, but high absorption and high shrinkage Red ash.

ii. Scoria (red ash)

Scoria is a volcanic cinder which generally has a rough surface and high porous nature, with its pores chiefly in the form of vesicles instead of the more tube like, interconnected pores of the pumice. Scoria varies in color often within the same cone and may be black, red, gray or brown in color. The black color is mostly due to its high iron content while the red color is caused by oxidation of iron in the scoria, which might have happened because of rainfall during the eruption. Scoria aggregate is found extensively in Ethiopia especially in the Great Rift Valley, which crosses the North-Eastern part of the country. It is mainly used as a base coarse material in road construction and as an aggregate in the manufacturing of masonry blocks (Abebe D. 2005).

F. Crush aggregate

For the most part, concrete aggregates are comprised of sand, gravel, and crushed rock derived from natural sources, and is therefore referred to as natural mineralaggregates.

2.4.3. cement

Well over 95% of the cement used in concrete throughout the world is Portland cementin its various forms.It is by no means a simplematerial, and its complexities have an impact onthe properties and behavior of concrete from mixingright through to the end of its life(Peter D,2010).Portland cement (OPC) shall be used as a binder material for the motor mix.Cement should be stored in a dry place, moisture free.(GZT,2008).IS:10262 has classified the OPC grade-wise from A to F based on 28 day compressive strength as follows:-

Table 2.2: classified the OPC

Category	Strength (MPa)
A	32.5 – 37.5
B	37.5 – 42.5
C	42.5 – 47.5
D	47.5 – 52.5
E	52.5 – 57.5
F	57.5 – 62.5

Cement shall be stored in bags or containers in an enclosed, ventilated space that would protect it from deterioration. Cement shall always be stored off the ground. The off the ground formation method shall be subject to approval by the Engineer. Different types and consignments of cement shall be stored distinctly separated and with markings showing the type and date of consignment(BACTCON).

2.4.4. Machinery & Equipment

Must be in perfect condition and sufficient in numbers to suit the daily production needs. Regularcleaning, maintenance of all machinery & equipment is essential to keep the agreed quality standards An adequate stock of spare parts for all machinery has to be kept, in order to safe guard production. (GZT, 2008).

2.4.4. Production

Before production can commence, all materials have to be approved by an official concrete lab. The mixing and batching will be strictly done on the mix ratio provided by the official concrete lab. The mixing (best results are with a compulsory mixer) should be done thoroughly, until a uniform consistence of the mortar is achieved. The ready mortar mix is poured into the vibrating mould of the block making machine. Duration of compaction depends on the type of machine and vibrator used, but is approx. 3 seconds after compaction the unset (green) HCB is dropped on the Floor for curing(GZT,2008).

CHAPTER THREE

MATERIAL AND METHODOLOGY

Research methodology involves the systematic procedures by which the researcher starts from the initial identification of the problem to its conclusions. Thus, research methodology consists of all general and specific activities of research, and it seems that research design and methodology have the same meaning i.e. mapping strategy of research. The methodology consists of procedures and techniques for conducting a study. Itinvolves such general activities as identifying problems, the variables that plan to extract from the data and the operational definitions of the variables. It also include the research design, study population, sample size and selection, sampling techniques and procedure, data collection methods, data quality control (validity and reliability), procedure of data collection, data analysis, Ethical consideration and Plan for dissemination.

3.1. Study Design

This research was conducted in EiABC laboratory, Addis Ababa.The study was conducted from June 2017 up to November 2017. The studywas conducted in terms of quantitative methods. The sampled aggregate typewasexperimented in the laboratory then the result of the study compared with standard specifications and reviewed literatures therefore, conclusion and recommendation are drawn on based on the results.

The study designs used for this research were comparative and lab based study. The laboratory test was conducted compressive strength of HCB for age of 7, 14 and 28 days. HCB produced by pumice, red ash crushed and combination of those three aggregate. The tests conducted were compressive strength, dry shrinkage of block and density of block compares the results of each casted block with ES.

3.2. StudyProcedure

The study procedure carried out by pursuing international specifications and laboratory procedures such as ES, ACI, ASTM and BS reviewed. Literatures which were related with engineering properties of Ingredients for Production of HCB use for ribbed slab (for Non load bearing).Making materials such as cement, sand, aggregate (pumice, red ash crushed 01) and waterand also articles, journals and reference books were essential to obtain and analyze the data throughout the study. Aggregate used in this study has been examined by testing in the laboratory before production can commence.

3.3. Samplesize and sampling procedure

The procedure was accomplished according to ASTM C 702 in the laboratory to a convenient size for conducting a number of tests to describe the material and measure its quality in a manner that the smaller test sample portion is most likely to be a representation of the larger sample and thus of the total supply. The size of samples having free moisture on the particle surfaces by quartering method. Quarteringmethod isDivide the sample as described and beneath the blanket is even amount. All aggregate test including in this study follow this two steps quartering sample dividing method and measuring samples.

.

Figure 3.1;Quartering method and measuring samples

3.4. StudyVariables

Dependent variables: - Effect of aggregate density on properties of HCB

- Compressive strength

Independent variable: - Aggregate types

- Moisture content of aggregate

-Weightof aggregate

3.5. Data Collection Process

The aggregates had been sampled and subjected to various tests so as to understand their properties towards engineering applications. Sampled aggregate for the laboratory test samples are taken from the site around kara koria, Addis Ababa. Later the sampled subjected to various tests to determine their physical and mechanical engineering property in the laboratory.

3.6.Aggregate Testing

The blocks are made out of mixture of cement, sand and aggregate. It saves cement in construction work, bringing down cost of construction considerably. For dense blocks aggregates should be well graded to ensure that the small particles occupy the spaces between the larger ones and leave a minimum of voids Suitable aggregates are usually obtained from natural sources or from industrial by-processes all aggregates, whether fine or coarse, must be free from silt, clay, dust, organic matter, salts or other chemical impurities. That could interfere with the bond between cement and aggregate or cause deleterious chemical reactions. When HCB required high strength,as much large sizeof aggregate as possible with a proper range of gradation should be included in the mix.

According to ASTM C 125,aggregate of low density used to produce lightweight concrete including: pumice, scoria, volcanic cinders, tuff andproducts of coal or coke combustion. Crushstone isthe product resulting from the artificial crushing of rocks or large cobblestones, substantially all faces of which have resulted from the crushing operation.

I. Sieve analysis of aggregate

Sieve analysis used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. According to ASTM C 136, the results usedto determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products. ASTM C 125, describe fine aggregate*:* aggregate passing the 3⁄8-in. (9.5-mm) sieve.

The sample of aggregate shall be air-dried to substantially constant. It is not necessary to dry aggregate by oven for the sieve analysis test.

Figure 3.2:sieve shaker

Table 3.1:Grading requirements for aggregate ES 81:2001 and ASTM C33 -C78

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

.

II. Fineness modulus

Sieve analysis is done in order to determine the fineness modulus of aggregate and the relative amount of various sizes of particles presents in the aggregate using sieve of square or round opening starting with the largest. The summarization of cumulative percentage of a sample of aggregate retained on specified series of sieves (excluding intermitted sieves) divided b 100 called fineness modulus.

$$\text{Fineness modulus} = \frac{\text{total of cumulative percentage of retained \%}}{100}$$

III. **Specificgravity and water absorption**

The ratio of mass of a volume of a material at a stated temperature to the mass of the same volume of distilled water at a stated temperature. The specific gravity and porosity of aggregates greatly influence the strength and absorption of concrete.There are different types of specific gravity such as bulk specific gravity, apparent specific gravity and bulk saturated surface dry specific gravity. Bulk specific gravity refers to total volume of the solid including pores of the aggregates while apparent specific gravity refers to the volume of the solid includes the impermeable pores but not the capillary ones. Water absorption is known as the amount of moisture absorbed into the aggregates. Absolute specific gravity: define in ASTM E12(8) is the ratio of the mass of unit volume of material (without pores) to the mass of the same volume of gas-free distilled.

Figure 3.3**:** Specific gravity of coarse aggregate, process of Immerse the basket with the sample

a) Pycnometer of aggregate b) Aggregate drayed by oven

Figure 3.4:Specific gravity and water absorption of sand

Absorption values are used to calculate the change in the weight of an aggregate due to water absorbed in the pore spaces within the constituent particles, compared to the dry condition.

IV. Silt content

sand used for construction should be clean ,free from dust ,loam ,clay, vegetable matter and wind – blown(very fine sand) .Silt is unnecessary part of sand with a diameter less than 0.07 5mm .If there is too much silt the aggregate will have less adhesive property with cement resulting in weaker bond strength with a probability of porosity. Moreover, it decreases workability by absorbing water .According to the ES it is recommended to wash the sand or reject if the silt content exceeds a value 6%.

Figure 3.5:silt content of sand

V. Organic impurity

Substances such as organic matters, clay, shale, coal, iron pyrites, etc. which are weak, soft, fineor may have harmful physical or chemical effects on the aggregates are considered to be deleterious. They affect the properties of concrete in green as well as in hardened state and are undesirable. They may be classified as those interfering with the process of hydration, i.e. organic matters, coatings such as clay. Affecting the development of bond between aggregateand the cement paste, and, unsound particles which are weak or bring about chemical reactionbetween aggregate and cement paste. The surface coated impurities in aggregate can be removedby adequate washing. However, chemically-bonded stable coating which cannot be so removedmay increase shrinkage cracks. The salts present in the sea-shore sand should be washed outotherwise efflorescence is caused afterwards. Mica, if present in sand, reduces the strength ofconcrete.

Figure 3.6:impurity of sand

VI. Moisture content of aggregates

It is well known to engineering that water-cement ratio affects the workability and strength of concrete .A design water-cement ratio is usually specified based on the assumption that aggregate are inert (nether absorb nor given water to the mixture) but in most case aggregate from different sources do not comply with this i.e. wet aggregate give water to the mix and drier aggregate (those with low saturation level moisture content) take water from the mix affecting ,in both case ,the designed water-cement ratio and therefore workability and strength of the mix. In order to correct for this discrepancies, the moisture content of aggregate has be determined.

According to ASTM C 70 – 94 This test method is not widely used. However, it is a convenient procedure for field or plant determination of moisture content of fine aggregate. If specific gravity values are known and if drying facilities are not available. It can be used to adjust aggregate weights for moisture content and to determine surface moisture contribution to mixing water in Portland cement concrete.

a) Oven dry sample b) Weight of oven dry sample

Figure 3.7:Moisture content of aggregates

VII. Unit weight of aggregate

ASTM C 29/C 29M – 91, a state that Unit weight is the traditional terminology used to describe the property, which is weight per unit volume (more correctly, mass per unit volume or density. According to ASTM C 125,bulk density or unit weight: of aggregate, the mass of a unit volume of bulk aggregate material (the unit volume includes the volume of the individual particles and the volume of the voids between the particles).

Unit weight can defined as the weight of given volume of aggregate .It is thus a density measurement and also known as bulk density. But this alternative term is similar to bulk specific gravity, which is quite a different quantity and perhaps is not a good choice. Apparatus: Balance, tamping rod, measure (a cylindrical metal measure).

Figure 3.8:unit weight of aggregate

3.7.Cement

Ordinary Portland cement (OPC),Most common type used it isa hydraulic cement produced by pulverizing Portland-cement clinker, and usually containing calcium sulfate ASTM C 219. A mixture of finely divided hydraulic cementitious material, fine aggregate, and water in either the unhardened or hardened state; hydraulic mortar. Mortar cement is similar to masonry cement but must meet bond strength and air content criteria.

ASTM C 150 Standard Specification for Portland Cement, state that The cement shall be rejected if it fails to meet any of the requirements of this specification .At the option of the purchaser, retest, before using, cement remaining in bulk storage for more than 6 months or cement in bags in local storage in the custody of a vendor for more than 3 months after completion of tests and reject the cement if it fails to conform to any of the requirements of this specification.

3.8.Water

Water for concrete mixing and curing shall comply with the requirements of ASTM C94. Water shall be piped or otherwise stored in an enclosed container free from contamination (BACTON) British standard BS 3148 recommends surface water for concrete works by infiltration or impounding to allow suspended matter to settle if it is free from undesirable organic contents or an acceptable content of inorganic salts. According to Ethiopian Standard ES 2310:2005 water used for concretethe water used in the manufacture of concrete masonry units shall be free from matter harmful to concrete or reinforcement, or matter likely to cause efflorescence in the units.

3.9. After production of HCB for ribbed slab

1. Placing and Compaction

Immediately the block is made, it shall be released from the mold and removed with the pallet to a covered shed, to protect it against sun and strong winds. The blocks shall be stored in the shed until they are sufficiently hardened to permit handling without damage but in no case shall this period be less than 12 hoursIn the case of hand-operated machine, the mixture shall be placed into the mold in layers of about 50 to 75 mm and each layer thoroughly tamped with suitable tampers until the whole mold is filled up and struck off level with a trowel.

Concrete placement has an important effect on its quality in related to bond with previous placed concrete. During Placing of concrete in higher elevation or in tall forms, bleeding must be prevented specially for non-entrained concrete by placing more slowly and using stiffer consistency particularly in lower portion of the form. The delay should be short enough to allow the next layer of concrete to knit with the previous layer by vibration, thus preventing cold joints and honeycombing (Steven H, 2003).Deposition of concrete also very important, in order to place the concrete without segregation (asa result of damping in separate or individual piles, or at higher distance) and flow lines, seams,and planes of weakness or cold joints (that result from placing freshly mixed concrete on concretepast its initial set (Sydney M, 2003). In order to place the concrete in slab construction, p lacing should be started along the perimeter at one end of the work with each batch discharged against previously placed concrete.

Figure3: 9 Compacted and placing Ribbed HCB

2. **Curing**

ASTM 125 action taken to maintain moisture and temperature conditions in a freshly-placed cementitious mixture to allow hydraulic cement hydration pozzolanic reactions to occur so that the potential properties of the mixture may develop. Proper curing will improve durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing and deicers. It is important for water to be retained in concrete to prevent reduction of hydration due to evaporation. In addition to this, exposed concrete including exposed edges and joints, must be protected from losing water because it makes the concrete to shrink and surface cracking can result if these stress develop before the concrete has attained adequate tensile strength.The water used for curing and materials used for protection of concrete surface from losing ofwater such as coverings should be free from any substances that will cause stain or discoloring ofconcrete and water for pounding and immersion also, ambient temperature and relative humidityalso very important for curing concrete especially by fogging and Sprinkling of water. As ambient temperature above freezing and humidity is low sprinkling is very effective while continue spraying of fine fog are important to raise relative humidity.

3. **Drying**

After curing the blocks shall be dried under shade for a period of 4 weeks before being used on the work. They shall be stacked with voids horizontal to facilitate through passage of air. The blocks shall be allowed to complete their initial shrinkage before they are laid in a wall.

3.10.Test for Ribbed HCB

I. Compressive strength

The strength of hollow concrete is closely related to the specimen size and shape, method of poreformation, direction of loading, age, water content, water-cement ratio, degree of compaction, and cement content characteristic of its ingredients used, method of curing, size and number of holescreated. Both hollow structure of the air holes and mechanical condition of the pore shells have agreat influence on the compressive strength of hollow concrete block. The minimum compressive strength at 28 days being the average of six units, and the minimum Compressive strength at 28 days of individual units should be tested. Compressive strength of a concrete masonry unit shall be taken as the maximum load in Newton divided by the gross cross sectionalarea of the unit in square millimeters finally the results of the nearest 0.1 N/mm2, Separately for each unit and as the average for the six units will be recorded (Ethiopian standard (ES 596:2001); specification for concrete masonry units).

Table 3.2:Comprehensive strength of hollow concrete blocks at 28 days [ES 596:2001]

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

II. Dry shrinkage

The difference between the length of specimen which has been immersed in water and subsequently dried to constant length, all under specified conditions .It expressed as a percentage of the dry length of the specimen.The drying shrinkage of the units when unrestrained being the average of three units, shall be determined in the manner described and shall be as follows:

a) Load-bearing light-weight concrete masonry units, hollow (open or closed cavity) or solid

Grade A - 0’08 percent, max;and
Grade B - 0.09 percent, max

b) Non-load bearing light weight-O’09 percent, max concrete masonry units

ASTM C 129**,**standard specification for non-loadbearing concrete masonry units sate that ,at the time of delivery to the purchaser, the total linear drying shrinkage of units shall not exceed 0.065%Five percent of a shipment containing chips, not larger than 1 in. (25.4 mm) in any dimension, or cracks not wider than 0.02 in. (0.5 mm) and not longer than 25 % of the nominalheight of the unit is permitted.
ASTM C129,Total linear drying shrinkage shall be based on tests ofconcrete masonry units made with the same materials, concretemix design, manufacturing process, and curing method, conductedin accordance with Test Method ASTM C 426 not more than 24months prior to delivery.

III. Density of block

The density calculated by dividing the mass of a block by the overall volume, including holes or cavities and end recesses.For hollow concrete, low density is probably the most characteristic feature. This is due to the holes. In addition, it depend primary on the aggregate density and the proportions of aggregate because the particle density of individual grading fraction can differ considerably and thus willaffect the density of concrete. This property also influenced by the cement, water and air contents (ACI Committee 213, 2003).

The density of each block calculated as follows:

$$Density = \frac{mass\ of\ \ blocck\ \ in\ \ kg}{volume\ of\ \ specimen\ \ in\ \ cm^3 \times 10^6\, kg/m^3}$$

3.11.Mixing design

According to BACTON, design trial mix using the available materials to give the average minimum compressive strength as specified in the compressive strength requirements after casted and curried of 28 days.Blocks had uniform in texture, shape and size. With sharp arises and free from any cracks or defects. Blocks had produced under shed on a suitable smooth floor. Blocks wereremaining under shed and wet cured for a minimum of 7 days after casting.

A. Basic Considerations for mixdesign (ACI mix design)

- **Economy:-**The material costs are most important in determining the relative costs of different mixes. The labor and equipment costs, except for special concretes, are generally independent for the mix design. Since cement is more expensive than aggregate, it is clear that cement content should be minimized. This can be accomplished by:using the lowest slump that will permit handling,using a good ratio of coarse to fine aggregate and possible use of admixtures.
- **Workability:-**A good mix design must be capable of being placed and compacted, with minimal bleeding and segregation, and be finish able. Water requirements depend on the aggregate rather than the cement characteristics. Workability should be improved by redesigning the mortar faction rather than simply adding more water.
- **Strength and Durability: -** In general, the minimum compressive strength and a range of w/c ratios are specified for a given concrete mix. Possible requirements for resistance to freeze-thaw and chemical attack must be considered. Therefore, a balance or compromise must be made between strength and workability. A measure of the degree of consistency and extent of workability is the slump. In the slump test the plastic concrete specimen is formed into a conical metal mold as described in ASTM Standard C-143.

B. Mix Design Trial batch according to ACI 211.1

The proportion of ingredients shall be such as to produce a mixture, which will work readily into the corners and angles of the forms and around reinforcement without segregation of the material components. Where the proportion of ingredients given in the Concrete Class Section of the Specification is not applicable, trial batches shall be made and the mix from which the desired strength is established by testing shall be used for the works. The calculate mixture proportion should be checked by means of trial batches prepared and tested in accordance with ASTM C 192 .It should also be carefully observed for proper workability, freedom from segregation and finishing properties. Precise adjustments should be made in the proportions for subsequent batches in according with the APPENDEX A procedure.

First trial were made, the aim was to check only the quality of material. The dimension of block ware ignore in this first trial. Size of cube used in first trial $23 \times 11 \times 9$ in cm. The reason for first trial is the no available of machine for product ribbed HCB in EIABC Laboratory. To be economical, the first trial is mandatory, if the trial of quality of samples fall; it is essay to cast another cube. The material type, material proportion or percentage and curing method are the same with HCB that used for second trial. After first trial second trial was made to see aggregates are suitable for ribbed HCB related to dimension and holes. Since dimension and holes are the main future for HCB, it will affect the compressive strength of block.

Figure 3.10: measuring and mixing of sample for first trial and compressive strength of sample

Table: 3.3 First trials for compressive strength of HCB

Mix	Casted sample type	Age of 3 day trial casted cube, average of 3 unit of cube	
		Compressive strength in Mpa	Wight of casted in kg
1	Crushed	4.1	4.2
2	Red ash	3.7	3.8
3	Pumice	2.7	3.7
4	Combined of three aggregate	4.3	4.1

The first trial was indicate that according to BS the concrete has to get compressive strength at the age of 3 day is 40 %.According to ES for non-bearing block should gained minimize compressive strength 1.8 up to 2 Mpa at age of 28th day test. For this reason it is more than required and not economical so second mix design were made. By minimizing cement content from each mix of block, minimize the strength up required standard compressive strength.

Second trial of HCB ribbed slab. In this case the dimension of are consider. And satisfy 3rd day age of minimum compressive strength of HCB.

Table: 3.4 Second trial for compressive strength of HCB

Mix	Casted Cube type	Age of 3 day trial casted cube, average of 3 unit of cube		
		Compressive strength		Wight of casted in kg
		in mpa	In %	
1	Crushed	1.1	55	24
2	Red ash	0.9	45	20
3	Pumice	0.8	40	17
4	Combined of three aggregate	1.2	60	23

Figure :3.11 for second trial and compressive strength of sample

3.12.Cost of material

The costs of HCB in study martial and man power expanse, Note that the costs are determined by only the current prize of material used to conduct the research. As stetted in the limitation section on chapter one, because of time and moneythe cost of production beside Addis Ababa is not include in this research. cost of materials are listed on appendix E.

Table 3.5 Expense of material for production HCB

TYPE HCB	UNIT	QTY	unit rate	Amount
Crushed (01)	m^3	1.13	200	226
Red ash	m^3	0.8	63	50.4
Pumice	m^3	0.67	82	54.27

From above table it show that the price of aggregate used in this research are listed. From those aggregate types the low-priced was pumice, followed by red ash and at last crushed aggregate. To be economical the of cost, for the production of HCB for non-barring load for ribbed slab, pumice and red ash are more preferred than crushed aggregate.

B. **Man power**:used to product 96 Pisces of HCB with in half one dayor 4hrs

Table 3.6 Expense of man power for production HCB

Num Of Man Half Day	Manpower Expenses	Salary/Day	AMOUNT
4	DL(F)	80	40
2	DL (M)	100	50
1	Machine Operator	200	100
	TOTAL		**190**

CHAPTER FOUR

RESULTS AND DISCUSSION

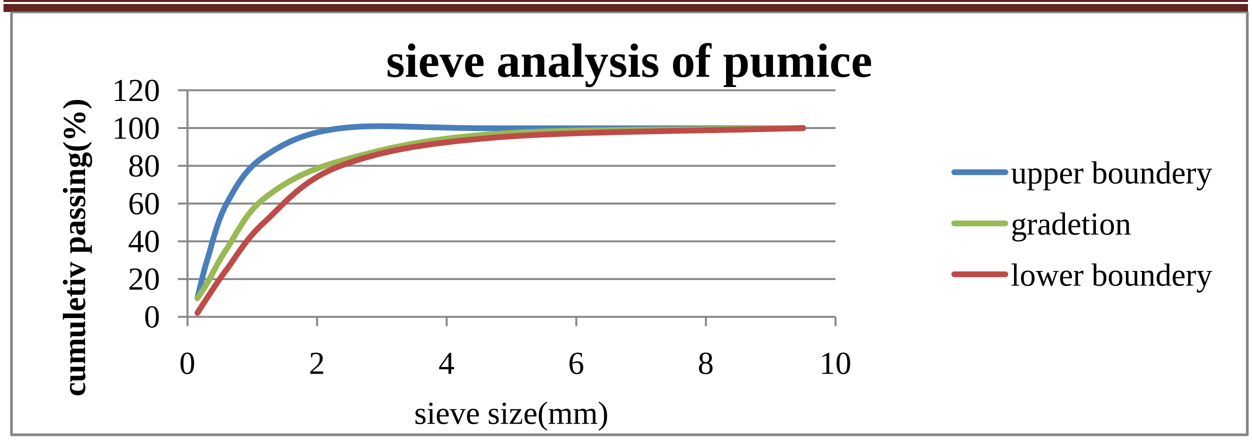
A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site.This study had carry out the property of HCB, compressive strength and block density test has been done. It also presents the results of experimental investigation on physical property of aggregate:- Sieve analysis of fine aggregate, specific gravity and water absorption, silt content ,organic impurity, moisture content of aggregates and unit weight of aggregate. After the laboratory result the effect of aggregate on the property of HCB has define using compressive strength and density of block affected by aggregate.

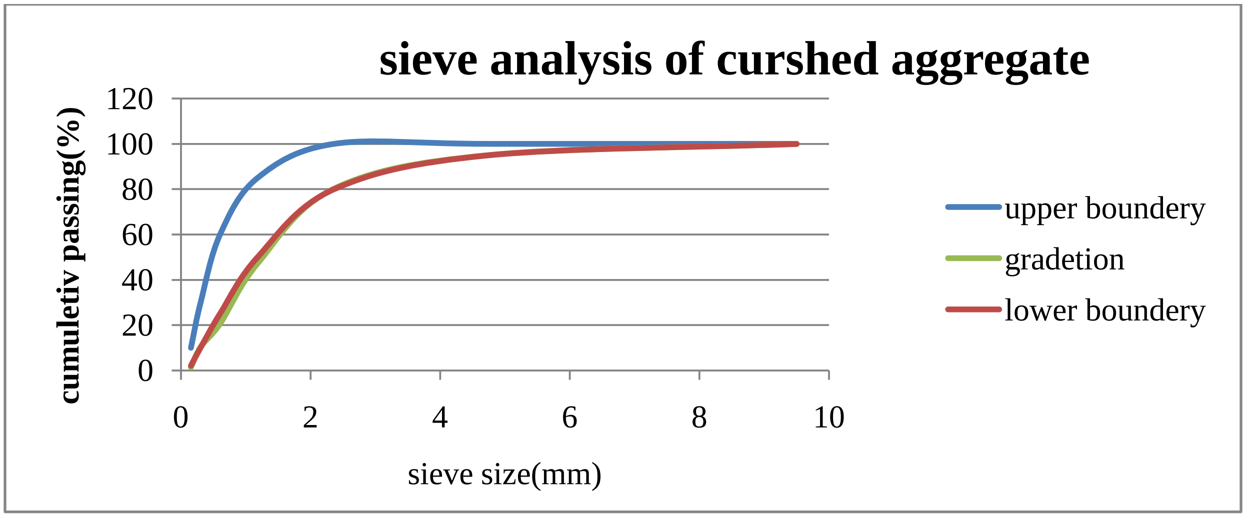
This section focuses on the experimental results obtained from each test and analysis of the test results. The Experimental tests were carried out to obtain the effect of aggregate on HCB used for ribbed slab. During experimentation, different types of tests were conducted as it has been explained in the previous section. This test results have been discussed and analyzed.

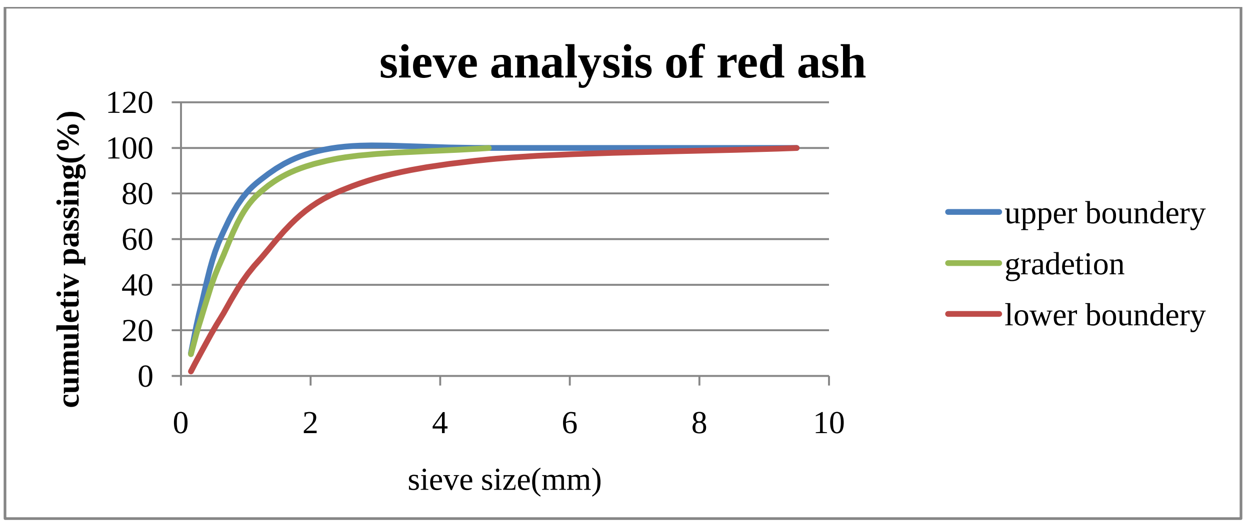
4.1 Aggregate testing

4.1.1 Sieve analysis

The Significance and Usethis test method is used primarily to determine thegrading of materials proposed for use as aggregates or beingused as aggregates. The results are used to determine complianceof the particle size distribution with applicable specificationrequirements and to provide necessary data for control ofthe production of various aggregate products and mixturescontaining aggregates. From experimental work conducted, the result of sieve analysis for fine and coarse aggregates is illustrated below in Annex C. In both cases, the results satisfy ASTM C136 and C33 Standards limit. Fine aggregate sizes are close to the lower limit of the standard as compared to the coarse aggregates.


sieve analysis of pumice
cumuletiv passing(%)
120
100
80
60
40
20
0
0
2
4
6
8
10
sieve size(mm)
upper boundery
gradetion
lower boundery


sieve analysis of curshed aggregate
cumuletiv passing(%)
120
100
80
60
40
20
0
0
2
4
6
8
10
sieve size(mm)
upper boundery
gradetion
lower boundery


sieve analysis of red ash
cumuletiv passing(%)
120
100
80
60
40
20
0
0
2
4
6
8
10
sieve size(mm)
upper boundery
gradetion
lower boundery

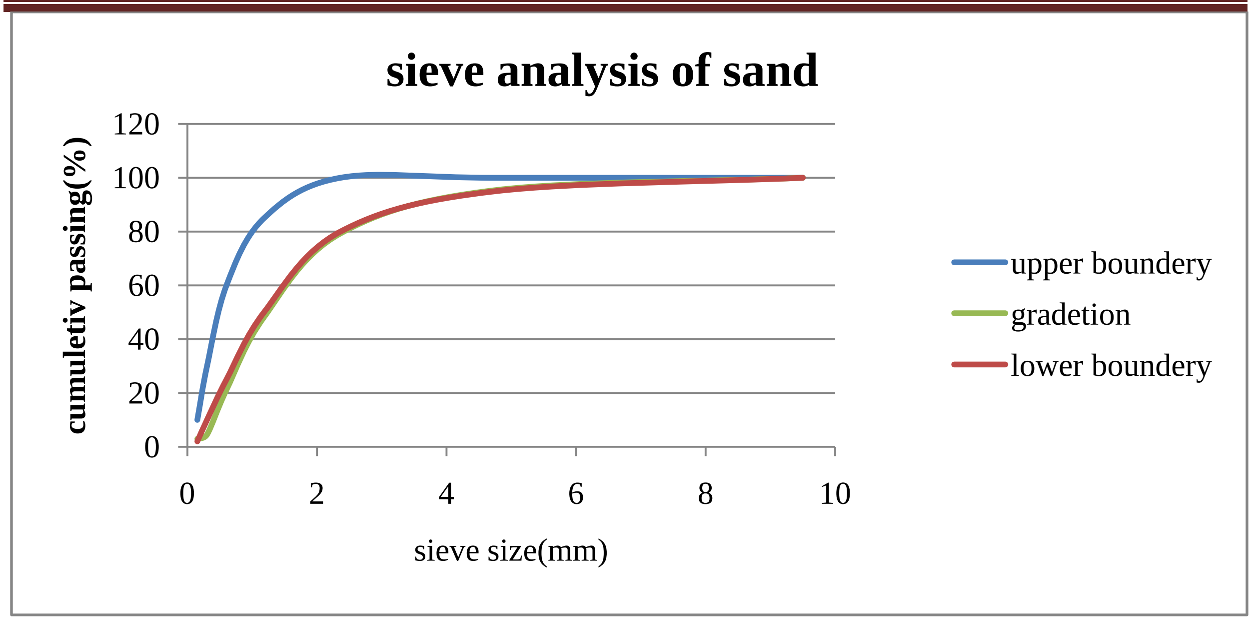


Figure: 4.1 Result of sieve analysis

4.1.2. Fineness modulus

It is a numerical index of fineness, giving some idea about the mean size of the particles in the aggregates. The fineness modulus (F.M.) varies between 2.0 and 3.5 for fine aggregate, between 5.5 and 8.0 for coarse aggregate and from 3.5 to 6.5 for all-in aggregate. Aggregate, whose F.M. is required, is placed on a standard set of sieves (80, 63, 40, 20, 12.5, 10, 4.75, 2.36, 1.18 mm and 600, 300, 150 m) and the set vibrated. The object of finding F.M. is to grade the given aggregate for the required strength and workability of concrete mix with minimum cement. Higher F.M. aggregate result in harsh concrete mixes and lower F.M. result in uneconomical concrete mixes.

From the test result all aggregate types are between the ranges,between 2.0 and 3.5. For fine aggregate, between 5.5 and 8.0 for coarse aggregate,for coarse aggregates (pumice, red ash and crushed) it is between 5.49 to 4.9 and fine (sand) is 3.5 . It is economical grading of aggregate.It is used as index to the finesse or coarseness and uniformity of aggregate supplied ,however it is not an induction of grading since there could be an infinite number of grading, which will produced a given fineness modulus. The result of finesse modules of aggregates are as follows;

Table 4.1:Summery for finesse modules

Sample aggregate	Finesse modules
Crushed	5.42
Red ash	5.34
Pumice	4.9
Sand	3.5

4.1.3 Specific gravity and water absorption

The result obtained from the laboratory test for apparent specific gravity,bulk specific gravity and water absorption are summarized on table 4.2.Throughout the test water absorption of aggregates were conducted .It is indicative of its quality. A low specific gravity may indicate high porosity and therefore poor durability and low strength. The concrete density will greatly depend on specific gravity .The result shown specific gravity and water absorption are inversely proportion. From table, it is between rage.sg 2.4 up to 3.

The laboratory standard for absorption is that obtained after submerging dry aggregate for approximately 24 hr. in water. Conversely, some aggregates when used may contain an amount of absorbed moisture less than the 24 hr.-soaked condition. These test results indicate that light aggregates (red ash and pumice) have more water absorption capacity than crushedaggregate and lower specific gravity.

Table 4.2**:** Specific gravity and water observation of crushed aggregate

Material Research And Testing Center(MRTC)				
Observation Sheet				
Determination Of Specific Gravity And Water Observation Of Crushed Aggregate				
Description			sample I	sample II
weight of sample tanker,(gm)		Gm		
weight of basket + sample + water		W1(gm)	1617	1633.9
weight of basket + water		W2(gm)	1302.2	1302.3
weight of SSD sample in air		W3(gm)	500	500
weight of oven dry sample		W4(gm)	496.2	495.8
specific gravity = W4/(W3-(W1 - W2))			2.68	2.94
Bulk specific gravity (SSD Basis) = W3/(W3-(W1 - W2)			2.70	2.97
apparent specific gravity = W4/(W4-(W1 - W2)			2.74	3.02
water absorption, dry weight WA =((W3 - W4) /W4)$\times$100			0.77	0.85
Average values	Specific gravity		2.83	
	apparent specific gravity		2.88	
	water observation		0.81	

From the table crushed aggregate had 2.83 of specific gravity is shows high specific gravity may indicate low porosity and therefore high durability and high strength, would accepted after production of ribbed slab HCB.

The water observation, which is 0.81 indicate that during mix design, water cement ratio would depended on this value. Relative to other aggregate type the water added is small.

Table 4.3: Specific gravity and water observation of pumice aggregate

Material Research And Testing Center(MRTC)				
Observation Sheet				
Determination Of Specific Gravity And Water Observation Of pumice Aggregate				
Description			sample I	sample II
weight of sample tanker,(gm)		gm		
weight of basket + sample + water		W1(gm)	3292	2273.9
weight of basket + water		W2(gm)	1858	1858
weight of SSD sample in air		W3(gm)	2000	2000
weight of oven dry sample		W4(gm)	1829.1	1807
specific gravity = W4/(W3-(W1 - W2))			3.23	1.14
Bulk specific gravity (SSD Basis) = W3/(W3-(W1 - W2)			3.53	1.26
apparent specific gravity = W4/(W4-(W1 - W2)			4.63	1.30
water absorption, dry weight WA =((W3 - W4) /W4) $\times$100			9.34	10.68
Average values	Specific gravity		2.40	
	apparent specific gravity			
	water observation		10.01	

From the table pumice aggregate had 2.40 of specific gravity is shows low specific gravity may indicate high porosity and therefore low durability and low strength ,relative to crushed aggregate would accepted after production of ribbed slab HCB.

The water observation, which is 10.01 indicate that, the amount of water added to mix design is higher. Consequently the strength that accepted from production of ribbed HCB is low compressive strength.

Table 4.4Specific gravity and water observation of red ash aggregate

Material Research And Testing Center(MRTC)				
Observation Sheet				
Determination Of Specific Gravity And Water Observation Of red ash Aggregate				
			sample No.	
Description			sample I	sample II
weight of sample tanker,(gm)		gm		
weight of basket + sample + water		W1(gm)	1599.5	1597.4
weight of basket + water		W2(gm)	1302.7	1308.9
weight of SSD sample in air		W3(gm)	500	500
weight of oven dry sample		W4(gm)	460.1	464.7
specific gravity = W4/(W3-(W1 - W2))			2.26	2.20
Bulk specific gravity (SSD Basis) = W3/(W3-(W1 - W2)			2.46	2.36
apparent specific gravity = W4/(W4-(W1 - W2)			2.82	2.64
water absorption, dry weight WA =((W3 - W4) /W4) $\times$ 100			8.67	7.60
average values	Specific gravity		2.41	
	apparent specific gravity		2.73	
	water observation		8.13	

From the table red ash or scoria aggregate had 2.73 of specific gravity is shows intermediate specific gravity. May indicate middling strength ,relative to crush aggregate and pumice aggregate would accepted after production of ribbed slab HCB.

Table 4.5 Specific gravity and water observation of sand aggregate

Material research and testing center(MRTC)				
Observation sheet				
Determination of specific gravity and water Observation of sand aggregate				
Description			sample No.	
			sample I	sample II
weight of sample tanker,(gm)		gm		
weight of basket + sample + water		W1(gm)	1608.1	1604.7
weight of basket + water		W2(gm)	1303.2	1309.3
weight of SSD sample in air		W3(gm)	500	500
weight of oven dry sample		W4(gm)	475.5	475.6
specific gravity = W4/(W3-(W1 - W2))			2.44	2.32
Bulk specific gravity (SSD Basis) = W3/(W3-(W1 - W2)			2.56	2.44
apparent specific gravity = W4/(W4-(W1 - W2)			2.79	2.64
water absorption, dry weight WA =((W3 - W4) /W4)$\times$100			5.15	5.13
average values	Specific gravity		2.50	
	apparent specific gravity		2.72	
	water observation		5.14	

Table: 4.6 Summery for Specific gravity and water absorption

Sampled aggregates	Specific Gravity	Water Absorption
Crushed	2.83	0.81
Pumice	2.4	10.01
Red ash	2.41	8.13
Sand	2.50	5.14

4.1.4 Silt Content

According to ES and ASTM, it is recommended to wash sand or change other qualified sand if the silt content exceeds a value of 6%. Form experimental result silt content of sand is satisfy Ethiopian standard.

Table: 4.7 Silt content of sand

Material Research And Testing Center(MRTC)			
Observation Sheet			
Determination Of Silt Content Of Sand			
Description		Sample	
		I	II
Amount of silt deposited above the sand	V1(gm)	1.5	1.4
total amount of sample	V2(gm)	27	27
silt content = ((V1 /V2)*100	%	5.56	5.19
Average silt content	%	5.37	

4.1.5 Moisture content of aggregates

As explain in previous chapter,in most case aggregate from different sources do not comply with this i.e. wet aggregate give water to the mix and drier aggregate (those with low saturation level moisture content) take water from the mix affecting workability and strength of the mix.

4.1.6 Unit weight of Aggregates

The weight effectively measures the volume that the graded aggregate will occupy in concrete and. The unit weight is simply measured by filling a container of known volume and weighing it. However the degree of compaction well change the amount of void space and hence the value of unit weight .Since the weight of the aggregate is rely on constant moisture content.

Table 4.8Unit weight of crush aggregate

Observation Sheet			
Determination Of Unit Weight Of Crushed Aggregate			
Description		fine aggregate	
		sample	
		I	II
volume of the mold	V(lit)	9	9
weight of the mold only	W(kg)	5.4	5.4
weight of the mold loosely with aggregate	W1(kg)	20	22
weight of the mold with aggregate fully compacted	W2(kg)	26	27
lose unit weight = ((W1 - W)/V)1000	kg/m3	1622	1844
compacted unit weight = ((W2 - W)/V)1000	kg/m3	2289	2400
Average loose unit weight	**kg/m3**	1733	
Average compacted unit weight	**kg/m3**	2344	

Table 4.9Unit weight of Pumice aggregate

Material Research And Testing Center(MRTC)			
Observation Sheet			
Determination Of Unit Weight Of pumice Aggregate			
		coarse aggregate	
Description		Sample	
		I	II
volume of the mold	V(lit)	9	9
weight of the mold only	W(kg)	5.4	5.4
weight of the mold loosely with aggregate	W1(kg)	14	14
weight of the mold with aggregate fully compacted	W2(kg)	15	15
lose unit weight = $((W1 - W)/V)\times 1000$	kg/m3	956	956
compacted unit weight = $((W2 - W)/V)\times 1000$	kg/m3	1067	1067
average loose unit weight	**kg/m3**	956	
average compacted unit weight	**kg/m3**	1067	

Table 4.10Unit weight of red ash aggregate

Material research and testing center(MRTC)			
Observation sheet			
Determination of unit weight of red ash aggregate			
		coarse aggregate	
Description		Sample	
		I	II
volume of the mold	V(lit)	9	9
weight of the mold only	W(kg)	5.4	5.4
weight of the mold loosely with aggregate	W1(kg)	16.5	16
weight of the mold with aggregate fully compacted	W2(kg)	17.5	16.5
lose unit weight = $((W1 - W)/V)\times 1000$	kg/m3	1233	1178
compacted unit weight = $((W2 - W)/V)\times 1000$	kg/m3	1344	1233
average loose unit weight	**kg/m3**	1206	
average compacted unit weight	**kg/m3**	1289	

Table 4.11 Unit weight of sand aggregate

Material research and testing center(MRTC)			
Observation sheet			
Determination of unit weight of sand aggregate			
		fine aggregate	
Description		Sample	
		I	II
volume of the mold	V(lit)	9	9
weight of the mold only	W(kg)	5.4	5.4
weight of the mold loosely with aggregate	W1(kg)	15.5	15.5
weight of the mold with aggregate fully compacted	W2(kg)	17.5	17.5
lose unit weight = $((W1 - W)/V)\times 1000$	kg/m3	1122	1122
compacted unit weight = $((W2 - W)/V)\times 1000$	kg/m3	1344	1344
average loose unit weight	**kg/m3**	1122	
average compacted unit weight	**kg/m3**	1344	

Table: 4.12Unit weights of Aggregates

Sample aggregate	Loose unit weight (kg/m3)	Compacted unit weight (kg/m3)
Crushed	1733	2345
Red ash	1206	1289
Pumice	956	1087
Sand	1122	1344

4.2 Compressive strength

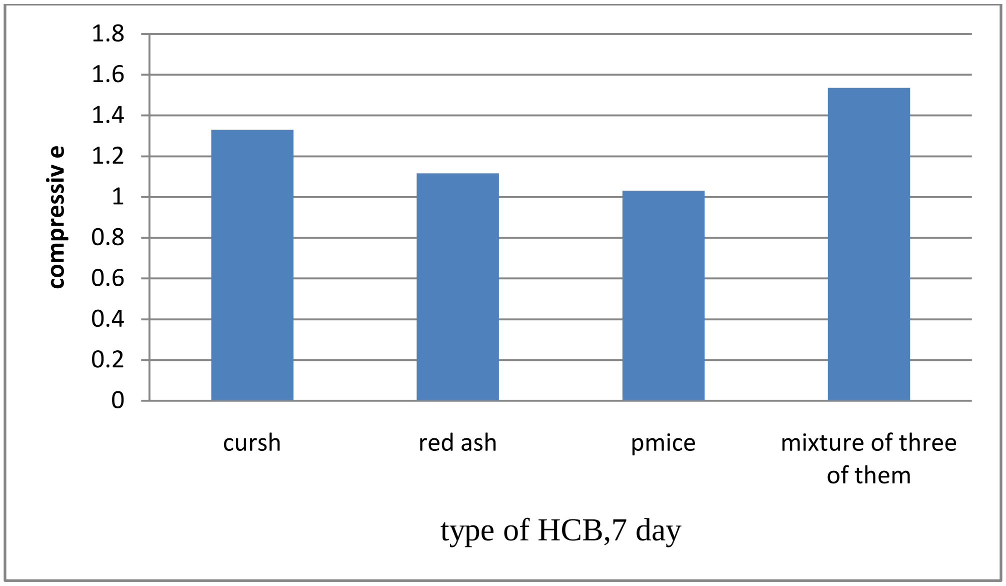
All units shall be sound and free of cracks or other defects which interfere with the proper placing of the unit or impair the strength or performance of the construction. The minimum compressive strength, Ethiopian standard CES 24- 2013 recommends class C strength (average strength of 6 hollow blocks not less than 2 Mpa and individual strength not less than 1.8 Mpa).It is also been found that areduction in density due to formation of holes will results in a significant drops in strength. (CEB/FIPManual, 1977).

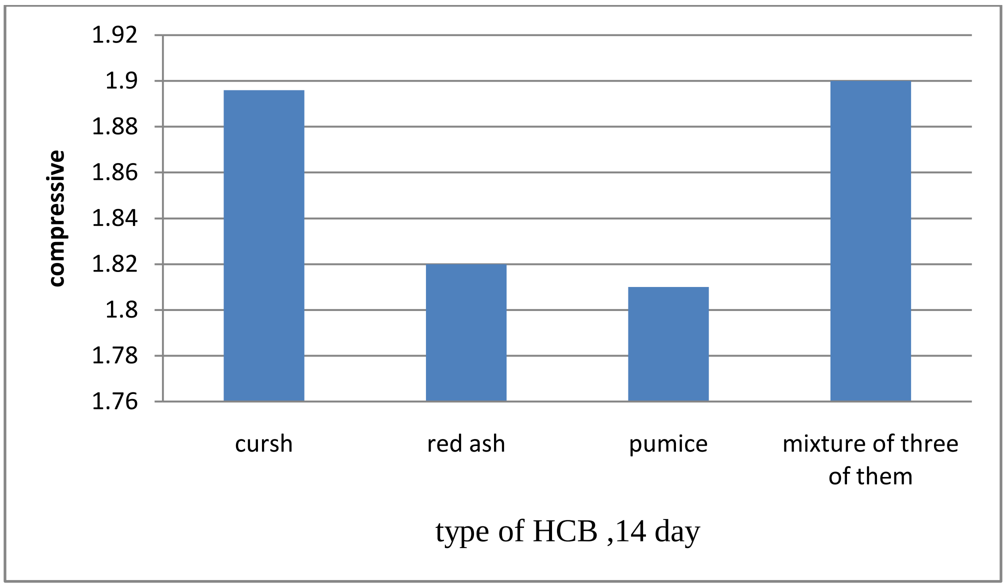
The compressive strengths of HCB were determined after 7, 14 and 28 days of curing. For each of the mixes the mean values of six ribbed blocks were taken as their compressive.

Table 4:13 result of compressive strength

	Type of ribbed HCB	Trial compressive strength		average 7^{th} day test compressive strength		Average 14^{th} day test compressive Strength		Average 28^{th} day test compressive strength	
		Weight(kg)	Mpa	weight	Mpa	weight	Mpa	Weight	Mpa
1	Mixed	24.66	1.83	22.41	1.9	21.16	2	19.08	2.3
2	crushed	22	1.81	21.33	181	20.58	1.97	18.667	2.13
3	red ash	20.16	1.6	19.99	1.53	19.16	1.828	15.58	2
3	Pumice	16.33	1.4	16.55	1.1	15.41	1.81	13.5	1.95

Form test result mixed HCB have the highest compressive strength ,highest density ,followed by crushed HCB,red ash and finally pumice HCB had the smallest compressive strength, but still persuade the standard of minimum compressive strength . The results also expelled as graphic form below:


1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
compressiv e
cursh
red ash
pmice
mixture of three of them
type of HCB,7 day


1.92
1.9
1.88
1.86
1.84
1.82
1.8
1.78
1.76
compressive
cursh
red ash
pumice
mixture of three of them
type of HCB ,14 day

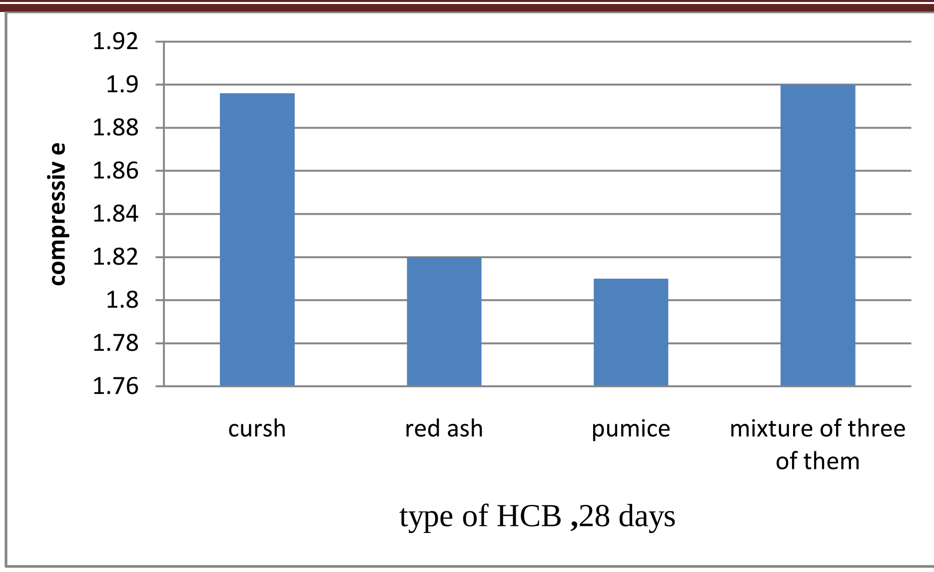


Figure 4.2: Result of compressive strength

4.3 Density of block

For non-load bearing interior walls and exterior panels walls in steel or reinforced concrete framed construction when protected from weather by rendering or by some other efficient treatment and their density should be between 600 - 900 kg/m3

$$Density = \frac{mass\ of\ \ blocck\ \ in\ \ kg}{volume\ of\ \ specimen\ \ in\ \ cm^3 \times 10^6\, kg/m^3}$$

Table 4.14 Summary Laboratory result of density of block

Sampled aggregate for production of HCB	Average Density (kg/m^3)
Mixed of pumice ,red ash and crushed	1124.03
Crushed	1056.2
Red ash	901.163
Pumice	784.884

From the result average of density is shown by descending order. It shows that aggregate type have effect on the density of blocks .According to Indian standard ,for non-bearing block the range of density should be between 600 - 900 kg/m^3. by using crushed and mixed of three type of aggregate had greater density than IS .on the other hand using red ash and pumice for production f HCB had acceptable value of density .From the result mixed HCB and crushed are denser than red ash and pumice.

4.4 Dry shrinkage

IS 2185 (Part 1):2005 state thatAfter curing the blocks, they shall be dried for a period of 4 weeks before beingused on the work. In case of curing as oncelow pressure steam curing has been done, the blocksshall -be dried at ambient temperature for a period ofseven days. The blocks shall then be stacked with voidshorizontal to facilitate through passage of air. It shallbe ensured that the blocks have been thoroughly driedand allowed to complete their initial drying shrinkagebefore supply to the work-site.The drying shrinkage of the units when unrestrainedbeing the average of three units, shall not be exceed 0.065 percent.

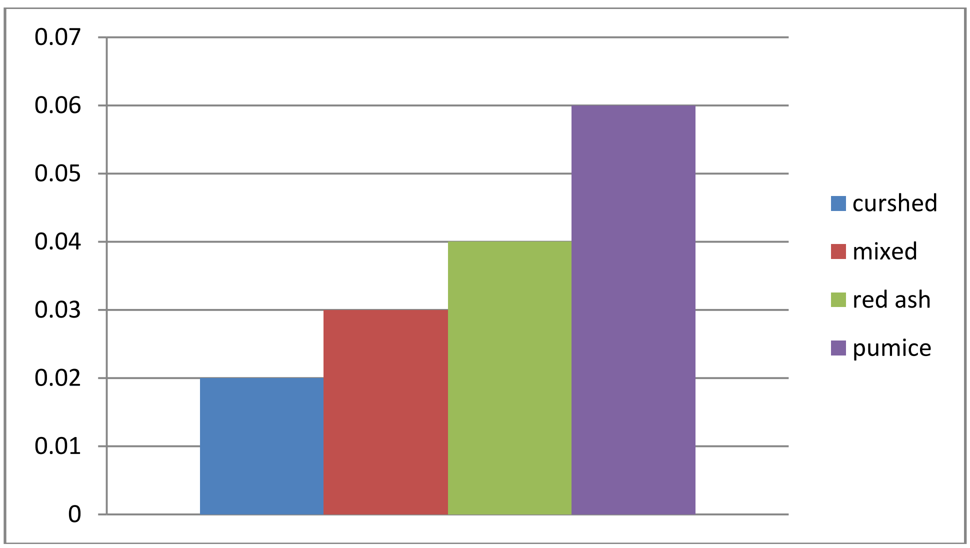


Figure 4.3: Result of dry shrinkage

4.5 Cost comparison of HCB Production materials

The material are evaluated accordingto currentprice of market .According to the data (APENDEX E), HCB produced by red ash aggregate had the lowest value of all aggregate. It indicates it is more applicable for constriction. Followed red ash,pumice aggregate had lower price ofcrushed aggregate. At last crushed HCB and mixed HCB had expansive price .

Table 4.15 Expense of material for production HCB

Crushed HCB cost expanse

Man power		Material expense		Equipment expense	
title	Amount	Type	Amount	Type	usage
DL	1.97	Cement	1.75	HCB mould machine rate	0.36
		Crushed aggregate	7.41	Gres	0.09
		Sand	3.9	Light power fee	0.02
		Water	0.28		
	1.97 birr	Total	13.34 birr	Total	0.47 birr
Total cost					**15.78 birr**

Mixed HCB cost expense

Man power		Material expense		Equipment expense	
Title	Amount	Type	Amount	Type	Usage
DL	1.97	Cement	2.0025	HCB mould machine rate	0.36
		Crushed aggregate	2.1	Gres	0.09
		Pumice aggregate	0.8324	Light power fee	0.02
		Red ash aggregate	0.6615		
	1.97 birr	Total	4.86	Total	0.47 birr
Total cost					**15.78 birr**

Pumice HCB cost expense

Man power		Material expense		Equipment expense	
Title	Amount	type	Amount	type	usage
DL	1.97	Cement	2.825	HCB mould machine rate	0.36
		pumice aggregate	2.542	Gres	0.09
		Sand	4.26	Light power fee	0.02
		water	0.875		
	1.97 birr	Total	10.502 birr	Total	0.47 birr
Total cost					**13.07 birr**

Red ash HCB cost expense

Man power		Material expense		Equipment expense	
title	Amount	type	Amount	type	usage
DL	1.97	Cement	2.505	HCB mould machine rate	0.36
		Red ash aggregate	3	Gres	0.09
		Sand	3.66	Light power fee	0.02
		Water	0.7525		
	1.97 birr	Total	**9.915** birr	Total	0.47 birr
total					**12.355 birr**

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATION

The general objective of this research was to determine aggregate property , compare their result production for ribbed slab HCB .Based on conducted laboratory test results to investigate aggregate density on property of HCB , conclusions were made and recommendations are forwarded as follow:

5.1 Conclusions

This study was conducted based on aggregate property used for production of ribbed slab HCB in Ethiopia. The obtained result show the property of aggregate such as Sieve analysis of aggregates, finessemodules, specific gravity and water absorption, moisture content of aggregates , unit weight of aggregate and density of aggregate affect the compressive strength of the HCB. It was concluded that the higher aggregate density had higher compressive strength of HCB can get.From the Laboratory result of density of block. According to Indian standard for non load bearing block the range of density should be between 600 - 900 kg/m$^{3.}$ The mixed of three aggregate HCB had density of 1124.03kg/m^3, Crushed HCB 1056.2kg/m^3 Red ash 901.163kg/m^3 and pumice 784.884 kg/m^3 .Mixed HCB and crushed HCB had larger value than the standard. Red ash and pumice HCB had middling density of block.It was observed that pumice have high dry shrinkage than mixed, crushed and red ash HCB.

From the result crushed aggregate had highest specific gravity than pumice and red ash aggregate. It indicates low porosity therefore high durability and high strength had gain. Next to crushed, red ash was the next higher value of specific gravity. The water observation of Crushed aggregate was lowest value .Which indicated that during mix design, water cement ratio would depended on this value. Relative to other aggregate type the water added is small. From the product of mixed of the three aggregate had largest compressive strength related to crushed ,red ash and pumice HCB Compressive strength are 2.3, 2.13, 2 and 1.95 Mpa respectively. It was noticed that mixed of the three aggregate and crushed HCB had a larger value of compressive strength than non load bearing HCB class C of Ethiopian standard suggested .It indicate that mixed and crushed HCB was not economical to used for non load bering .On the hand HCB produced by red ash and pumice were between the range of ES (1.8-2Mpa),which were satisfy Ethiopian standard .

Finally, it was concluded that the comparison of cost of was as follow: the cheapest was red ash HCB, pumice HCB, mixed and at last crashed HCB

5.2 Recommendations

Based on this study, the following recommendations have been forwarded

- Mixed HCB and crushed HCB had larger value than the standard. Red ash and pumice HCB had middling density of block .It indicate that mixed and crushed HCB was not economical to used for non load bearing .For non load bearing class C HCB used for ribbed slab should use light density of block ,adequate compressive strength and cost efficient is HCB produced by pumice and red ash aggregate
- Based on this tested resultsafter curing the blocks, they shall be dried for a period of 4 weeks before being used on the work. to all HCB type had influenced by dry shrinkage ,due to moisture content of aggregate
- For better or greater compressive strength for crushed and mixed of aggregate is more effective to use on slab construction.

REFERENCES

1. Abdullahi. M.,(2012), Effect of aggregate type on Compressive strength of concrete, international journal of civil and structural engineering.
2. AbebeDinku,(2005), The Need for Standardization of Aggregates For Concrete Production inEthiopian Construction Industry, Addis Ababa.
3. AbebeEshetu ,(2005), Concrete Production and Quality Control in Building Construction industry of Ethiopia, Addis Ababa.
4. ACI Committee 213 ,(2003), Guide for Structural Lightweight-Aggregate Concrete, AmericanConcrete Institute, Farmington Hills.
5. American Geological Institute ,(1960), Glossary of Geology and Related Sciences.
6. ASTM C 125 Standard Terminology Relating to Concrete and Concrete Aggregates
7. ASTM C 128 Standard Test Method for Specific Gravity and Absorption of Fine Aggregate
8. ASTM C 136 Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
9. ASTM C 138 Standard Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete
10. ASTM C 150 Standard Specification for Portland Cement
11. ASTM C 40 – 99 Standard Test Method for Organic Impurities in Fine Aggregates
12. ASTM C 70 – 94 Standard Test Method for Surface Moisture in Fine Aggregate
13. ASTM C 702 Standard Practice forReducing Samples of Aggregate to Testing Size
14. ASTM C129 standard specification for non load bearing concrete masonry units.
15. ASTM C192 Standard Practice for Making and Curing Concrete Test Specimens in the Laboratory
16. ASTM Standard C-143Standard Test Method forSlump of Hydraulic-Cement Concrete
17. BS 3148 British standard
18. Domone andJohn Illston,(2010), Construction Materials Their nature and behavior, Fourth edition Edited byPeter (pp,118,- (pp 114). ,pp 83,85)
19. Duggal S.K(2008);building material;3rd revised edition ,Allahabad (U.P).
20. Edward G.Nawy ,(2008),concrete construction engineering Handbook.
21. ES 2310,(2005) Ethiopian Standard water used for concrete

22. GZT,(2008), university capacity bulging program,Hollow Concrete Block Production & Quality Management Guidelines
23. Hanson, J.A., Replacement of lightweight aggregate fines with natural sand in structuralconcrete, Journal of ACI, Proc. 61 (No. 7; 1964), 779-94.
24. Hossain, Khandaker MA, Lachemi, (2007), The Mixture Design, Strength, Durability, and FireResistance of Lightweight Pumice Concrete, Canada.
25. I.Struct. E./Conc. Soc,(1987), Guide to the Structural Use of Lightweight Aggregate Concrete, London.
26. IS: 2185 part I, (2005), Indian standard concrete masonry units, specification part 1 hollow and solid concrete blocks (third revision)
27. IS:2185 part II,(2005),Indies standard specification for concrete masonry units
28. Kosmatka, Steven H.; Kerkhoff, Beatrix; and Panarese, William C.(2003); Design and Control of Concrete Mixtures, EB001, 14th edition, Portland Cement Association, Skokie, Illinois, USA.
29. Marsh. B K ,(1997), Design of normal concrete mixes, Building Research Establishment Second edition.
30. Matthew, P.W and Bennett D.F.H, (1990), Economic long span concrete floors, (1st edition): British cement association
31. MethaP.K ,(2001), concrete microstructure property and material part ii hollow and solid lightweight concrete blocks third reprint december 1996
32. MikyasAbayneh,(1970), Concrete making properties of Lightweight Aggregate Concrete made withEthiopian Pumice and Scoria, Msc. Thesis for Israel Institute of Technology, Haifa.
33. Mohammed AregaAli,Dec ,(2006), how high could buildings made of ribbed or flat slab construction without shear walls be built? (case study)
34. Mohammed AregaAli,Dec,(2006). How high could buildings made of ribbed or flat slab construction without shear walls be built? (case study)
35. Neville A,M and J.J Brooks (2010),concrete technology ,2nd edition .
36. Pedro, N.Q., and David, W. F., (2003), the Effects of Aggregates Characteristics on the Performance of Portland cement Concrete, Research Report Icar – 104-1F Project Number 104]

37. PilarArmand-Ugón/ NúriaMartí ,(2014),TYPES OF STRUCTURAL FLOORS ,structures, Construction II. Systems. 2nd year.
38. Soraya Serna Muñoz Rafal krzywon PhD CEngUniversidad Politécnica de Valencia2010/2011) Insitu concrete floor systems
39. Steven H. Kosmatka, Beatrix Kerkhoff, and William C. Panarese, (2003), Design andControl of Concrete Mixtures (14th edition) published by Portland Cement Association,Skokie, Illinois, USA
40. Sydney Mindess, Francis J.Young and Darwin David (2003); Concrete (2nd Edition)
41. Techno economic feasibility report on concrete hollow & solid block", Building Materials & Technology Promotion Council Ministry of Housing & Urban Poverty Alleviation Government of India New Delhi 2005

Appendix A

Picture taken during casting and testing of HCB

Aggregates (crushed 01, pumice and red ash scoria) used in this study

Test for first trial

Weighting of ribbed HCB

Ribbed slab under constraction

Appendix B

Laboratory processes for tests

1. **Sieve analysis**

Apparatus: Balance, sieve shaker, brush, shovelBalance*:* Balances or scales used in testing fine shall have readability and accuracy as follows:

For fine aggregate, readable to 0.1 g and accurate to 0.1 g or 0.1 % of the test load, whichever is greater, at any point within the range of use.

Sieve*s*: The sieve cloth shall be mounted on substantial frames constructed in a manner that would prevent loss of material during sievingTest procedure was in accordance to ASTM Code procedure as follow.

1. Sieves were nested in the order of decreasing size of opening from top to bottom and sample The reduced minimum required sample was taken from quartered sample.
2. The required aggregates were placed in the top sieve.
3. Using mechanical sieve shaker the sample was sieved at least 10-15 minutes.
4. As soon as sieving process completed each retained aggregate mass was measured and No aggregates were allowed to retain on the sieve

2. **Specific gravity of fine(sand) aggregate**

Apparatus:- balance ,wire basket (6.3 mm or finer mess),oven, dry soft cloth, airtight container sieve (4.75 mm),and buoyancy balance .Material used for the test 2 kg of sample of aggregate (rejecting all material passing 4.74 mm sieve) by using sample quartering .

Procedure for coarse (crushed, pumice and red ash) aggregate

1. A sample of 2 kg of aggregate was taken.
2. Immersed the basket with the sample in distilled water at a temperature between 22 to 32º c with a cover of at least 50 mm of water above the top of the basket.
3. Removed the entrapped air, immediately after immersion, from the sample by lifting the basket containing it 25 mm above the base of tank and allowing it to drop 25 times at the rate of about one drop per second .kept the basket with sample completely immersed during the operation and for a period of 24± ½ hrs. Afterward.
4. After 24± ½ hrs.jolt and the sample has weightedthe basket with sample in water,(Wa).

5. Removed them from the water and allow to drain for a few minutes.
6. Empty the basket gently on to drain for a few minute.
7. Then return the empty basket to the water ,jolt 25 times and weight in water (Wb)
8. The aggregate are placed on dry cloth are gently surface dried with the cloth, and are completely surface dry. Then weight the aggregate ,(Mssd)
9. Then place the aggregate in an oven at a temperature of 100 to 110ºc and maintain at this temperature for 24± ½ hrs.
10. After 24 hrs. remove the sample from the oven, cool it in air tight container (for about 1 to 3 hrs)and weight it,(md)

Apparatus:-balance, capacity l kg or more, pycnometer

Procedure: the same with the above procedure but different from step 7

7. Immediately introduced in to the pycnometer 500 gm of fine aggregate sample has prepared and fill with water to approximately 90% of the capacity
8. Roll, invent and agitate the pycnometer to eliminate all air bubbles .adjust its temperature to 23± 1.7ºc.
9. Determine the total weight of the pynocnmeter, sample and water and recorded.
10. Remove the fine aggregate from the pycnometer, dried to constant weight at a temperature of 105 ±5ºc cool in air at room temperature for ½ to 1 ½ hrs, and weigh.
11. It was determined the weight of the pycnometer filled to its calibrated capacity with water at 23±107ºc

3. Silt content of sand

Apparatus: glass cylinder or jar (more than 100 ml capacity), spoon, funnel

Procedure:

1. The has Filled the cylinder or jar with the sand sample to a depth of 75 ml.
2. The water has added until the level about ¾ full of the cylinder or jar.
3. The mixture has sneaked vigorously for about a minute.
4. The sand waskept, undisturbed for at least an hour.
5. The silt being of finer particles than sand would settle above the sand in a form of layer.
6. It has measured the thickness of silt layer.

4. organic impurities

The sample das Filled a glass bottle to the approximately level with the fresh hydroxide solution, approximately 75-mL (21⁄2-fluid oz) level .It was Added the sodium until the volume of the fine aggregate and liquid, indicated after shaking. The solution that has prepared not longer than 2 h previously. Hold the bottle with the test sample and the bottle with the solution side-by-side, and compared the color of light transmitted through the supernatant liquid above the sample with the color of light transmitted through the standard color solution. Recorded whether the color of the liquid is lighter, darker, or equal to the

Color of the standard color solution, and then it was allowed to stand for 24 h.

5. **moisture content**

Apparatus:

Balance, dish, oven and trowel

Procedure;

1. A sample has weight 2 kg coarse aggregate and 500 gm fine aggregate separately A
2. The sample has oven dried for about 24 hrs with a temperature of 105º to 110º c
3. Removed the sample from the oven and placed them on desiccators for about an hour in order to cool without absorbing water from the atmosphere.
4. The aggregate has separately weighted (oven dry weight ,B)
5. Calculate the moisture content of the aggregate.

Calculation:Where A=weight of (wet) original sample (g)

$\%\text{moisture content} = \frac{(A - B) \times 100}{B}$ B=weight of oven dry sample (g)

6. **Unit weight**

Compact weight determination

Roding procedure

1. The sample has filled the measure 1/3 full and levels the surface with fingers. Tod the layer of aggregate with 25 strokes of tamping road evenly distributed over the surface. Filled the measure 2/3 full and again level rod ads above .Finally filled the measure to overflowing and again rod above.

2. It was Compacted each layer by dropping the measure 50 time in the manner described above 25 time on each side.
3. The surface has leveled of the aggregate with finger or straight edge.
4. Weight the measure and its content and record the net weight of the aggregate .divide this weight by the volume of the measure and result is the compact unit weight.

Lose weight determination

4. The sample has Filled measured to overflowing by means of a shovel or scoop, discharge the aggregate from a height not exceeding 50 mm .Above the top of the measure, take care to prevent segregation of the particle size.
5. The surface has leveled of the
6. It has measured weight of sample and its content and recorded the net weight of the aggregate. Divide the weight by the volume of the measure the loose unit. Figure: 3.9 shows process of unit weight of aggregate

Appendix C

Experimental test results

Sieve analysis for pumicesample:

Material research and testing center(MRTC)								
Observation sheet								
Sieve analysis of pumice								
ASTM sieve Designation	sieve size(mm)	weight retained (gm)			retained %	cumulative retained (%)	cumulative passing(%)	Gradation
		sample I	sample II	Average				
0.375(3/8)	9.5			0	0.00	0.00	100.00	100
No.4	4.75	15.68	15.14	15.41	3.10	3.10	96.90	97
No.8	2.36	71.5	70.98	71.24	14.33	17.44	82.56	83
No.16	1.18	99.3	98.46	98.88	19.90	37.33	62.67	63
No.30	0.6	133.1	133.7	133.4	26.84	64.17	35.83	36
No.50	0.3	90.2	89.6	89.9	18.09	82.26	17.74	18
No.100	0.15	40.1	39.2	39.65	7.98	90.24	9.76	10
No.200	0.75	30.1	35.56	32.83	6.61	96.85	3.15	3
Pan		15.45	15.9	15.675	3.15	100.00	0.00	0
Sum		495.43	498.54	496.98	100.00	491.39		

Sieve analysis for crushed aggregate sample:

material research and testing center(MRTC)									
observation sheet									
sieve analysis of crushed aggregate									
ASTM sieve designation	sieve size(mm)	weight retained (gm)			retained %	Cumulative retained (%)	Cumulative passing (%)	Gradation
		sample I	sample II	average				
0.375(3/8)	9.5			0	0.00	0.00	100.00	100
No.4	4.75	28	21	24.5	4.91	4.91	95.09	95
No.8	2.36	75	73	74	14.82	19.72	80.28	80
No.16	1.18	169	161	165	33.04	52.76	47.24	47
No.30	0.6	133	133	133	26.63	79.40	20.60	21
No.50	0.3	43	59	51	10.21	89.61	10.39	10
No.100	0.15	45	45	45	9.01	98.62	1.38	1
No.200	0.75	0.2	1	0.6	0.12	98.74	1.26	1
Pan		0.5	0.5	0.5	0.10	98.84	1.16	1
Sum		493.7	493.5	493.6	98.84	542,59		

Sieve analysis for red ash sample:

material research and testing center(MRTC)									
observation sheet									
sieve analysis of red ash									
ASTM sieve designation	sieve size(mm)	weight retained(gm)			retained %	cumulative retained (%)	cumulative passing(%)	Gradation
		sample I	sample II	average				
0.375(3/8)	9.5			0	0.00	0.00	100.00	100
No.4	4.75	23	26	24.5	4.93	4.93	95.07	95
No.8	2.36	81	73	77	15.49	20.42	79.58	80
No.16	1.18	141	158	149.5	30.08	50.51	49.49	49
No.30	0.6	126	121	123.5	24.85	75.36	24.64	25
No.50	0.3	72	78	75	15.09	90.45	9.55	10
No.100	0.15	51	35	43	8.65	99.10	0.90	1
No.200	0.75			0	0.00	99.10	0.90	1
Pan				0	0.00	99.10	0.90	1
Sum		494	491	492.5	99.10	538.99		

Sieve analysis for Sandsample:

Material research and testing center(MRTC)									
Observation sheet									
Sieve analysis of Sand									
ASTM sieve designation	sieve size(mm)		weight retained (gm)		retained %	Cumulative retained (%)	Cumulative passing (%)	Gradation
		sample I	sample II	average				
0.375(3/8)	9.5			0	0.00	0.00	100.00	100
No.4	4.75	25	21	23	4.62	4.62	95.38	95
No.8	2.36	90	70	80	16.06	20.68	79.32	79
No.16	1.18	150.2	160	155.1	31.14	51.82	48.18	48
No.30	0.6	139	130	134.5	27.01	78.83	21.17	21
No.50	0.3	76	90	83	16.66	95.49	4.51	5
No.100	0.15	7.6	8.3	7.95	1.60	97.09	2.91	3
No.200	0.75	10	15	12.5	2.51	99.60	0.40	0
Pan		0	0	0	0.00	99.60	0.40	0
Sum		497.8	494.3	496.05	99.60	547.73		

AppendixD

Test result of HCB

1. Trial of HCB

I. For HCB made by crushed aggregate

Sample	Weight	compressive strength
1	24	1.78
2	24.5	1.88
3	23.5	1.78
Average	**24**	**1.81**

II. For HCB made by pumice aggregate

Sample	Weight	compressive strength
1	16.5	1.3
2	17	1.6
3	15.5	1.26
Average	**16.33**	**1.39**

III. For HCB made by red ash aggregate

Sample	Weight	compressive strength
1	19	1.3
2	21	1.6
3	20.5	1.8
Average	**20.17**	**1.57**

IV. For HCB made by mixture of three of them aggregate

Sample	Weight	compressive strength
1	23	1.9
2	21.5	1.7
3	23.5	1.9
Average	**22.67**	**1.83**

2. Density of HCB

For crushed					For mixed			
	mass	volume	density			mass	volume	density
1	19	0.0172	1104.65		**1**	19.5	0.0172	1133.72
2	18	0.0172	1046.51		**2**	20	0.0172	1162.79
3	17.5	0.0172	1017.44		**3**	18.5	0.0172	1075.58
Average			**1056.2**		**Average**			**1124.03**
For red ash					**For pumice**			
	mass	volume	density			mass	volume	density
1	16	0.0172	930.233		**1**	14	0.0172	813.953
2	15	0.0172	872.093		**2**	13	0.0172	755.814
3	15.5	0.0172	901.163		**3**	13.5	0.0172	784.884
Average			901.163		**Average**			784.884

3. Compressive strength of 7th day test

I. For crushed HCB

Sample	wet weight	Surface dry weight	compressive strength
1	22	21.7	1.5
2	22.5	22.5	1.57
3	21.5	21.5	1.23
4	20	20	1.3
5	21.5	21.5	1.2
6	21	21	1.18
test result at 7th day test	**21.42**	**21.33**	**1.33**

II. For mixture of crushed, pumice and red ash

Sample	wet weight	Surface dry weight	Compressivestrength
1	22	21.5	1.6
2	20.5	20.5	1.7
3	22.5	22.5	1.72
4	22	22	1.6
5	21	21	1.5
6	21	21	1.5
Average	**21.50**	**21.42**	**1.60**

III. For red ash

Sample	wet weight	s.dry weight for each	compressive strength
1	19	18.46	1.3
2	21	21	1.6
3	20.5	20.5	1.5
4	20	20	1.7
5	20	20	1.5
6	20	20	1.6
Average	**20.08**	**19.99**	**1.53**

IV. Pumice

Sample	wet weight	Surface dry weight	compressive strength
1	16.5	15.85	1.3
2	17	17	1.6
3	15.5	15.5	1
4	16	16	1
5	17	17	1.2
6	18	18	0.9
Average	**16.67**	**16.56**	**1.17**

Compressive strength of 14thday test

I. For crushed

Sample	wet weight	Surface dry weight for each (kg)	compressive strength (Mpa)
1	20	20	1.9
2	19.5	19.5	1.8
3	21	21	1.9
4	21.5	21.5	1.97
5	21.5	21.5	1.96
6	20	20	1.85
Average	**20.58**	**20.58**	**1.90**

II. for mixture of three of them

Sample	wet weight (kg)	Surface dry weight for each (kg)	compressive strength (Mpa)
1	21	21	1.91
2	19	19	1.8
3	20.5	20.5	2
4	19	19	1.8
5	20.5	20.5	2
6	21	21	1.9
Average	**20.17**	**20.17**	**1.90**

III. for read ash HCB

Sample	wet weight (kg)	s.dry weight for each (kg)	compressive strength (Mpa)
1	18.5	18.5	1.76
2	19	19	1.86
3	19.5	19.5	1.89
4	20	20	1.9
5	19.5	19.5	1.81
6	18.5	18.5	1.75
Average	**19.17**	**19.17**	**1.83**

IV. for Pumice HCB

Sample	wet weight (kg)	s.dry weight for each (kg)	compressive strength (Mpa)
1	14	14	1.8
2	16	16	1.8
3	14.5	14.5	1.8
4	15	15	1.8
5	16	16	1.76
6	17	17	1.9
Average	**15.42**	**15.42**	**1.81**

Compressive strength at 28th day test

I. Crushed

Sample	wet weight (kg)	s.dry weight for each (kg)	compressive strength (Mpa)
1	19	19	2.1
2	18	18	2.2
3	17.5	17.5	2
4	20.5	20.5	2.12
5	19.5	19.5	1.9
6	20	20	2.2
Average	**19.08**	**19.08**	**2.09**

II. mixture of three of them

Sample	wet weight (kg)	s.dry weight for each (kg)	compressive strength (Mpa)
1	19	19	2.1
2	18	18	2
3	18.5	18.5	2.1
4	19	19	1.98
5	19.5	19.5	2
6	18	18	2
Average	**18.67**	**18.67**	**2.03**

III. red ash

Sample	wet weight (kg)	s.dry weight for each (kg)	compressive strength (Mpa)
1	16	16	1.92
2	16	16	1.8
3	15.5	15.5	1.9
4	16	16	2
5	15	15	1.89
6	15	15	1.96
Average	**15.58**	**15.58**	**1.91**

IV. Pumice

Sample	wet weight (kg)	s.dry weight for each (kg)	compressive strength (Mpa)
1	13.5	13.5	1.81
2	14	14	1.82
3	13	13	1.82
4	13	13	1.97
5	13.5	13.5	1.93
6	14	14	1.8
Average	**13.5**	**13.5**	**1.86**

Appendix E

Cost of material

Result for trial mix of aggregates

Mix	HCB type	Materials quantity in volume to obtain HCB m³					
		Cement		Aggregate		Sand	
1	Crushed HCB	0.31 m³	17%	0.48 m³	43%	0.99 m³	55%
2	Red ash HCB	0.35 m³	14 %	0.34 m³	30%	1.36 m³	55%
3	Pumice HCB	0.33 m³	16 %	0.36 m³	17%	1.35 m³	66%
4	Combined of three HCB	0.15 m³	8.6 %	0.16,0.16,0.16 m³	9.2,9.2,9.2%	1.10 m³	63%

Crushed HCB material used	Material quantity	Cost of material	
		Unit rate	amount
Cement	0.7 kg	2.5 birr	1.75
Crushed aggregate	0.037 m³	200/m³	7.41
Sand	0.065m³	60/m³	3.9
Water	0.16 liter	1.75 birr	0.28
Total material cost			**13.34 birr**

pumice HCB material used	Material quantity	Cost of material	
		Unit rate	amount
Cement	1.13 kg	2.5 birr	2.825
pumice aggregate	0.031 m³	82/m³	2.542
Sand	0.071m³	60/m³	4.26
water	0.5 liter	1.75 birr	0.875
Total material cost			**10.502 birr**

Red ash HCB	Material quantity	Cost of material	
		Unit rate	Amount
Cement	1.002 kg	2.5 birr	2.505
Red ash aggregate	0.05 m³	63/m³	3
Sand	0.061m³	60/m³	3.66
Water	0.43 liter	1.75 birr/m3	0.7525
Total material cost			**9.915** birr

Mixed HCB	Material quantity	Cost of material	
		Unit rate	Amount
Cement	0.801 kg	2.5 birr	2.0025
Crushed aggregate	0.0105 m³	200/m³	2.1
Pumice aggregate	0.0105 m³	82/m³	0.8324
Red ash aggregate	0.0105 m³	63/m³	0.6615
Sand	0.081m³	60/m³	4.86
water	0.075	1.75/m3	0.131
Total material cost			**10.5874**birr