JIMMA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT

Application of Fly Ash in Production of Hollow Concrete Block

A Thesis Submitted to school of graduate studies of Jimma University, Jimma University Institute of Technology, Department of Civil Engineering in Partial Fulfillment of the Requirements for the Degree of Masters Science in Construction Engineering and Management

BY:-MULUGETA DEBELE HORDOFA

October /2017
Jimma, Ethiopia

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October, 2017

Jimma, Ethiopia

DECLARATION

"I, Mulugeta Debele undersigned declare that the MSc thesis entitled "Application of Fly Ash in Production of Hollow Concrete Block, case study in alemgena" which is original work of my own, have not been presented to any other university and that all sources of materials used in this thesis have been duly acknowledged."

Name: Mulugeta Debele ________________ ________________

Signature Date

Place: Jimma University Institute of Technology faculty of Civil and Environmental Engineering (Construction Engineering and Management)

Date: October, 2017

This is to certify that the above declaration made by the candidate is correct to the best of my knowledge.

Main Advisor: Prof.Dr. -Ing.Esayas Alemayehu __________ _______________

Signature Date

Co-Advisor: Mr. Sintayehu Assefa (MSc) ____________ _____________

Signature Date

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ABSTRACT

Now days, 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 material used to produce hollow concrete block different from place to place depend on the availability of material. At Ayika Addise textiles and investment group used Coal as alternative for energy recourses to produce textiles at sebeta zone around alemgena. So that To prevent fly ash from entering the atmosphere the company used power plants machine to gather it and keep it from being carried with the exhaust gases out of the stack and used for production of HCB as construction material. Using fly ash by partial replacement of cement for production of HCB indirectly reduce environmental pollution.

The main objective of this study was to compare the compressive strength of hollow concrete blocks with and without fly ash. Specifically it focused in determining workability with and without fly ash, the compressive strength of both blocks, to compare the cost of production and to determine the optimum replacement of fly ash for ordinary port land cement. This experimental study was conducted by preparing two types of HCB test samples. The first test sample of HCB was produced by using mix proportion 1:3:2:1 of cement, sand, crushed aggregate 00 and crushed aggregate 01 respectively as a control group. The second sample HCBs were produced with fly ash by using cement, sand, crushed aggregate 00 and crushed aggregate 01. The ratio of cement to aggregate used was 1:6. Out of one part of cement the fly ash was replaced with 10%, 15%, 20%, 25% and 30%, amounts of fly ash by mass.

According to this study, the fly ash amount which gives a higher strength was achieved at 10%, 15%, 20%, 25% and 30% of fly ash content respectively, which was comparatively the compressive strength of HCB decrease as replacement of fly ash increase. Even though the result was satisfy the requirement of a higher compressive strength for load bearing hollow concrete block.

The production cost of HCBs with fly ash was found lower than the HCB without fly ash. Depend on workability; fly ash concrete has low workability than a conventional Portland cement concrete as shown on the discussion and as the percentage of fly ash increase the workability was decrease. The study further recommended to the micro and small HCB producers to increase the production of HCB with fly ash, for the contractors and clients of Alemgena to use this product.

Keywords*- Compressive Strength, Fly Ash, Hollow concrete block, workability,*

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ABBREVIATION

AASHTO	American Association State Highway and Transportation Officials
ASTM	American Society for Testing and Materials
ACI	American Concrete Institute
Al_2O_3	Aluminum oxide
CaO	Calcium oxide
CMU	concrete masonry unit
CO_2	carbon dioxide
ES	Ethiopian Standard
ESP	Electrostatic precipitation
Fe_2O_3	Iron oxide
HCB	Hollow concrete block
JU	Jimma University
K_2O	Potassium oxide
MgO	Magnesium oxide
Na_2O	Sodium oxide
OPC	Ordinary Portland cement
SiO_2	Silicon dioxide
SO_3	Sulphur Trioxide
TiO_2	Titanium dioxide
UF	utilization factor

CHAPTER ONE
INTRODUCTION

1.1 Background of the study

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. These hollow blocks are commonly used in compound walls due to its low cost. These hollow blocks are more useful due to its lightweight and ease of ventilation. The blocks and bricks are made out of mixture of cement, sand and stone chips. 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 (MOHUPAGI, 2009).

Cement concrete hollow blocks have an important place in modern building industry. They are cost effective and better alternative to burnt clay bricks by virtue of their good durability, fire resistance, partial resistance to sound, thermal insulation, small dead load and high speed of construction. Concrete hollow blocks being usually larger in size than the normal clay building bricks and less mortar is required, faster of construction is achieved (MOIG, 2011).

The modern recommended practice is to dispense with several 'on the spot' operations and replace them with the manufactured materials. That site operation is often left to workers who do not have the skills to the desirable extent and cannot be adequately supervised, resulting in such work often being shady and expensive. Economical and efficient construction techniques demand excellent micro-planning, determining as to which of the building materials should be manufactured on a mass scale, setting out and promoting such manufacturing facilities and popularizing their use(Maroliya., 2012).

The development of construction technology is closely related to the development of adequate mechanization and handling technology, the latter involves both the provisions of equipment as well as the handling dexterity.

Recycling of industrial wastes has actually environmental, economical and technical benefits. These benefits can be seen from two different angles, one from the point of the waste producer and the other from the user part.

For the producer, the benefits of recycling industrial wastes are economical and environmental for the user additional technical benefits may be attained from recycling. For the producer, the environmental benefit can be attained as far as the waste is recycled. It is independent of where it is recycled. But the economical benefit is determined on the demand for the waste by different users. One of the greatest environmental concerns in construction industry is the production of cement which emits large amount of CO_2 gas to the atmosphere. It is estimated that 1 tone clinker production releases 1 tone CO_2 and Mixing of clinker to supplementary materials called blending is considered as a very effective way to reduce CO_2 emission (sing, 2015).

1.2. Statements of the problem

In the view of global warming efforts one is to reduce the emission of CO_2 to the environment. Therefore Cement Industry is the major in contributor in the emission of CO_2 as well as using up high levels of energy resources in the production of cement. By replacing cement with a material of pozzolanic characteristic, such as the coal ash (fly ash), the cement and the concrete industry together can meet the growing demand in the construction industry as well as help in reducing the environmental pollution (Jatale, 2013).

Coming to Ethiopia's energy resource condition, the country's energy demand is increasing from time to time. Due to high population growth industrial development improved living standards and other factors. More over most of the major economic sectors are dependent on imported petroleum products, while the prices of these products are increasing at alarming rates; due to these interrelated problems the country has been search alternative options that utilize locally available resources. For example recent exploration studies show that there are more than 300 million tons of coal reserves in different parts of the country as described in appendix four , yet not put in to economic uses(Elfu, 2007). Coal is one of the most important non-renewable natural local energy carrier mineral resources; it can contribute significantly for the economic growth and to make Ethiopia self-reliant as it can be used for different economic functions such as:-Domestic fuel (source of energy for house hold); fuel for thermal plants (ceramic plant processing; cement manufacture), power generation (electric power) (Elfu, 2007) And When coal is burned in a power plant, it leaves behind of the furnace bottom ash, and some of which is carried upward by the hot combustion gases of the furnace which is fly ash.

To prevent fly ash from entering the atmosphere, power plants use various collection devices to gather it and keep it from being carried with the exhaust gases out of the stack and used for construction work. So in Sebeta Zone around Alemgena the Ayka Addise Textile and Investment Groups Company have been used 60 tons coal to manufacture textile per day, from those 17% was fly ash. The Ayka Addise Textile and Investment Groups coal waste estimated annually around more than 3723 m^3, which implies that using coal waste as cement replacing material can indirectly reduce CO_2emission to the atmosphere by3723 m^3 or 62.05% annually.

1.3. Significance of the Study

This study is to compare the compressive strength of HCB using fly ash and without using fly ash around sebeta zone which is providing helpful information to various stake holders to save environmental and cost minimization for production of HCB. From the study Owners, contractors and consultants are benefit as far as the waste of fly recycled as a source of information for building construction projects as alternative material a in sebeta zone.

The study is provide lessons that will help the concerned body can come up with appropriate measures to address problems resulting from using fly ash on the compressive strength of HCB and also other researchers will be using the findings as a reference for further research on compressive strength of HCB.

1.4. Justification of the study

The motivation for conducting this study was providing the bench marks under which the compressive strength of hollow concrete block should be improved. Facts show that; in sebeta zone there are a lot of companies, from that Ayika Addise textile and investment group have been using coal for energy production. When coal is burned in a power plant, it leaves behind of the furnace bottom ash and some of which is carried upward by the hot combustion gases of the furnace which is fly ash. To prevent fly ash from entering the atmosphere, power plants use various collection devices to gather it and keep it from being carried with the exhaust gases out of the stack and used fly ash as alternative material for production of HCB.

1.5. Research Questions

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

1. Is that important to determining physical property of material and chemical analysis for compressive strength?
2. Dose the result of the test was satisfy the Ethiopian building construction standard of HCB?
3. How determine the comparative replacement of fly ash by cement to produce load bearing HCB.
4. Is that has cost benefit using partial replacement of fly ash by cement to produce hollow block concrete?

1.6. Objectives

1.6.1. General objective

The key objective of this research study was to determine the compressive strength of hollow concrete block with and without fly ash

1.6.2. Specific Objectives.

- ❖ To determine physical property of material and chemical analysis of fly ash.
- ❖ To determine the compressive strength HCB with and without coal ash.
- ❖ To determine the comparative replacement of fly ash by cement to produce load bearing HCB.
- ❖ To compare the cost of production using partial replacement of cement by fly ash to produce HCB with respect to conventional HCB.

So that the researcher was conduct to check the compressive strength of HCB by using fly ashes as alternative material for construction work.

CHAPTER TWO
REVIEW OF LITERATURE

2.1 Introduction

This chapter provides a review of literature on the comparing the compressive strength of Using coal ash for the Productions of hollow Concreting block materials. The main purpose of a literature review is to establish the academic and research areas that are relevant to the subject under study.

2.2. Theoretical review

One of the basic requirements of human being to sustain in the world is shelter. After evolution of human being, the need of shelter meant for safety, arises. In ancient time, man started taking shelter in caves, excavated below ground level and under hanging mountain cliffs and this type of shelter just provided safe place from environmental limit. The concept of stability and safety as per structural features of shelter were completely out of mind. With the development and maturity of human mind, man began to modify the structural formation of shelter so as to address the increasing needs and facilities which an optimum shelter design possessed. After achieving a feat by the use of easily available material like mud in construction walls and then the technique of burnt clay brick masonry to form structural part of shelter, there was still a long journey is coming out for the best possible material for construction of stable and safe structural units of shelter. The desire for search of safe and stable structural materials keeping in view the economy of whole structure, paved way for usage of hollow concrete blocks (Thorat, 2015).

Cellular blocks are masonry units that contain one or more formed voids that do not fully penetrate the block. The selection of cellular blocks can have significant advantages over solid blocks where weight is a prime consideration. The reduced unit weight makes for ease of handling, reduced floor/foundation loading, economic and efficient productivity. They do not require special laying techniques and can be laid on a full bed of standard 1:1:5-6 cement: lime: sand (or equivalent) or general purpose mortar for most applications(AOCP, 2007)

Hollow concrete blocks are substitutes for conventional bricks and stones in building construction.

They are lighter than bricks, easier to place and also confer economics in foundation cost and consumption of cement. In comparison to conventional bricks, they offer the advantages of reduced mortar consumption, light weight and greater speed of masonry work (Maroliya, 2012).

In view of the fact that the builders are yet to become familiar with the use of hollow concrete blocks, this will help them to appreciate the essential constructional details and adopt hollow concrete block masonry in a large scale wherever it is economical (Maroliya., 2012). In view of these advantages, hollow concrete blocks are being increasingly used in construction activities.

2.3. Materials for hollow concrete block

2.3.1 .Cement

Cement paste is the binder in concrete or mortar that holds the fine aggregate, coarse aggregate or other constituent's together in a hardened mass. The properties of concrete depend on the quantities and qualities of its constituents. Because cement is the most active component of concrete and usually has the greatest unit cost, its selection and proper use are important in obtaining most economically the balance of properties desired for a particular concrete mixture. Most cement will provide adequate levels of strength and durability for general use. It is usually satisfactory and advisable to use general-purpose cement that is readily obtainable locally. General-purpose cements are described in ASTM C 150 as Type I or Type II, in ASTM C 595. When such cement is manufactured and used in large quantity, it is likely to be uniform and its performance under local conditions will be known (ACI, committee 1999).

The three constituents of hydraulic cements are lime, silica and alumina. In addition, most cement contains small proportions of iron oxide, magnesia, sulphur trioxide and alkalis. There has been a change in the composition of Portland cement over the years, mainly reflected in the increase in lime content and in a slight decrease in silica content. An increase in lime content beyond a certain value makes it difficult to combine completely with other compounds. Consequently, free lime will exist in the clinker and will result in unsound cement.

An increase in silica content at the expense of alumina and ferric oxide makes the cement difficult to combine and form clinker (S.K.Duggal, 208).The approximate limits of chemical composition in cement are given in table 2.1

Table 2.1 Chemical composition of Portland cement

Oxide	Function	Composition (%)
CaO	Controls strength and soundness its deficiency reduces strength and setting time	60-65
SiO_2	Gives strength Excess of it causes slow setting	17-25
Al_2O_3	Responsible for quick setting, if in excess, it lowers the strength	3-8
Fe_2O_3	Gives colour and helps in fusion of different ingredients	0.5-6
MgO	Imparts colour and hardness If in excess, it causes cracks in mortar and concrete and unsoundness	0.5-4
$Na_2O + K_2O$	These are residues, and if in excess cause efflorescence and cracking makes cement sound	0.5-1.3
TiO_2		0.1-0.4
P_2O_5		0.1-0.2
SO_3		1-2

Source **(S.K.Duggal, 208)**

2.3.2. Fly Ash

Fly ash is a waste material derived from the burning of coal in power generating plants. As the demand for electricity increases so does the production of fly ash. Since its disposal is costly and environmentally unsound, much research is currently underway to find engineered uses for this waste material (Wanzek, 1992).

Fly ash is byproduct of coal combustion used in order to generate electricity, which is widely available worldwide and lead to waste management proposal. Thus, geopolymer concrete produced by using fly ash is an excellent alternative to overcome the abundant fly ash by product. Fly ash is a pozzolanic material which is being used as a supplement material in the production of Portland cement concrete due to its cementations properties (Nordin, 2016) .

The physical, mineralogical and chemical properties of fly ash will strongly affect the performance of fly ash. The use of high fineness and low carbon content of fly ash will reduces the water demand of concrete which allow the production of concrete at lower water content when compared to a Portland cement concrete of the same workability (Nordin, 2016).

2.3.3. How fly ash helps in concrete?

2.3.3.1 Reduced Heat of Hydration

In concrete mix, when water and cement come in contact, a chemical reaction initiates that produces binding material and consolidates the concrete mass. The process is exothermic and heat is released which increases the temperature of the mass When fly ash is present in the concrete mass, it plays dual role for the strength development. Fly ash reacts with released lime and produces binder as explained above and renders additional strength to the concrete mass. The unreactive portion of fly ash act as micro aggregates and fills up the matrix to render packing effect and results in increased strength (NTPCIEG, 2007).

The large temperature rise of concrete mass exerts temperature stresses and can lead micro cracks. When fly ash is used as part of cementitious material, quantum of heat liberated is low and staggers through pozzolanic reactions and thus reduces micro-cracking and improves soundness of concrete mass (Openshaw, 1992).

2.3.3.2 Workability of Concrete

Fly ash particles are generally spherical in shape and reduce the water requirement for a given slump. The spherical shape helps to reduce friction between aggregates and between concrete and pump line and thus increases workability and improve pump ability of concrete.

Fly ash use in concrete increases fines volume and decreases water content and thus reduces bleeding of concrete (Subramani, 2015).

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected. The test method is widely standardized throughout the world, including in ASTM C143 in the United States and EN 12350-2 in Europe. The apparatus consists of a mold in the shape of a frustum of a cone with a base diameter of 8 inches, a top diameter of 4 inches, and a height of 12 inches. The mold is filled with concrete in three layers of equal volume.

Each layer is compacted with 25 strokes of a tamping rod. The slump cone mold is lifted vertically upward and the change in height of the concrete is measured. Four types of slumps are commonly encountered, as shown in Figure 2.1. The only type of slump permissible under ASTM C143 is frequently referred to as the “true” slump, where the concrete remains intact and retains a symmetric shape (Koehler, 2003).

A collapse slump will generally mean that the mix is too wet or that it is a high workability mix, for which the slump test is not appropriate. Very dry mixes; having slump 0 – 25 mm are used in road , low workability mixes; having slump 10 – 40 mm are used for foundations with light reinforcement, medium workability mixes; 50 - 90 for normal reinforced concrete placed with vibration, high workability concrete; > 100 mm (Arthur, 2007).

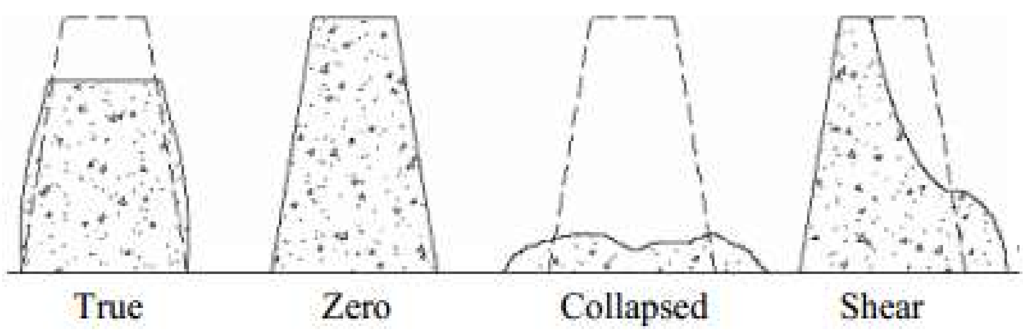

Fig. 2.1 Four Types of Slump

2.3.3.3 Permeability and Corrosion Protection

Water is essential constituent of concrete preparation. When concrete is hardened, part of the entrapped water in the concrete mass is consumed by cement mineralogy for hydration. Some part of entrapped water evaporates, thus leaving porous channel to the extent of volume occupied by the water. Some part of this porous volume is filled by the hydrated products of the cement paste. The remaining part of the voids consist capillary voids and gives way for ingress of water. Similarly, the liberated lime by hydration of cement is water-soluble and is leached out from hardened concrete mass, leaving capillary voids for the ingress of water (NTPCIEG, 2007).

Higher the water cement ratio, higher will be the porosity and thus higher will be the permeability. The permeability makes the ingress of moisture and air easy and is the cause for corrosion of reinforcement.

Higher permeability facilitates ingress of chloride ions into concrete and is the main cause for initiation of chloride induced corrosion (NTPCIEG, 2007) .

Additional cementitious material results from reaction between liberated surplus lime and fly ash, blocks these capillary voids and also reduces the risk of leakage of surplus free lime and thereby reduces permeability of concrete.

2.3.3.4 Environmental Benefits of Fly Ash Use in Concrete

Use of fly ash in concrete imparts several environmental benefits and thus it is eco-friendly. It saves the cement requirement for the same strength thus saving of raw materials such as limestone, coal etc required for manufacture of cement (Consultancy, 2009).

Manufacture of cement is high-energy intensive industry. In the manufacturing of one tone of cement, about 1tonne of CO_2 is emitted and goes to atmosphere and less requirement of cement means less emission of result in reduction in green house gas emission. Due to low calorific value and high ash content in Indian Coal, thermal power plants in India, are producing huge quantity of fly ash. This huge quantity is being stored / disposed off in ash pond areas. The ash ponds acquire large areas of agricultural land. Use of fly ash reduces area requirement for pond, thus saving of good agricultural land (NTPCIEG, 2007).

2.3.4 Chemistry of Fly ash

Fly ash is complex material having wide range of chemical, physical and mineralogical composition. The chemistry of fly ash depends on the type of coal burnt in boiler furnace, temperature of furnace, degree of pulverization of coal, efficiency of ESP etc.

2.3.4.1 Chemical Composition of fly ash

The major constituents of most of the fly ashes are Silica oxide (SiO), alumina oxide ((Al_2O_3), ferric oxide (Fe_2O_3) and calcium oxide (CaO). The other minor constituent of the fly ash are MgO, Na_2 O, and K_2O, SO, MnO, TiO and unburned carbon. There is wide range of variation in the principal constituents - Silica (25- 60%), Alumina (10-30%) and ferric oxide (5-25%). When the sum of these three principal constituents is 70% or more and reactive calcium oxide is less than 10% - technically the fly ash is considered as or class F fly ash. Such types of fly ash have been produced by burning of anthracite or bituminous coal and possess pozzolanic properties. If the sum of these three constituent is equal or more than 50% and reactive calcium oxide is not less than 10%, fly ash will be considered as also called as class C fly ash. These types of fly ash are commonly produced by burning of lignite or sub-bituminous coal and possess both pozzolanic and hydraulic properties (Openshaw, 1992).

Siliceous fly ash characteristically contains a large part of silicate glass of high silica content and crystalline phases of low reactivity mullite, magnetite and quartz. The active constituents of class F fly ash is siliceous or alumino-silicate glass.

In calcareous or class C fly ash the active constituents are calcium alumino-silicate glass, free lime (CaO), anhydrate (CaSO), tricalcium aluminate and rarely, calcium silicate. The glassy materials of fly ash are reactive with the calcium and alkali hydroxides released from cement fly ash system and forms cementitious gel, which provide additional strength (NTPCIEG, 2007).

2.3.4.2 Physical Properties of fly ash

The fly ash particles are generally glassy, solid or hollow and spherical in shape. The hollow spherical particles are called as cenospheres. The fineness of individual fly ash particles are rage from 1micron to 1mm size. The fineness of fly ash particles has a significant influence on its performance in cement concrete. The fineness of particles is measured by measuring specific surface area of fly ash by Blaine's specific area technique. Greater the surface area more will be the fineness of fly ash. The other method used for measuring fineness of fly ash is dry and wet sieving. The specific gravity of fly ash varies over a wide range of 1.9 to 2.55 (Openshaw, 1992).

2.3.5 Pozzolanic Properties of fly ash

Fly Ash is a pozzolanic material which is defined as siliceous and aluminous material which in itself possesses little or no cementitious value, chemically react with Calcium Hydroxide (lime) in presence of water at ordinary temperature and form soluble compound comprises cementitious property similar to cement. The Pozzolana term came from Roman. About 2,000 years ago, Roman used volcanic ash along with lime and sand to produce mortars, which possesses superior strength characteristics & resistances to corrosive water (NTPCIEG, 2007).

The best variety of this volcanic ash was obtained from the locality of pozzoli and thus the volcanic ash had acquired the name of Pozzolana.

2.3.6 Quality of Fly Ash as per BIS, ASTM

2.3.6.1 Bureau of Indian Standard

To utilize fly ash as a Pozzolana in Cement concrete and Cement Mortar, Bureau of Indian Standard (BIS) has formulated IS: 3812 Part - 1 2003. In this code quality requirement for siliceous fly ash (class F fly ash) and calcareous fly ash (class C fly ash) with respect its chemical and physical composition have been specified in table2. 2 & table 2.3

Table 2.2 Chemical Requirement type of fly ash according to IS (3812 Part - 1 2003)

Sl. No.	Characteristic	Requirements	
		Siliceous fly ash	**Calcareous fly ash**
i)	Silicon dioxide (SiO2) + Aluminum oxide (Al2O3) + Iron oxide (Fe2O3), in percent by mass, Min...	70	50
ii)	Silicon dioxide in percent by mass, Min.	35	25
iii)	Reactive Silica in percent by mass, Min (Optional Test)	20	20
iv)	Magnesium Oxide (MgO), in percent by mass, Max. .	5	5

v)	Total sulphur as sulphur trioxide (SO_3), in percent by mass, Max.	3	3
vi)	Available alkalis as Sodium oxide (Na_2O), percent by mass, Max.	1.5	1.5
vii)	Total Chlorides in percent by mass, Max	0.05	0.05
viii)	Loss on Ignition, in percent by mass, Max.	5	5

Table 2.3 Physical Requirements of fly ash according to IS (3812 Part - 1 2003)

Sl. No	**Characteristics**	**Requirements for Siliceous fly ash and Calcareous fly ash**
i)	Fineness- Specific surface in m2/kg by Blaine's permeability method, Min.	320
ii)	A particle retained on 45micron IS sieve (wet sieving) in percent, Max. (Optional Test)	34
iii)	lime reactivity – Average compressive strength in N/mm2, Min.	4.5
iv)	Compressive strength at 28 days in N/mm2, Min.	Not less than 80 percent of the strength of corresponding plain cement mortar cubes
v)	Soundness by autoclave test - Expansion of specimen in percent, Max.	0.8

2.3.6.2 ASTM International for Fly ash

ASTM International C-618-03 specifies the chemical composition and physical requirements for fly ash to be used as a mineral admixture in concrete. The standard requirements are given in table2. 4 and table 2.5:

Table2. 4 Chemical Requirements Type of Fly Ash according to ASTM (C-618-03)

Sl. No.	**Characteristic**	**Requirements**	
		Class F (Siliceous fly ash)	**Class C (Calcareous fly ash)**
i)	Silicon dioxide (SiO_2) + Aluminium oxide (Al_2O_3) + Iron oxide (Fe_2O_3), in percent by mass, Min.	70	50
ii)	Sulfur trioxide (SO_3), max. Percent	5	5
iii)	Moisture content, max. , percent	3	3
iv)	Loss on ignition, max., percent	6	6

Table2. 5 Physical Requirements of fly ash according to ASTM (C-618)

Sl. No	**Characteristics**	**Requirements for class F & Class C fly ash**
i)	Fineness- amount retained when wet sieved on 45 micron (No. 325) sieve, Max., percent	34
ii)	Strength Activity index ❖ With Portland Cement, at 7 days, min. , percent of control ❖ With Portland cement, at 28 days, min,, percent of control	 75^{C} 75^{C}
iii)	Water requirement, max, percent of control	105
iv)	Soundness Autoclave expansion or contraction, Max., percent	0.8

v)	Uniformity Requirements: The density and fineness of individual samples shall not vary from the average established by ten preceding tests, or by all preceding tests if the number is less than ten, by more than ❖ Density, max. Variation from average, percent. ❖ Percent retained on 45 micron (no. 325), max. variation, percentage points from average	 -5 -5

2.3.7 Production of Fly Ash

In the production of fly ash, coal is first pulverized in grinding mills before being blown with air into the burning zone of the boiler. In this zone the coal combusts producing heat with temperatures reaching approximately 1500°C (2700°F). At this temperature the non-combustible inorganic minerals (such as quartz, calcite, gypsum, pyrite, feldspar and clay minerals) melt in the furnace and fuse together as tiny molten droplets. These droplets are carried from the combustion chamber of a furnace by exhaust or flue gases. Once free of the burning zone, the droplets cool to form spherical glassy particles called fly ash. The fly ash is collected from the exhaust gases by mechanical and electrostatic precipitators (Thomas, 2007). This figure was show the Schematic layout of a coal-fired electrical generating station.

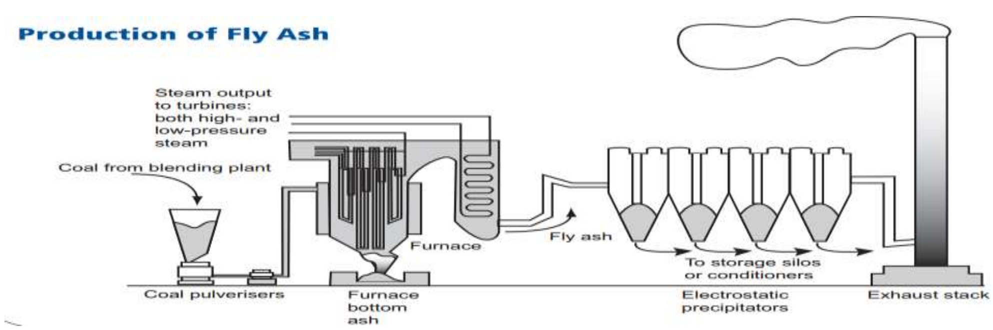

Fig.2.2 production of fly ash

Fly ash is a by-product of burning pulverized coal in an electrical generating station. Specifically, it is the unburned residue that is carried away from the burning zone in the boiler by the flue gases and then collected by either mechanical or electrostatic separators at shown in the above Figure. The heavier unburned material drops to the bottom of the furnace and is termed bottom ash; this material is not generally suitable for use as a cementitious material for concrete, but is used in the manufacture of concrete masonry block (Thomas, 2007).

2.3.8. Types of Fly-Ash

I) Class F fly- ash

The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementations compounds (Kartikey, 2013).

II) Class C fly ash

Fly ash produced from the burning of younger lignite or sub bituminous coal, in addition to having pozzolanic properties, also has some self-cementing properties. In the presence of water, Class C fly ash will harden and gain strength over time. Class C fly ash generally contains more than 20% lime (CaO). Unlike Class F, self-cementing Class C fly ash does not require an activator. Alkali and sulfate (SO4) contents are generally higher in Class C fly ashes (Kartikey, 2013).

2.3.9 Disposal of Fly Ash

In the past, Fly Ash produced from coal combustion in thermal power plants was simply dispersed into the atmosphere. At thermal power plants, Fly Ash is presently collected or disposed by using either dry or wet systems. Worldwide, more than 65% of Fly Ash is disposed in landfills and ash ponds (Millia, 2013). The Fly Ash is a resource material, if not managed well, this may pose environmental and health problems.

I. Dry Fly Ash Disposal system

In dry disposal system, electrostatic precipitation (ESP) is the most popular and widely used method of emission control today which enables collection of dry Fly Ash. After collecting the Fly Ash in ESP, it is then transported by trucks or conveyors at the sight and disposed of by constructing a dry embankment (Jamianagar, 2013)

II. Wet Fly Ash Disposal System

In wet disposal system, the Fly Ash is mixed with water and transported as slurry through pipe and disposed of in ash ponds or dumping areas near the plants. Being cheaper than any other manner of Fly Ash removal, it is widely used method at present in India (Jamianagar, 2013).

III. Environmental Considerations

The environmental aspect of Fly Ash disposal aims at minimizing air and water pollution. Directly related to these concerns is the additional environmental goal of aesthetically enhancing ash disposal facilities. The Fly Ash produced by thermal power plants can cause all three environmental risks-air, surface water and ground water pollution (kentuck, 2001).

2.3.10 Utilization of Fly Ash

There are numerous advantages of Fly Ash utilization some of them are follows: Saving of space for disposal , Saving of scare of natural resources , Energy saving, firstly because the material is automatically produced as a by-product and no energy is consumed for its generation and secondly because it can replace material which otherwise would need to be produced by consuming energy , Protection of environment, as in construction it can partly replace cement, production of which entails energy consumption and CO2 emissions (Jamia, 2013).

2.3.11 Effect of Fly Ash on Properties of Concrete

Fly ash is suitable for utilization as pozzolanic material and it reacts chemically with calcium hydroxide at room temperature to form compounds that have cementation properties in the presence of moisture. Fly ash consists of a high amount of reactive silica and alumina.

These reactive elements complete the hydration chemistry of cement. On hydration, cement produces C–S–H gel and free lime such as $CaOH_2$, which binds and reinforces the concrete. Water, sulphates and CO_2 that exist in the environment attack the free lime causing the deterioration of the concrete. However, cement technologists observed that the reactive elements present in fly ash resolves the free lime problem of the cement and turn the concrete from deteriorate into durable. The distinction between fly ash and OPC becomes apparent under optical microscope. The morphological properties of fly ash make the fly ash to flow and blend freely in mixtures.(Nordin, 2016)

2.3.12. Introduction to aggregates

Aggregates are a granular material used in construction. The most common natural aggregates of mineral origin are sand, gravel and crushed rock. A product by itself when used as railway ballast or arm our stones, aggregates are also a raw material used in the manufacture of other vital construction products such as ready-mixed concrete (made of 80% aggregates), pre-cast products, asphalt (made of 95% aggregates), lime and cement(UEPG, 2006) According to the source material aggregates can be classified as,

- Natural aggregates, produced from mineral sources. Sand and gravel are natural aggregates resulting from rock erosion. Crushed rock is extracted from quarries.
- Secondary aggregates, secondary materials arising from industrial processes.
- Recycled aggregates, produced from processing material previously used in construction.

Natural aggregates come from rock of which there are three broad geological classifications: igneous, sedimentary and metamorphic. Natural aggregates are extracted from natural deposits by quarrying and mining. Rock is blasted or dug and then reduced in size by series of crushers and screens to prepare for aggregate use. Sand and gravel are extracted from alluvial or marine deposits.

2.3.12.1 Fine Aggregate

Those fractions from 4.75 mm to 150 micron are termed as fine aggregate. The river sand and crushed sand is used in combination as fine aggregate conforming to the requirements of IS: 383. The river sand is washed and screened, to eliminate deleterious materials and over size particles (Pitroda, 2012).Fine aggregate is the inert or chemically inactive material, most of which passes through a 4.75 mm IS sieve and contains not more than 5 per cent coarser material.

The fine aggregates serve the purpose of filling all the open spaces in between the coarse particles (Kattankulathur, 2016).Thus; it reduces the porosity of the final mass and considerably increases its strength.

Usually, natural river sand is used as a fine aggregate However, at places, where natural sand is not available economically; finely crushed stone may be used as a fine aggregate (Kattankulathur, 2016).

2.3.12 .2 Coarse Aggregate

Construction aggregate, or simply "aggregate", is a broad category of coarse particulate material used in construction, including sand, gravel etc. Maximum coarse aggregate size used is 20 mm and the minimum coarse aggregate size used is 12 mm. coarse aggregates are particles greater than 4.75mm, but generally range between 9.5mm to 37.5 mm in diameter. Coarse aggregate is produced by crushing quarry rock, boulders, cobbles, or large-size gravel. After harvesting, aggregate is processed: crushed, screened, and washed to obtain proper cleanliness and gradation (Kattankulathur, 2016).

2.3.13. Setting Time

The impact of fly ash on the setting behavior of concrete is dependent not only on the composition and quantity of fly ash used, but also on the type and amount of cement, the water-to-cementitious materials ratio (w/cm), the type and amount of chemical admixtures, and the concrete temperature. It is fairly well-established that low-calcium fly ashes extend both the initial and final set of concrete (Thomas, 2007).

During hot weather the amount of retardation due to fly ash tends to be small and is likely to be a benefit in many cases. During cold weather, the use of fly ash, especially at high levels of replacement, can lead to very significant delays in both the initial and final set. These delays may result in placement difficulties especially with regards to the timing of finishing operations for floor slabs and pavements or the provision of protection to prevent freezing of the plastic concrete. Practical considerations may require that the fly ash content is limited during cold-weather concreting (Wang, 2006).

The use of set-accelerating admixtures may wholly or partially offset the retarding effect of the fly ash. The setting time can also be reduced by using ASTM C150 Type III (or ASTM C1157 Type HE) cement or by increasing the initial temperature of the concrete during production (for example, by heating mix water and/or aggregates). Higher-calcium fly ashes generally retard setting to a lesser degree than low-calcium fly ashes, probably because the hydraulic reactivity of fly ash increases with increasing calcium content. However, the effect of high-calcium fly ashes is more difficult to predict because the use of some of these ashes with certain cement-admixture combinations can lead to either rapid (or even flash) setting or to severely retard setting (Roberts, 2007)

2.3.14. Hollow Concrete blocks (HCB) Production.

Cement concrete hollow blocks have an important place in modern building industry. They are cost effective and better alternative to burnt clay bricks by virtue of their good durability, fire resistance, partial resistance to sound, thermal insulation, small dead load and high speed of construction. Concrete hollow blocks being usually larger in size than the normal clay building bricks and less mortar is required, faster in construction (MSMEDI, 2011).

There are different types of machine and equipment used to produce HCB, like hydraulically operated concrete block making machine, Concrete mixer, Water dosing pump, Ram and mould for hollow blocks, Wheel borrows with pneumatic wheels and etc.

According to low cost housing project of Ethiopia (2003), the machines used to produce HCBs are electrical vibrating machines which have 1.5 HP motor to make sure, that the vibration is strong enough to compact the concrete sufficiently in the moulds and to achieve the required strength. Before starting production the different materials used to produce the HCB will be dry-mixed thoroughly on a clean and dry ground by hand. Then the mixture will be put in the mixer with the appropriate amount of water required (water to cement ratio of 0.49 – 0.55). The mixture is inserted into the mould and vibrated for about 60 seconds before extruded as HCBs. The machines can produce three pieces at a time and it was transported by two people on a wooden pallet.

The HCB remains on the wooden pallet for 24 hrs. Then it is being cured covered by a plastic sheet to enhance the curing process and preventing the water from evaporation. Curing-time is at least 10 days before using the HCBs for construction. It is important to write the date of production on the HCB so that the mason can easily identify the HCBs, ready for construction (MFAELH, 2003).

The materials required for the production of HCBs and their mixing ratio differs from site to site depending on the availability of the building materials and the ratio that fulfils the required strength. This holds true for all types of HCBs production (MFAELH, 2003).

Table 2.6 Proportioning of concrete for the manufacture of CHBs

This is done in two different ways	**By weight or volume. The most common method is by volume (e.g. using a bucket)**
Mixture	For CHBs: Mix Proportion 1:7, as per structural engineer's specification
Water	Clean water should be used. Shall not exceed 28 liters per 40 kilograms per bag of cement, slump test (as per ASTM C-143) shall not exceed 10cm, unless specified by a structural engineer.
Mixing time	If batch mixer is used, use accurate timing and measuring devices to operate as per manufacturer's instructions. Revolutions should be between 14 and 20 per minute.
Curing	After being removed from the mould, the CHBs should be covered with a plastic sheet or tarpaulin and kept damp and shaded for at least 7 days in order to effectively cure. This can be achieved by continually spraying them with water or keeping them under water in tanks. A good curing process leads to less cracking and a stronger, harder, denser and more durable concrete.

Source,(GSC, 2014)

2.3.14.1 Classification of hollow concrete blocks in different standards

I) Based on Ethiopian standard (ES).

According to ES 596 (2001) hollow concrete blocks shall meet four classes depending on their compressive strength, as class A, class B, class C and class D

- ❖ Class A, B and C are load bearings
- ❖ Class D: are used for non-load

Table 2.7 Compressive strength of hollow concrete blocks at 28th days

Type of hollow concrete block	Class	Minimum compressive strength (N/mm2)	
		Average of 6 unit	**Individual units**
Load bearing	A	5.5	5.0
	B	4.5	4.0
	C	3.5	3.0
Non load bearing	D	2.0	1.8

Source, ES 596 (2001)

II) Based on American Society for Testing and Materials

According to ASTM C90-70 and ASTM C129-70 hollow concrete blocks are mainly classified as load bearing and non- load bearing in terms of compressive strength. The classification is listed in Table (2.7) as shown below.

Table.2.8 Compressive strength of hollow concrete blocks (ASTM C90-70) and (ASTM C-129-70)

Type of hollow concrete block	Grade	Minimum compressive strength (N/mm2)	
		Average of 3 units	**Individual units**
Load bearing	Type N (I and II)	6.9	5.5
	Type S (I and II)	4.8	4.1
Non load bearing	(type I and type II)	Average of 5 units	Individual units
		3.5	3.0

As shown in Table 2.7, ASTM classifies hollow concrete blocks as load bearing and non-load bearing. There are two grades under load bearing these are type N and type S. grade N are used for general use such as in exterior walls below and above grade level. Grade S are used only above grade level. Both grades have two types such as moisture controlled units known as Type I and non moisture controlled units known as type II. The non-load bearings are also grouped under type I and type II.

Hollow concrete blocks used for wall construction classified as load bearing and non load bearing depends on their structural function. According to ASTM C90-70 hollow load bearing concrete blocks have three weight classifications those are normal weight, medium weight and light weight blocks as listed in Table 2.8 (Kahsay, 2014)

Table 2.9 weight classification of hollow concrete block in ASTM C90-70

Classification of hollow block	**kg/m3**
Light weight	Less than 1682
Medium weight	1682-2002
Normal weight	2002 or more

2.3.15 Block Density

For hollow concrete, low density is probably the most characteristic feature. This is due to the holes. In addition, it depend primary on the aggregate density and the proportions of aggregate because the particle density of individual grading fraction can differ considerably and thus will affect the density of concrete. This property also influenced by the cement, water and air contents (ACI Committee 213, 2003).

$$density = \frac{mass\ of\ block\ inkg}{volume\ of\ specimen\ in\ m3}$$ ....eq (2.1)

2.3.16 Compressive Strength

Compressive strength is a mechanical test used to find the maximum amount of compressive load that, under a gradually applied load, a given solid material can sustain without fracture. Compressive strength is calculated by dividing the maximum load by the original cross-sectional area of a specimen in a compression test. Some materials fracture at their compressive strength limit; others deform irreversibly. Compressive strength is a key value for designing structures. The compressive strength of concrete is the most common performance measurement used by engineers when designing buildings and other structures (Ramujee, 2016).

2.3.17 Production cost

Generally Production costs are costs consumed or used to reach a final goal. They also classify production costs in to two, which is direct cost of production and indirect cost of production. Direct costs are costs related only to that product. They can be direct cost of materials, labor and equipment that are directly involve in the production process. Indirect cost of production cannot be directly booked under a specific activities but they are required to keep the whole projects operational. This are also called overhead costs, head office and site overhead costs (Luca C., 2008).

According to Calin M, (2003) $\text{productivity} = \frac{\text{quantity of work produced}}{\text{time duration}}$.............Eq (2.2)

$\text{Utilization factor} = \frac{1}{\text{crew production (output)}}$ .... Eq (2.3)

And labor unit cost = utilization factor times wage rates (daily or hourly).............. Eq (2.4)

CHAPTER THREE

METHODOLOGY

3.1. Introduction

This chapter presents and describes the approaches and techniques the researcher used to collect data and investigate the research problem.

The study methodology leads to accomplish the research objectives. The first activity in this research was review literatures related to the research from different sources like: text books, research papers, journals, magazine, and web Internet.

Then, the material used for hollow concrete block (HCB) produced should collected from available source and laboratory experimentations have been carried out. So, in order to obtain the final results, first the researcher determine physical property of material like aggregate, sand, chemical test for fly ash and concrete making data collection and testing have been performed. Then, the prepared concrete samples for hollow concrete block have been tested for both in the fresh and hardened states. For the fresh state workability property of concrete has been checked and for hardened concrete compressive strength tests have been carried out at age of 7, 14 and 28 days.

The results obtained from experiment were discussed and presented in tables and figures. Finally, conclusions are drawn and recommendations have been forwarded.

3.2 Study Area

The study area of this research was in sebeta town which is located 24km by road southwest of Addis Ababa. The experimental test was conducted at different place such as Jimma university construction material laboratory, at Walkite university construction material laboratory and at Addis Ababa geological survey of Ethiopia for chemical analysis of fly ash.

3.3. Study Population

The population of this experimental study was HCB with and without fly ash

3.3 Study period

The research has taken seven months and it was started on April 2017 and it was ended on October 2017, which was including from data collection up to the final paper submission.

3.4 Research Design.

The study was experimental and carried out on hallow concrete blocks with and without fly ash. The Experimental design has been used for this research during the study period, in order to provide the most reliable proof by studied the quality of the raw material of hollow concrete block and identified their effect on concrete properties mainly workability and compressive strength of hollow concrete block and other design parameter physical property of material, cost benefit comparison and setting time.

3.4 Study variables

- Dependent variable:
  - Compressive strength
- Independent variable
  - -gradation of aggregate
  - -workability
  - - Percentage of fly ash and Amount of cement
  - - Silt content

-Quality of material like sand, aggregate, water, cement and etc.

3.5 Sampling techniques

The sampling technique has been using for this research was a non-probability Sampling technique which is the purposive method. This sampling technique was proposed based on the information that the researcher have and the aim or goal of the researcher to be achieved. For material laboratory test, the samples was depends on the types of test requirement and standards. The output of the study was compared with the strength of normal HCB compressive strength through laboratory tests. To determine the sample size of test it needs standards' and specifications. According to Ethiopian standard the minimum requirement was 6 samples of HCB for mean compressive strength and the size of HCB (40 cm *20 cm *20 cm).

Different researcher is take different percent of partial replacement of cement by fly ash. According to (Sainath, 2016) the impacts of partial replacement of cement by fly ash studies are conducted on concrete mix cementious materials at 7.5%, 15%, 25%flyash replacement levels. According to (Goud, (2016) with mineral admixture has used 10%, 20% and 30% of fly ash replacement by mass of cement.

Depend on this view for each test the researcher was add partial replacements of cement by fly ash with 0%, 10%, 15%, 20%, 25% and 30%. Since, the characteristic strength of concrete is usually measured by using compression test machine for compressive strength at different age. For this study the researcher was conducted at age of 7th, 14th and 28th compressive strength testing days performed with total of 108 samples of HCB.

Table 3.1 show the total Sample size selected of HCB with and without fly ash was put into a table

Percentage of replacement for HCB with and without fly ash	Number of samples for			Total
	7th day	14th day	28th day	
0	6	6	6	18
10	6	6	6	18
15	6	6	6	18
20	6	6	6	18
25	6	6	6	18
30	6	6	6	18
Total	36	36	36	**108**

For each percentage replacement, 6 samples were selected for each testing days (7th, 14th and 28th). A total of 6 samples x 3 testing days x 6 sample kinds = **108 samples** were prepared**.**

3.6 Sources of Data

Both primary and secondary data sources would be used. Secondary data needed for this research has been collecting from different journals, book, web site etc. and the primary sources were laboratory experimental outputs.

3.7 Data Collection

Generally fly ash, ordinary Portland cement, crushed aggregates and sand were materials used in this study. But they were also divided in to two. These were materials for HCB with fly ash and materials for HCB without fly ash.

3.7.1 Materials for hollow concrete blocks without fly ash

Materials used to produce HCB without fly ash were:

- Cement: - Type of Cement used to produce HCB was Capital- Ordinary Portland cement (OPC) whose Cement Grade 42.5N CEM which is available in market.
- Crushed aggregate 01
- Sand
- Crushed aggregate 00
- Water: - used Drinkable water (potable water) for produced HCB

Sources of materials:

- Cement- local market
- Crushed aggregate- local market
- Fine aggregate - local market
- Sand- local market

3.7.2. Materials for hollow concrete blocks with fly ash

Materials used to produce HCB with fly ash were:

- Capital Ordinary Portland cement(OPC)
- Crushed aggregate (01 & 00)
- Sand and
- fly ash

Sources of materials:

- Cement- local market
- Crushed aggregate- local market
- Sand –local market
- Fly ash -was taken from Ayika Addise Textile and investment group PLC

Fig.3.1. wastage of fly ash at Ayika Addise textile and investment group

The raw material of fly ash was extracted from Jimma zone and Iluababor zone According to Mr.Eiliays told to researcher during data collected. This fly ash was deposit in form of pond or hole in Ayika Addise Textile and investment group PLC Company. The researcher was taking the wet sample from industry and dries it in the sun and sieve by 150 micro meters to use for test.

The researcher was conduct chemical analysis before used the sample at Addisabeba Geological survey of Ethiopia to determine silica analysis. The test method determined according to ASTM.

3.8. Laboratory tests of material property of HCB produced

- Tests on crushed aggregate and sand according to ASTM Standard Procedures:-
    - ❖ sieve analysis or gradation –ASTM C136
    - ❖ water absorption –ASTM C127
    - ❖ unit weight –ASTM C33
    - ❖ specific gravity –ASTM C127
    - ❖ moisture content –ASTM C566
    - ❖ silt content for sand –ASTM C117
    - ❖ compressive strength – ES596 C.D4.2001

- Tests on cement according to ES and ASTM:-
    - ❖ Consistency test/ ASTM C187
    - ❖ Initial and final setting time test with and without fly ash
    - ❖ Fineness of cement test with and without fly ash
- Test on workability according to standard
    - ❖ Slump test with and without fly ash ASTM C143

3.9 Block making Machine

The machines used to produce HCBs was hydraulic machines, which have 1.5 HP motor to make HCB and the vibration was strong enough to compact the concrete sufficiently in the moulds and to achieve the required strength. Before starting production, the different materials used to produce the HCB were put on the machine by hand and the dry-mixed carefully has done on the back of the machine. The appropriate amounts of water added on the dry mix with water cement ratio 0.55.

3.10 Water

Water available in Jimma institute of technology and Walkite university laboratory was used for the study. Natural water that is drinkable and has no pronounced taste or odour is used as mixing water for concrete. Excessive impurities in mixing water not only may affect setting time and concrete strength, but can also cause efflorescence, discoloration, corrosion of reinforcement, volume instability, and reduced durability.

3.11 Determining property of materials

The property of all materials necessary for describing the type of materials used and also properties that can affect the production of HCB were determined prior to production.

The test methods used for the aggregates are listed in Table 3.2

Table 3.2 Property tests and test methods of material.

Property Tests	**Test Method**
Sieve analysis(sand, crushed aggregate and gravel 00)	ASTM C136,C33
Unit weight (sand, crushed aggregate, and gravel 00)	ASTM C29
Silt content(sand and gravel 00)	ASTM C117

specific gravity and absorption (sand, crushed aggregate, red ash, and gravel 00)	ASTM C127, BS 812:part 2:1995
Moisture content (sand, crushed aggregate, ,and fine aggregate l00)	ASTM C 566
Test Methods use to find out properties of Cement	
Compressive Strength for cement	ASTM109/C109M
Setting Time	ASTM C 191
Specific Gravity	ASTM C 188

3.12 Production of hollow blocks

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

3.12.1 Proportioning the materials

The two most widely used cement to aggregate ratios are 1:6 and 1:8 for hollow concrete blocks production (SRCCD, 2008).

In the study area which is in sebeta zone around alemgena the micro and small enterprises most of them use cement to aggregate ratio of 1:6. There for the study was conducted by using 1:6 mix proportions for both type of HCB.

3.12.2 Proportioning for HCB without fly ash

The materials required for the production of HCBs and their mixing ratio differs from site to site depending on the availability of the building materials and the ratio that fulfils the required strength. This holds true for all types of HCBs production.

Based on observation most of micro and small HCB enterprises use 1:3:2:1 ratio of cement, sand, gravel 00 and crushed aggregate respectively for producing HCB. The study was also conducted by using this 1:3:2:1 ratio without fly ash to produce the blocks.

3.11.3 Proportioning for HCB with fly ash

The proportion material used to produce HCB with fly ash was varying in cement content from the above HCB produced without fly ash. The amount of cement was decrease by (10%, 15% 20% 25% and 30%) of 1bag cement or 50kg.

Table3 .3 Show the amount of fly ash and cement with their ratio.

%age fly ash of 50kg cement	Cement(kg)	Fly ash(kg)	Ratio (fly ash in kg/50kg in cement, sand, 00agg, 01agg respectively.)
0%	50	0	1:3:2:1this was for conventional HCB
10%	45	5	5/50:3:2:1
15%	42.5	7.5	7.5/50 :3:2:1
20%	40	10	10/50:3:2:1
25%	37.5	12.5	12.5/50 :3:2:1
30%	35	15	15/50 :3:2:1

This table indicated the amount of sand, 00aggregate 01aggregate were constant for all percentage (%) but the changed one was only the amount of cement and fly ash depend on percentage. So the ratio of cement describe with fly ash with decimal form that means for example 5/50 was indicated in table 3.3, 5kg of fly ash out of 50kg cement indirectly 5kg fly ash and 45kg cement was used for 10% age replacement of fly ash.

3.13 Production process

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

3.14 Compressive strength test

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 test was carried out on the blocks prepared to compare the compressive strength of the hollow blocks with and without fly ash. Compressive strength test of 7th, 14th and 28th days were conducted and the 28 days age of HCB average for the six units would be recorded and also camper the result according to ES 596 C.D4.2001 after regularly cured by spraying water for 7 days.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

Hollow concrete block is a building material which made up of from cement, sand, aggregate (fine and coarse), water and also can used pozzolanic material such as fly ash. It's obvious that, HCB can be produced by anybody through mixing of concrete ingredients, but the important point bear in mind is producing acceptable HCB quality with a reasonable economy. To produce acceptable quality, it's important to make physical characteristic test and chemical tests on materials used for the investigation before any HCB produced, experiments are carryout. So, this chapter elaborates the general properties of the materials used in the production of HCB for the research, cost and chemical property of fly ash and also finally mechanical property (compressive strength) of HCB was investigated.

4.2 Physical Properties of Materials

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

4.2.1 Sieve analysis of crushed aggregate 01

The normal weight aggregates for making hollow concrete blocks needs to have property of concrete aggregate. The test method used was (ASTM C 136) and the detailed result obtained is attached on appendix one.

Table 4.1 crushed aggregate 01 sieve analysis versus (ASTM C136)

Sieve size(mm)	**Cum. %pas**	**ASTM limits**		**Remark**
		Min	**Max**	
19	100	100	100	Ok
12.5	98.75	90	100	Ok
9.5	76.25	40	80	Ok
4.75	11.25	0	20	Ok
2.36	0.25	0	10	Ok
Pan	0			

According to (ASTM C136-Standard Specification for Aggregates Concrete Masonry Units, the passing percentage requirements full fill the standard of ASTMC136.the maximum size of coarse aggregates used for hollow concrete block was 10 mm which was found between sieve 12.5 and sieve 9.5 the experiment conducted used to determine the particle size distribution of the coarse and fine aggregate down to 2.36mm.as seen in the fig. 4.1 the aggregate 01 was satisfy the ASTM C136 which is the cumulative percentage passing was with the interval.

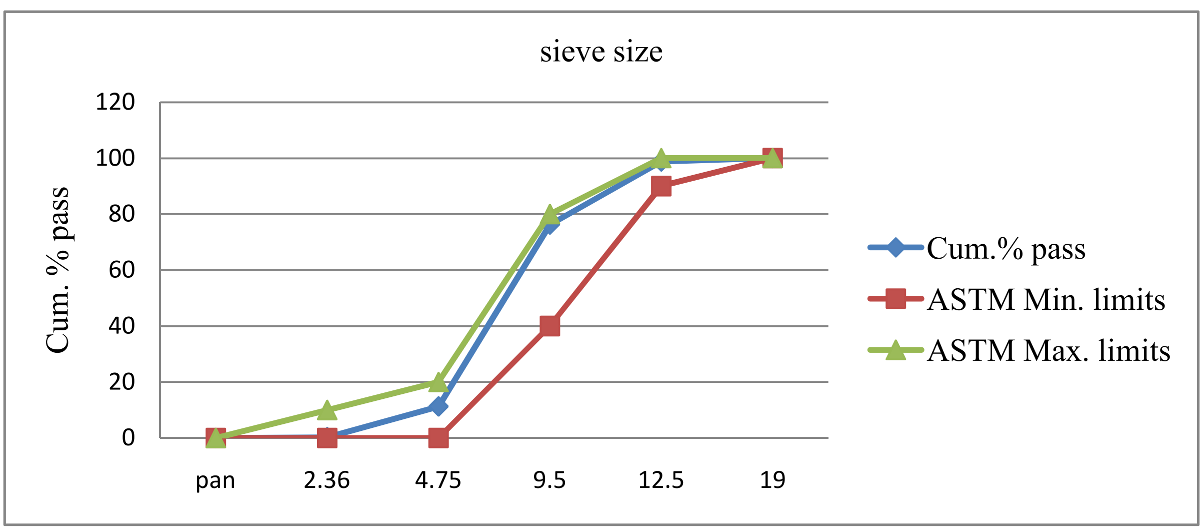

Fig.4.1 graph of crushed aggregate 01

4.2.2 Sieve analysis of crushed aggregate 00

The crushed aggregate"00" indicates that the aggregate is fine and used as fine aggregate in construction.

Table 4.2 Sieve analysis of gravel 00 versus ASTM limits

Sieve size	Cum. %pas	ASTM limits		Remark
		Min	Max	
9.5	100	100	100	Ok
4.75	97.5	95	100	Ok
2.36	82.5	80	100	Ok
1.18	52.2	50	85	Ok
0.6	25.2	25	60	Ok
0.3	9.7	5	30	Ok
0.15	2.05	0	10	Ok
pan	0			Ok

F.M=3.31Since the Aggregate 00 is used as fine aggregate it should fulfill the gradation requirement specified for fine aggregates by ASTM C33. According to the test result, the fineness module was 3.31which is within the ASTM C33 limits (2.3-3.1). But the result is out of limitation. But even if the cumulative percentage passing was full fill the standard.

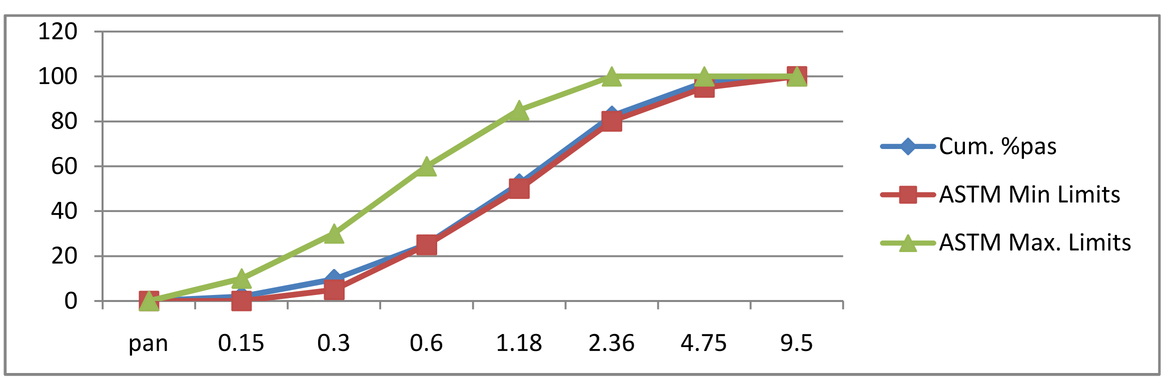

Fig.4.2 graph of aggregate 00

4.2.3 Sieve Analysis of Sand

Table 4.3 Sieve analysis of sand versus ASTM C33 limit

Sieve size	Cum. %pas	ASTM limits		Remark
		Min	Max	
9.5	100	100	100	OK
4.75	92	95	100	OK
2.36	85	80	100	OK
1.18	61.5	50	85	OK
0.6	30.5	25	60	OK
0.3	25	5	30	OK
0.15	2.5	0	10	OK
pan	0			

F.M=3.13

According to ASTM C33 fine aggregates should have fineness modules between 2.3 and 3.1; the sand used has fineness modules of 3.13, this means it is all most within the ASTM limits and the cumulative percentage passes was with the interval as shown on fig.4.3.

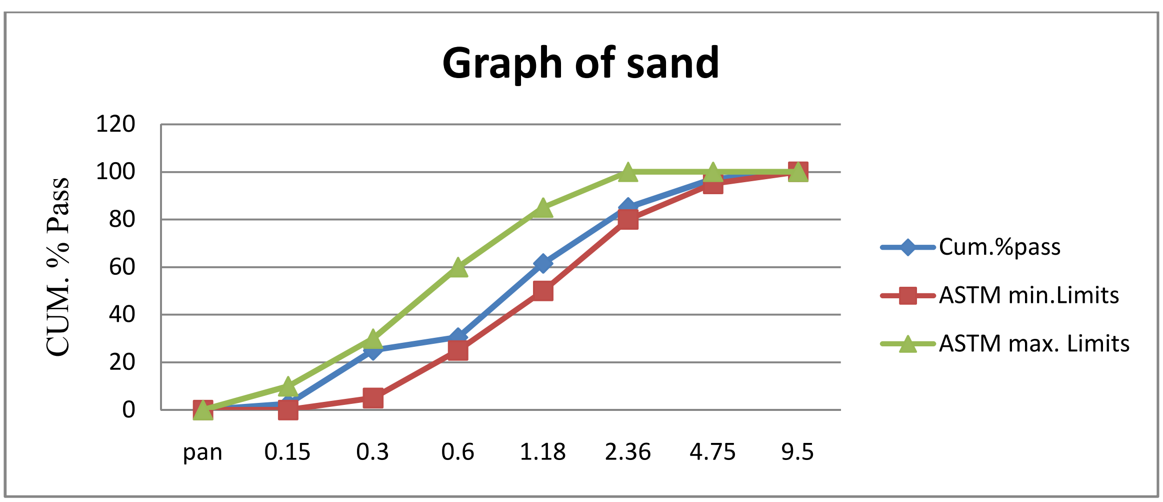

Fig.4.3 graph of sand

4.2.4. Bulk Unit weight

Table 4.4 showed the test results of unit weight of crushed aggregate 01, sand and aggregate 00.

Table 4.4 Unit weight of used aggregates and sand

Aggregates	Bulk Unit weight
Aggregate 01	1491.11kg/m^3
Aggregate 00	1508.55 kg/m^3
Sand	1480 kg/m^3

According to ASTM C33 limits the bulk unit weight from 1200-1760 kg/m3. The unit weights described in Table 4.4 was within the limits. Therefore, the aggregates fulfill specification of ASTM C33.

4.2.5. Specific gravity and absorption

Table 4.5 Bulk specific gravity (SSD) and absorption

Aggregates	Bulk specific g. (ssd)	Absorption
Aggregate 01	2.66	2.75%
Aggregate 00	2.68	1.97%
Sand	2.46	1.69%

According to ASTM C33, the limitation for bulk specific gravity (SSD) is from 2.4 to 3.0. Accordingly the aggregates were within ASTM limitations. Absorption for coarse aggregate from 0.2% to 4% and for fine aggregates 0.2 to 2%. So the test result of table 4.5 was satisfy the requirement of ASTM C33 From Table 4.5 the crushed aggregate 01 as coarse aggregate is between 0.2% and 4%. And both sand and gravel 00 were within the limits of fine aggregates.

4.2.6 Moisture content and silt content

Table 4.6 Moisture content and silt content

Aggregates	Moisture content (%)	Silt content (%)
Crushed agg.01	1.95%	-
Crushed agg.00	1.93%	2.75%
Sand	2.3%	5.82%

According to ASTM C33, silt content should not be greater than 3%. Aggregate 00 satisfy the ASTM C33 requirement but sand is not fulfilled. According to ES silt content should not be greater than 6%. Both crushed aggregate 00 and sand fulfill ES requirement. And the moisture contents should be within 0.5% to 2%. All aggregates are within the limits except moisture content of sand. As shown on table 4.6 the moisture of sand was out of the range of ASTM C33.

4.3 Chemical analysis of fly ash

Conducting the chemical analysis of fly ash was very important to determine the characteristic of fly ash whether or not class C or class F type of fly ash. The result of Chemical analysis fly ash determined at geological survey of Ethiopia shows in the table 4.7

Table 4.7 shows the chemicals Analytical results of fly ash in percent.

Contents	Percentage by mass
Calcium oxide, CaO	0.01
Silicon dioxide, SiO_2	42.28
Aluminium oxide, Al_2O_3	26.72
Iron oxide, Fe_2O_3	3.04
Magnesium oxide, MgO	0.88
Sodium oxide, Na_2O	2.00
Potassium oxide, K_2O	0.48

Titanium dioxide, TiO_2	0.54
LOI, (Loss-on-ignition)	16.53
MnO	0.08
P_2O_5	0.18
H_2O	5.60

Table 4.8 ASTM Specification for type of Fly Ash

Class	Description in ASTM C 618	Chemical Requirements
F	Fly ash normally produced from burning anthracite or bituminous coal that meets the applicable requirements for this class as given herein. This class of fly ash has pozzolanic properties.	SiO2 + Al2O3 + Fe2O3 ≥ 70%
C	Fly ash normally produced from lignite or sub bituminous coal that meets the applicable requirements for this class as given herein. This class of fly ash, in addition to having pozzolanic properties, also has some cementitious properties. Note: Some Class C fly ashes may contain lime contents higher than 10%.	$SiO_2 + Al_2O_3 + Fe_2O_3 \geq 50\%$

According to ASTM C618 fly ash was classified in two types: Class C and Class F depend on the amount of silica, Alumina and ferric oxide. If the summation of (SiO_2) + (Al_2O_3) + (Fe_2O_3) greater than 70% it is class F and if less than 70% it is class C. So that this study result of chemical composition of coal ash at Ayika Addise Textile and Investment Group PLC Shows that on the table 4.7. From the table (4.7) the sum (SiO_2) + (Al_2O_3) + (Fe_2O_3) constituents is 72.04% which is more than 70% and reactive calcium oxide is 1% which is less than 10% - technically the fly ash is considered as class F fly ash. Such type of fly ash is produced by burning of anthracite or bituminous coal and possesses pozzolanic properties.

4.4 Setting time

One of the most important properties of cement is its setting time, as this will regulate how much time the contractor will have to get the concrete placed and finished. The setting of Blended cement takes longer than Ordinary Portland cement as described in the following table 4.9 up to 4.14. As the result shows in the table, as the percentage of fly ash increase the initial and final setting time was increase and also the amount of water was increase due to fly ash percentage incremental.

Table 4.9: summary of the physical properties of Capital cement

<table>
<tr><th>Material</th><th>Type of Cement</th><th colspan="2">Types of cement test for 0% fly ash</th><th>Test result</th></tr>
<tr><td rowspan="4">Cement</td><td rowspan="4">Ordinary Portland cement(OPC) without fly ash</td><td colspan="2">-Cement Consistency test
➢ W/C ratio (%)
➢ Water(ml)
➢ Penetration (mm)</td><td>
27%
81ml
10</td></tr>
<tr><td rowspan="2">Setting Time</td><td>Initial</td><td>65min.</td></tr>
<tr><td>Final</td><td>4hr</td></tr>
<tr><td colspan="2">Specific gravity</td><td>3.15</td></tr>
</table>

Table 4.10: summary of the physical properties of Capital cement with fly ash

<table>
<tr><th>Material</th><th>Type of Cement</th><th colspan="2">Types of cement test for 10% fly ash</th><th>Test result</th></tr>
<tr><td rowspan="4">Cement</td><td rowspan="4">Ordinary Portland cement(OPC) with fly ash</td><td colspan="2">-Cement Consistency test
➢ W/C ratio (%)
➢ Water(ml)
➢ Penetration (mm)</td><td>
28%
84ml
11</td></tr>
<tr><td rowspan="2">Setting Time</td><td>Initial</td><td>71min.</td></tr>
<tr><td>Final</td><td>4hr. 20min.</td></tr>
<tr><td colspan="2">Specific gravity</td><td></td></tr>
</table>

Table 4.11: summary of the physical properties of Capital cement with fly ash

Material	**Type of Cement**	**Types of cement test for 15% fly ash**		**Test result**
Cement	Ordinary Portland cement(OPC) with fly ash	-Cement Consistency test ➢ W/C ratio (%) ➢ Water(ml) ➢ Penetration (mm)		 30% 90ml 9.5
		Setting Time	Initial	75min.
			Final	6hr.
		Specific gravity		

Table 4.12: summary of the physical properties of Capital cement with fly ash

Material	Type of Cement	Types of cement test for 20% fly ash		Test result
Cement	Ordinary Portland cement(OPC) with fly ash	-Cement Consistency test ➢ W/C ratio (%) ➢ Water(ml) ➢ Penetration (mm)		 32% 96ml 10
		Setting Time	Initial	90min.
			Final	7hr.

Table 4.13: summary of the physical properties of Capital cement with fly ash

Material	Type of Cement	Types of cement test for 25% fly ash		Test result
Cement	Ordinary Portland cement(OPC) with fly ash	-Cement Consistency test ➢ W/C ratio (%) ➢ Water(gm) ➢ Penetration (mm)		 33% 99ml 10.5
		Setting Time	Initial	105min.
			Final	7hr:40min

Table 4.14: summary of the physical properties of Capital cement with fly ash

Material	Type of Cement	Types of cement test for 30% fly ash		Test result
Cement	Ordinary Portland cement(OPC) with fly ash	-Cement Consistency test ➢ W/C ratio (%) ➢ Water(ml) ➢ Penetration (mm)		33% 99ml 9
		Setting Time	Initial	105min.
			Final	<10hr.

The EN 197-1:2000 limits the initial setting times for composite Portland cement not to be less than 45 minutes and also according to Ethiopian standard also specifies initial and final setting time for Portland cement (ES C.D5.2002), to be 45 minutes and 600 minutes, respectively.

Comparing the obtained test results of investigation indicated in above Table 4.9-4.13, all fly ash added cement produced satisfy the requirements specified of Ethiopian standards.

4.5 Workability

The slump test is the most well-known and widely used test method to characterize the workability of fresh concrete. The inexpensive test, which measures consistency, is used on job sites to determine rapidly whether a concrete batch should be accepted or rejected. As the amount of fly ash increase the workability decrease compared with a Portland cement concrete of the same slump. Which means the workability was Very dry mixes or low workable as shown in the table 4.15.

Table 4.15 shows the result of slump test

Percentage of fly ash	Height of the slump(mm)	Description
0	35	medium workability
10	25	Low workability 25% and 30% was true slump
15	5	
20	3	
25	0	
30	0	

According to ASTM C143-98 Standard Test Method Concretes having slumps less than 1/2 in. [15 mm] may not be adequately plastic and concretes having slumps greater than about 9 in. [230 mm] may not be adequately cohesive for this test the fig.4.4 and 4.5 result was not satisfy the requirement of ASTM C143. But for this test the slump should be less than 40mm according to Eric P. Koehler (2003).

Fig.4.4 without fly ash   fig.4.5 with fly ash

4.6 Comparisons of compressive strength results

To meet the objectives of this research, the compressive strength of each blocks produced was conducted according to ES 596 C.D4.2001 after regularly cured by spraying water for 7 days.

The compressive strength test results for each sample are listed on Appendix Two. In terms of comparing compressive strength the two kinds of HCBs produced mainly HCB with and without fly ash were computed. Since the HCB with coal ash (fly ash) samples were produced by considering different percentage amount of fly ash, from 10% up to 30% each of them were compared with the HCB without fly ash.

4.6.1 The determined compressive strength of HCB with and without fly ash.

As shown in the Table 4.15 the mean compressive strength of The HCB which was produced by mix ratio of 1:3:2:1, one bag of cement, 3 box of sand, 2 box of fine aggregate and 1 box of crushed aggregate 01 was determined for 7th, 14th and 28th testing days and the average for each testing days or the mean compressive strength were determined according to their age testing day.

Table .4.15 Mean compressive strength of HCB without fly ash

Testing day	**Mean compressive strength(average of 6 HCB) in MPa**
7^{th}	3.56
14^{th}	3.77
28^{th}	5.44

The result of table 4.15 used for comparison of, hollow concrete blocks (HCB) produced with fly ash from 10 percent up to 30 percent by mass of cement. As the age of HCB increase the compressive strength also increase.

Table 4.16 Comparison 7 days Mean compressive strength of HCB with and without fly ash

Testing day	**Compressive strength**	**Percentage of replacement of fly ash**
7^{th} days	3.56	Conventional (0%)
	3.31	10%
	3.25	15%
	3.02	20%
	2.29	25%
	2.19	30%

As observed from the table 4.16 the result was shown as the percentage of fly ash increase the compressive strength of seven day was decrease. But comparatively 0% result was better than 10% result and 10% result also better than 15% result and the same comparative for 20%, 25% and 30%.

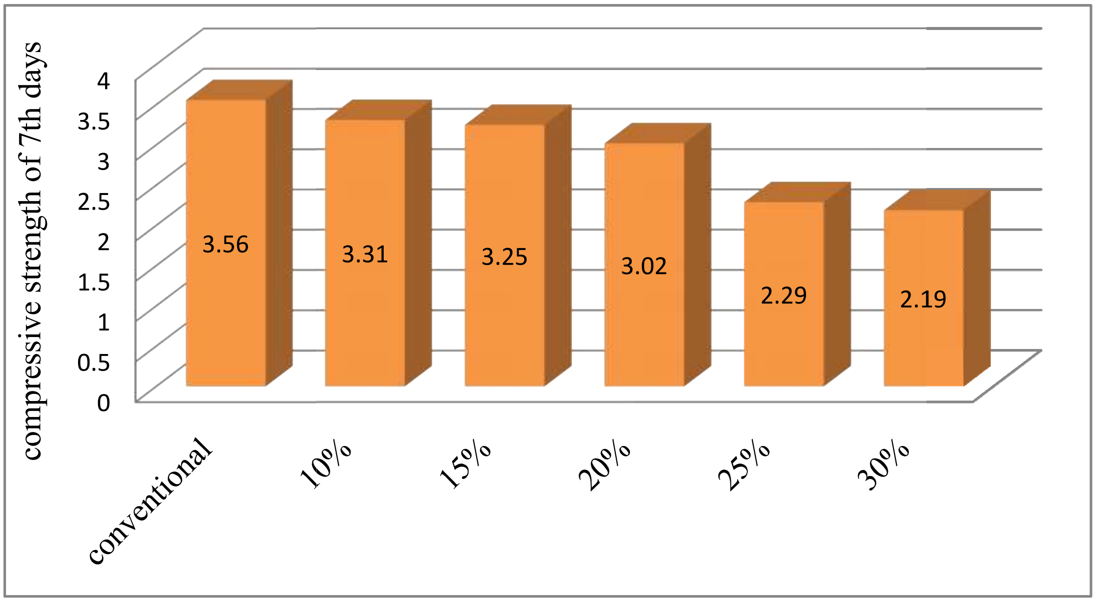

Fig.4.6 the compressive strength of 7th days

As shown in the fig.4.6 the compressive strength of 7th days was decrease as the percentage of fly ash increase was clearly described.

Table 4.17 the 14th days Mean compressive strength of HCB with and without fly Ash

Testing day	**Compressive strength**	**Percentage of replacement of fly ash**
14th days	3.77	Conventional (0%)
	3.72	10%
	3.35	15%
	3.27	20%
	2.73	25%
	2.44	30%

As observed from the table 4.17 the result was shown as the percentage of fly ash increase the compressive strength of 14th day was decrease. But comparatively 0% result was better than 10% result and 10% result also better than 15% result and the same comparative for 20%, 25% and 30%. For the compressive strength of each percentage replacement was taken six sample of HCB and their result was written in table 4.17.

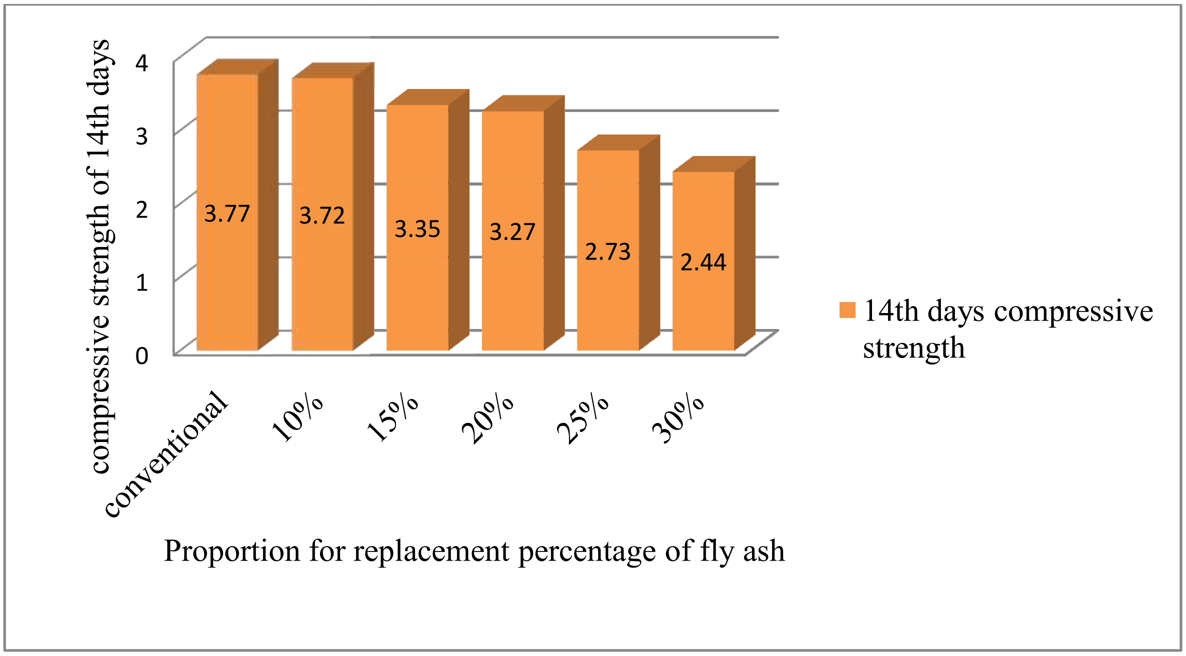

Fig. 4.7 the compressive strength of 14^{th} days of HCB

As shown on the fig.4.7 and table 4.17 the compressive strength of 14^{th} days of HCB increased as compared with the 7^{th} day's compressive strength. This incremental was indicate due to the curing age of HCB. As the curing age of HCB increase the compressive strength was also increase.

Table 4.18 Comparison 28th days Mean compressive strength of HCB with and without fly ash.

Testing day	Compressive strength	Percentage of replacement of fly ash
28^{th} days	5.44	Conventional (0%)
	4.66	10%
	4.49	15%
	4.33	20%
	4.00	25%
	3.81	30%

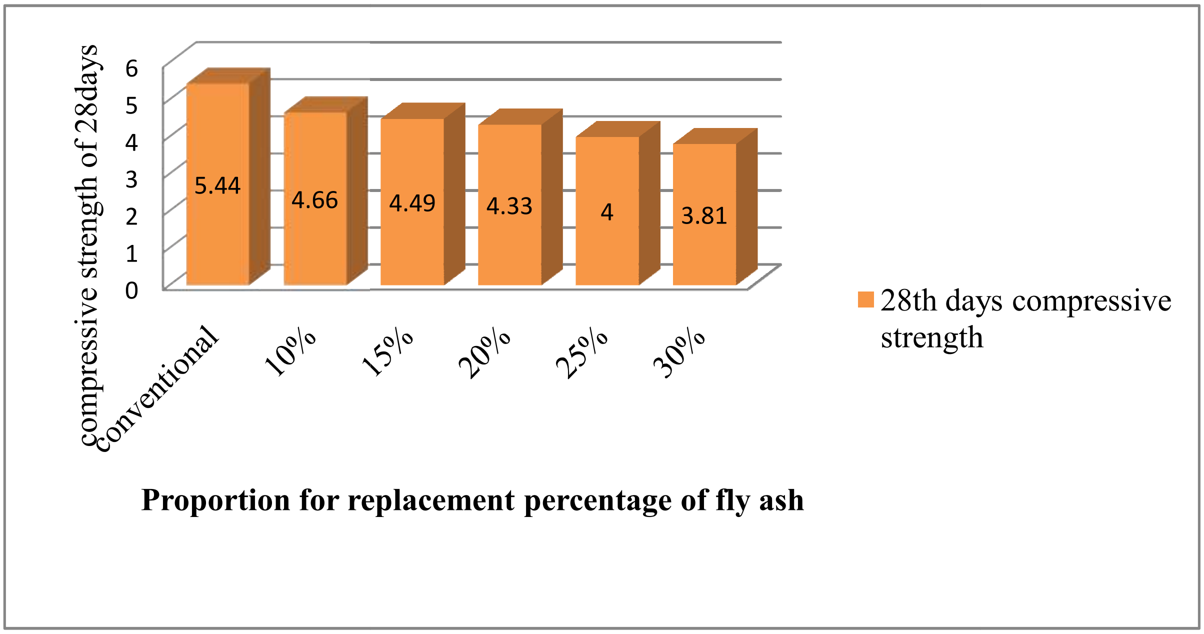

Fig. 4.8 the compressive strength of 28th days of HCB

As shown on the fig.4.8 the compressive strength of 28th days of HCB increased as compared with the 14th day's compressive strength. This incremental was indicate the curing age of HCB. Depend on the 28th compressive strength it was possible to determine the classes of hollow concrete block. So if the result was between 5.5 and 4.5 it was class B and if it was between 4.5-3.5 it was class C according to ES596. So as observed from fig. 4.8 the 10% was class B and the other one were class C.

Generally as discussed in the above table of compressive strength the result were indicated as the percentage of fly ash increase the compressive strength was decrease and also as the age of tasting day increase the compressive strength also increase.

4.7 Cost comparisons

Direct production cost comparisons

The direct cost of producing both types of HCB considered is unit cost of production. The major components of the unit cost are: - direct unit cost of materials, labor and equipment

4.7.1 Direct unit costs of HCB without fly ash.

I) Direct material unit cost: a format as shown in table 4.19 was used to calculate the direct material unit cost.

Table 4.19 Direct material unit cost of HCB without Fly ash

Material Cost (DMUC)				
Type of Material	Unit	Qty *	Rate(birr)	Cos/ Unit, (birr)
Crushed agg.00	(m3)	0.0044	500	2.2
Crushed agg.01	(m3)	0.0022	437.5	0.96
Sand	(m3)	0.0066	500	3.30
Cement	kg	2.77	2.6	7.20
total materials cost/block				**13.66**

II) Direct labor unit cost: a format as shown in Table was used to calculate the direct labor unit cost.

Table 4.20 Direct labor unit cost of HCB without Fly ash

Labor Cost (DLUC)				
Labor by Trade	No.	UF	Daily wage(birr)	cost/unit, (birr)
Operator	1	0.000667	150	0.10005
D/L	5	0.0033	70	0.233
total labor cost/block				**0.33**

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

Table 4.21 Direct equipment unit cost of HCB without Fly ash

Equipment Cost (DEUC)				
Type of Equipment	No.	UF	rent/day	cost/unit, (birr)
HCB machine	1	0.000667	700	0.4669
total equipment cost/ block				**0.46**

Total unit cost of production at 0%= DMUC+DEUC+DLUC=13.66+0.33+0.46=**<u>14.45</u>**

Utilization Factor (UF) were calculated for direct labor cost and equipment cost, it was calculated by dividing the number of labor, operator, equipment for crew production per day example for machine 1/1500 =0.000667 (the output per day was 1500HCB) The same calculation for daily labor(D/L) and operator at shown in table 4.20 direct labor cost.

Where,

DMUC= direct material unit cost

DEUC= direct equipment unit cost and

DLUC= direct labor unit cost.

4.7.2 Direct unit costs of HCB with fly ash.

I) direct material unit cost: a format as shown in table 4.22 was used to calculate the direct material unit cost with fly ash to produced HCB.

Table 4.22 Direct material unit cost of HCB with Fly ash of 30%

Material Cost (DMUC)				
Type of Material	Unit	Qty *	Rate (birr)	Cos/ Unit, (birr)
Crushed agg.00	(m3)	0.0044	500	2.2
Crushed agg.01	(m3)	0.0022	437.5	.96
Sand	(m3)	0.0066	500	3.3
Fly ash	kg	0.831	0.06	0.05
Cement	kg	1.939	2.6	5.04
total materials cost/block				**11.55**

II) Direct labor unit cost: a format as shown in Table 4.23 was used to calculate the direct labor unit cost.

Table 4.23 Direct labor unit cost of HCB with Fly ash

Labor Cost (DLUC)				
Labor by Trade	No.	UF	Daily wage (birr)	cost/unit, (birr)
Operator	1	0.000667	150	0.10
D/L	5	0.0033	70	0.23
total labor cost/block				**0.33**

III) Direct equipment unit cost: the direct cost of equipment is also calculated using the same format with the above table.

Table 4.24 Direct equipment unit cost of HCB with Fly ash.

Equipment Cost (DEUC)				
Type of Equipment	No.	UF	rent/day, (birr)	cost/unit, (birr)
HCB machine	1	0.000667	700	0.46
total equipment cost/ block				**0.46**

Direct cost of labor and equipment cost were the same both in the production HCB with and without fly ash but the cost of cement was varies depend on the percentage of replacement of fly ash. The cost of sand and aggregate also the same with both production of with and without fly ash.

Total unit cost of production with fly ash =.DMUC+DEUC+DLUC=11.55+0.33+0.46=**12.34**

Table 4.25 Direct material unit cost of HCB with Fly ash of 25%

Material Cost (DMUC)				
Type of Material	Unit	Qty *	Rate (birr)	Cos/ Unit, (birr)
Crushed agg.00	(m3)	0.0044	500	2.2
Crushed agg.01	(m3)	0.0022	437.5	.96

Sand	(m3)	0.0066	500	3.3
Fly ash	kg	0.6925	0.06	0.04
Cement	kg	2.07	2.6	5.38
total materials cost/block				**11.88**

Table 4.26 Direct labor unit cost of HCB with Fly ash for 25%

Labor Cost (DLUC)				
Labor by Trade	No.	UF	Daily wage (birr)	cost/unit, (birr)
Operator	1	0.000667	150	0.10
D/L	5	0.0033	70	0.23
total labor cost/block				**0.33**

Table 4.27 Direct equipment unit cost of HCB with Fly ash.

Equipment Cost (DEUC)				
Type of Equipment	No.	UF	rent/day, (birr)	cost/unit, (birr)
HCB machine	1	0.000667	700	0.46
total equipment cost/ block				**0.46**

Total unit cost of production with fly ash =.DMUC+DEUC+DLUC=**11.88**+0.33+0.46=**12.67**

4.8 Cost comparison between HCBs with and without fly ash:

From the percentages replacement of fly ash (10%, 15%, 20%, 25% and 30%), the 30% fly ash was the optimum partial replacement of cement to produce load bearing HCB. The cost of productions also compared in the Table 4.25 for both HCB.

Table.4.28 Direct unit costs of HCB without and with fly ash HCB

Type of HCB	**Direct unit cost (birr)/HCB**
HCB without fly ash	14.45
25% fly ash	12.67
30% fly ash HCB	12.34

Table 4.28 indicated the cost of producing at 30% fly ash HCB decreases by 2.11 birr per HCB, at 25% fly ash HCB decreases by 1.78 birr per HCB from the cost of HCB without fly ash. So the same calculations done for the rest percentage of fly ash. As describe in table 4.28 if the percentage of fly ash increase the cost of production was decrease due to decrease of amount of fly ash. The cost of cement is expensive, on the other hand the partial replacement of fly ash HCB contains are cheaper than cement.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Conclusions

The main objective of this study was to determine the Application of Fly Ash in Production of Hollow Concrete block by compare the compressive strength of hollow concrete block with and without fly ash. During conducting this study it is concluded that the compressive strength of the HCB without fly ash was greater than the HCB with fly ash. But cost wise the HCB without fly ash incurred very higher direct cost of production than the HCB with fly ash.

To meeting the specific objectives of the study, the physical property material of HCB was conducted properly at laboratory like gradation, silt content, moisture content, setting time and chemical analysis of fly ash and also Thus tests were satisfy ASTM and ES as discussed in chapter four. The fly ash amount which gives a higher strength was achieved at 10%, 15%, 20%, 25% and 30% of fly ash content respectively, which was comparatively the compressive strength of HCB decrease as replacement of fly ash increase. Even though the result was satisfy the requirement of a higher compressive strength for load bearing hollow concrete block.

According to the 28th day mean compressive strength test results, hollow concrete blocks produced with fly ash were categorized as load bearing Class B and class C based on Ethiopian standards (ES596, 2001).

According to this study Chemical analysis fly ash determined at geological survey of Ethiopia result shows in the table 4.7 the fly ash categorized as class F based on ASTM C618-03 This class of fly ash has pozzolanic properties.

Generally it is concluded that, by using fly ash as partial replacement of cement a higher reduction in cost of production, a small reduction in compressive strength than the HCB without fly ash were achieved and also as the compressive strength result were indicated when the percentage of fly ash increase the compressive strength was decrease and as well as the age of tasting day increase the compressive strength also increase.

5.2 Recommendations

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

I) <u>For sebeta zone Administration Office</u>

Concrete blocks containing fly ash should be promoted as a new construction material to replace the existing blocks in market. So construction division of sebeta zone Administration should create awareness to the users of HCB about the use of fly ash to produce HCB. The construction division should also encourage the micro and small HCB production enterprises for their contribution in production of cost effective hollow concrete blocks.

II) <u>For contractors and micro and small HCB production enterprises</u>

If it is properly produced, with a small difference in compressive strength but with large amount of cost reduction HCB can be produced from fly ash. Therefore, it is recommended that the micro and small producers of hollow concrete blocks in sebeta zone should increase the production of HCB with partial substitute of fly ash as a replacement of cement.

III) **<u>For other Towns in Ethiopia where fly ash is abundantly available</u>**

For other Towns in Ethiopia where wastage of fly ash is abundantly available, it is recommended that to produce HCB with partial substitute of fly ash of class F as a replacement of cement should adopt the use of fly ash in HCB production.

IV) **<u>For construction materials research centers</u>**

The governmental and non-governmental materials research centers are recommended to conduct further studies on fly ash as a hollow concrete block production material, in areas where fly ash is abundantly available and spatially for non-loading bearing HCB which means by replacing more than 30%.

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APPENDIX ONE

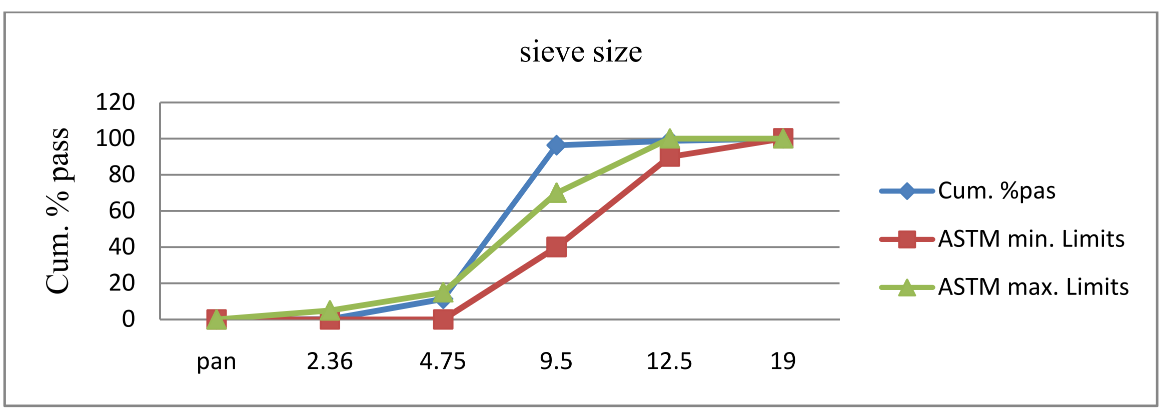
Laboratory Data Sheets for physical properties of aggregate and sand

PLACE	Jimma university, Jimma institute of technology
DEPARTMENT	Construction engineering and management
LABORATORY	Construction materials laboratory

Sample description: gravel 01 Test method: ASTM C136

1. Sieve analysis

Sieve size(mm)	Wt of sample retained(kg)	%age of retained	Cum.% retained	Cum. %pas	ASTM limits		Remark
					Min.	Max.	
19	0	0	0	100	100	100	
12.5	0.025	1.25	1.25	98.75	90	100	
9.5	0.05	2.5	3.75	96.25	40	70	
4.75	1.70	85	88.75	11.25	0	15	
2.36	0.22	11	99.75	0.25	0	5	
pan	0.005	0.25	100	0	0	0	



Unit weight with compaction

Sample description: aggregate 01

Test method: ASTM C29

Items	measurement		
samples	Sample 1	Sample 2	Sample 3
Capacity of cylinder(A)	3L	3L	3L
Weight of cylinder +sample (B)(kg)	5.04	5.01	5.08
Weight of cylinder (C)(kg)	0.57	0.57	0.57
Unit weight=(B-C)/A	1490	1480	1503.33
Mean unit weight=1491.11 kg/m^3			

Unit weight without compaction (Loss)

Sample description: aggregate 01

Test method: ASTM C29

Items	measurement		
samples	Sample 1	Sample 2	Sample 3
Capacity of cylinder(A)	3L	3L	3L
Weight of cylinder+sample(B)	4.56	4.48	4.47
Weight of cylinder (C)	0.57	0.57	0.57
Unit weight=(B-C)/A	1330 kg/m^3	1303.33kg/m^3	1300
Mean unit weight=1311.11 kg/m^3			

Moisture content

Sample description: 01Aggregate

Test method: ASTM C566

Description	Measurements		
samples	Sample 1	Sample 2	Sample 3
Weight of sample(A)	2kg	2kg	2kg
Oven dry weight(B)	1.97	1.965	1.95
Moisture (%) = (A-B/B)	0.0152	0.0178	0.0256
Mean of moisture=0.0195 or 1.95%			

Specific gravity and absorption

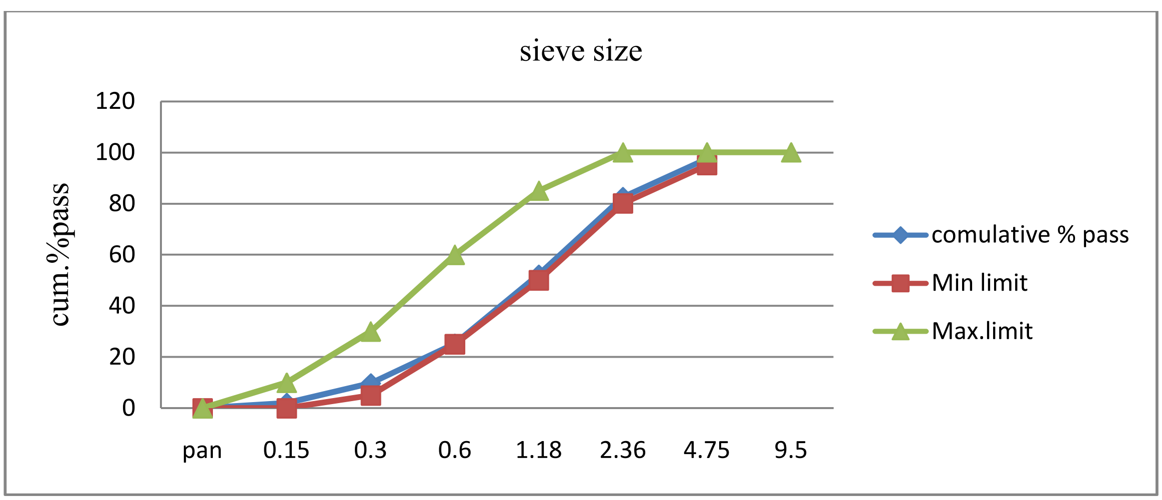
Sample description: crushed aggregate 01 Test method: ASTM C127

Description	Vir.	Weight in (kg)	
Samples		S1	S2
Weight of oven dry sample in air	A	1.97	1.98
Weight of saturated-surface dry sample in air	B	2.02	2.04
Weight of wire in water	C	0.26	0.26
Weight in water (of (SSD) sample +wire basket)	D	1.54	1.52
Weight in water of SSD=D-C	E	1.28	1.26
Bulk Sp.gr.(SSD)=B/(B-E)	BSG	2.729	2.6
Mean of bulk.sp.gr(SSD)=	2.66		
Absorption= (B-A)/A		0.025	0.030
Mean of absorption=	0.0275		

2. SIEVE ANALYSIS

Sample description: gravel 00 Test method: ASTM C33

Sieve size	Wt of sample retained	%age.Wt retained	Cum.%age retained	Cum. %pas	ASTM limits		Remark
					Min	Max	
9.5	0	0	0	100	100	100	Ok
4.75	0.05	2.5	2.5	97.5	95	100	Ok
2.36	0.3	15	17.5	82.5	80	100	Ok
1.18	0.606	30.3	47.8	52.2	50	85	Ok
0.6	0.54	27	74.8	25.2	25	60	Ok
0.3	0.31	15.5	90.3	9.7	5	30	Ok
0.15	0.153	7.65	97.95	2.05	0	10	Ok
pan	0.041	2.05	100	0			Ok



Unit weight

Sample description: 00Aggr.

Test method: ASTM C29

Items	Measurement		
samples	Sample 1	Sample 2	Sample 3
Capacity of cylinder(A)	3L	3L	3L
Weight of cylinder+sample(B)(kg)	5.1	5.08	5.11
Weight of cylinder (C)(kg)	0.57	0.57	0.57
Unit weight=(B-C)/A	1510kg/m^3	1503.33kg/m^3	1513.33kg/m^3
Mean unit weight=1508.88 kg/m^3			

Unit weight with compaction

Sample description: aggregate 01

Test method: ASTM C29

Items	measurement		
samples	Sample 1	Sample 2	Sample 3
Capacity of cylinder(A)	3L	3L	3L
Weight of cylinder +sample(B)(kg)	5.04	5.01	5.08
Weight of cylinder (C)(kg)	0.57	0.57	0.57
Unit weight=(B-C)/A	1490	1480	1503.33
Mean unit weight=1491.11 kg/m^3			

Moisture content

Sample description: 00aggregate

Test method: ASTM C566

Description	Measurements		
samples	Sample 1	Sample 2	Sample 3
Weight of sample(A)	2kg	2kg	2kg
Oven dry weight(B)	1.96	1.97	1.955
Moisture (%) = (A-B/B)	0.0204	0.0152	0.0230
0.0193 or 1.93%			

Specific gravity and absorption

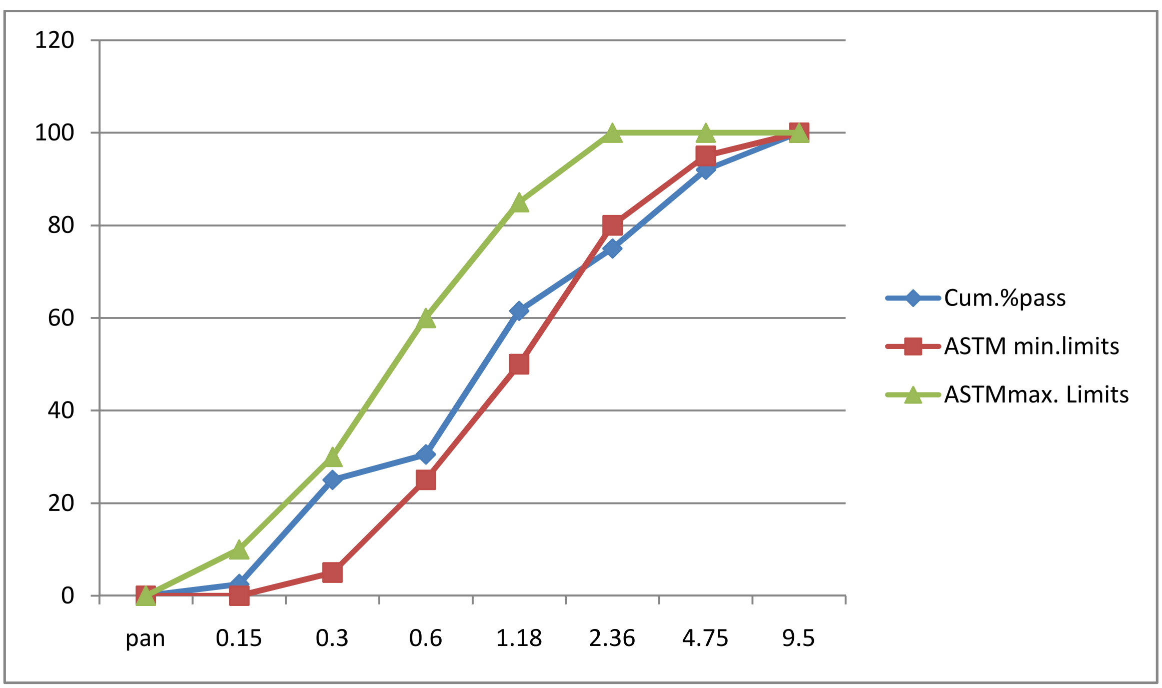
Sample description: fine aggregate 00 Test method: (BS 812: part 2:1995)

Description	Var.	Weight(kg)		
Samples(S)		S1	S2	S3
Mass of saturated surface-dry sample	A	0.5	0.5	0.5
Mass of pyknometer + sample + water	B	1.89	1.89	1.86
Mass of pyknometer + water	C	1.57	1.57	1.56
Mass of oven-dry sample	D	0.490	0.495	0.486
Bulk Specific gravity(SSD) =**A** /(**A** -(**B** - **C**))	BSG	2.77	2.77	2.5
Mean bulk sp.gr.=2.68				
Absorption=(A-D)/ D*100	Abs.	2.04	1.01	2.88
Mean absorption=1.976				

3. Sieve analysis of sand

Sample description: sand Test method: ASTM C33

Sieve size	Wt of sample retained	%age of retained	Cum.% retained	Cum. %pas	ASTM limits		Remark
					Min	Max	
9.5	0	0	0	100	100	100	OK
4.75	0.15	8	8	92	95	100	OK
2.36	0.29	17	25	75	80	100	NO
1.18	0.27	13.5	38.5	61.5	50	85	OK
0.6	0.62	31	69.5	30.5	25	60	OK
0.3	0.11	5.5	75	25	5	30	OK
0.15	0.45	22.5	97.5	2.5	0	10	OK
pan	0.05	2.5	100	0			



Unit weight

Sample description: Sand

Test method: ASTM C29

Items	Measurement		
samples	Sample 1	Sample 2	Sample 3
Capacity of cylinder(A)	3L(0.003m^3)	3L(0.003m^3)	3L(0.003m^3)
Weight of cylinder+sample(B)(kg)	4.97	5.05	5.01
Weight of cylinder (C)(kg)	0.57	0.57	0.57
Unit weight=(B-C)/A	1466.67kg/m^3	1493.33kg/m^3	1480kg/m^3
Mean unit weight=1480 kg/m^3			

Moisture content

Sample description: Sand

Test method: ASTM C566

Description	Measurements		
samples	Sample 1	Sample 2	Sample 3
Weight of sample(A)	2kg	2kg	2kg
Oven dry weight(B)	1.96	1.96	1.945
Moisture (%) = (A-B/B)	0.0204	0.0204	0.0283
Mean moisture content	0.023 or 2.3%		

Specific gravity and absorption Sample description: Sand

Test method: (BS 812: part 2:1995)

Description	Var.	Weight(kg)		
Samples(S)		S1	S2	S3
Mass of saturated surface-dry sample	A	0.5	0.5	0.5
Mass of pyknometer + sample + water	B	1.86	1.86	1.85
Mass of pyknometer + water	C	1.57	1.57	1.54
Mass of oven-dry sample	D	0.495	0.491	0.489
Bulk Specific gravity(SSD) =**A** /(**A** -(**B** - **C**))	BSG	2.381	2.381	2.63
Mean bulk sp.gr.=2.46				
Absorption=(A-D)/ D*100	Abs.	1.01	1.83	2.25
Mean absorption=1.696				

Silt content

Sample description: Sand

Test method: ASTM C117

Description	variable	Mass(Kg)
samples		S1
Original dry mass of the sample	A	1
Dry mass after washing	B	.945
Silt content=(A-B)*100 / B	5.82%	

APPENDIX TWO

Compressive strength test results

PLACE	Jimma university, Jimma institute of technology
DEPARTMENT	Construction engineering and management
LABORATORY	Construction materials laboratory

The seventh day (7th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
0%	1	0.08	19.12	321.5	4.02
	2	0.08	19.8	312	3.90
	3	0.08	17.82	186	2.33
	4	0.08	19	296.7	3.71
	5	0.08	18.72	225.6	2.82
	6	0.08	19.2	366.75	4.58

The seventh day (7th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
10%	1	0.08	15.73	215.6	2.70
	2	0.08	17.8	226.7	2.83
	3	0.08	18	375.5	4.69
	4	0.08	17.75	271.2	3.39
	5	0.08	16.74	253.53	3.17
	6	0.08	17.37	245.25	3.07

The seventh day (7th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
15%	1	0.08	19.84	270.7	3.38
	2	0.08	18.22	259.7	3.25
	3	0.08	19.01	328.2	4.10
	4	0.08	18.6	244.45	3.06
	5	0.08	18.42	218.2	2.73
	6	0.08	17.56	239.45	2.99

The seventh day (7th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
20%	1	0.08	18.58	247.7	3.10
	2	0.08	19.05	239.7	3.00
	3	0.08	18.78	178.53	2.23
	4	0.08	18.91	275	3.44
	5	0.08	17.95	256.76	3.21
	6	0.08	18.745	253.23	3.17

The seventh day (7th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
25%	1	0.08	18.03	182.2	2.28
	2	0.08	18.22	196.1	2.45
	3	0.08	18.75	175.15	2.19
	4	0.08	17.9	175.36	2.19
	5	0.08	18.01	179.85	2.25
	6	0.08	19.11	180.07	2.25
Compressive Strength Mean=2.27					

The seventh day (7th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
30%	1	0.08	18.69	168.5	2.11
	2	0.08	18.65	183.7	2.30
	3	0.08	18.04	189	2.36
	4	0.08	18.18	168.32	2.10
	5	0.08	17.85	166.4	2.08
	6	0.08	16.85	175.204	2.19
Compressive Strength Mean=2.19					

The seventh day (14th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
0%	1	0.08	16.75	261.9	3.27
	2	0.08	15.56	351.7	4.40
	3	0.08	16.5	273.8	3.42
	4	0.08	16.05	362.46	4.53
	5	0.08	16.45	274.68	3.43
	6	0.08	15.76	283.31	3.54
Compressive Strength Mean=3.77					

The seventh day (14th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
10%	1	0.08	17.11	373.5	4.67
	2	0.08	16.40	265.6	3.32
	3	0.08	16.29	336.7	4.21
	4	0.08	16.53	301.15	3.76
	5	0.08	16.72	245.36	3.07
	6	0.08	15.94	263.25	3.29
Compressive Strength Mean=3.72					

The seventh day (14th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M)
15%	1	0.08	17.11	263.5	3.29
	2	0.08	15.65	268.8	3.36
	3	0.08	16.53	249.5	3.12
	4	0.08	17.18	275.58	3.44
	5	0.08	17.12	265	3.31
	6	0.08	16.35	285.85	3.57
Compressive Strength Mean=3.35					

The seventh day (14th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
20%	1	0.08	16.66	262.6	3.28
	2	0.08	15.35	237.6	2.97
	3	0.08	15.25	263	3.29
	4	0.08	15.35	295.1	3.69
	5	0.08	17.1	238.85	2.99
	6	0.08	15.63	274	3.43
Compressive Strength Mean=3.27					

The seventh day (14th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
25%	1	0.08	16.1	209.5	2.62
	2	0.08	16.11	199.9	2.50
	3	0.08	15.81	236	2.95
	4	0.08	15.85	215.31	2.69
	5	0.08	17.05	232.06	2.90
	6	0.08	15.59	215.98	2.70
Compressive Strength Mean=2.73					

The seventh day (14th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
30%	1	0.08	15.33	174.50	2.18
	2	0.08	16.70	205.00	2.56
	3	0.08	16.57	173.50	2.17
	4	0.08	16.73	168.25	2.10
	5	0.08	15.95	279.21	3.49
	6	0.08	16.33	170.67	2.13
Compressive Strength Mean=2.44					

The seventh day (28th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
0%	1	0.08	17.91	357.40	4.47

	2	0.08	16.91	714.70	8.93
	3	0.08	19.25	381.90	4.77
	4	0.08	17.59	342.40	4.28
	5	0.08	17.75	369.65	4.62
	6	0.08	16.33	442.78	5.53
Compressive Strength Mean=5.44					

The seventh day (28th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
10%	1	0.08	16.17	352.7	4.41
	2	0.08	17.15	343.2	4.29
	3	0.08	16.75	357.4	4.47
	4	0.08	17.4	446.7	5.58
	5	0.08	17.15	299.3	3.74
	6	0.08	16.25	435.9	5.45
Compressive Strength Mean=4.66					

The seventh day (28th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
15%	1	0.08	19.4	459.5	5.74
	2	0.08	18.5	485.9	6.07
	3	0.08	16.3	211.4	2.64

	4	0.08	17.8	335.45	4.19
	5	0.08	16.95	373.06	4.66
	6	0.08	15.95	292.23	3.65
Compressive Strength Mean=4.49					

The seventh day (28th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
20%	1	0.08	17.75	311.20	3.89
	2	0.08	17.65	362.60	4.53
	3	0.08	16.53	360.30	4.50
	4	0.08	17.14	321.20	4.02
	5	0.08	17.39	360.45	4.51
	6	0.08	17.31	362.60	4.53
Compressive Strength Mean=4.33					

The seventh day (28th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)
25%	1	0.08	17.94	341.10	4.26
	2	0.08	17.45	317.10	3.96
	3	0.08	16.37	302.40	3.78
	4	0.08	16.45	341.05	4.26
	5	0.08	16.71	317.15	3.96

	6	0.08	17.25	302.40	3.78
Compressive Strength Mean=4.00					

The seventh day (28th) compressive strength of HCB without and with fly ash

Percent (%)	Sample NO-	Area(m^2) of HCB	Weight(kg)	Failure Load(KN)	Compressive strength(KN/M^2)	STRESS
30%	1	0.08	16.9	267.9	3.35	11.91
	2	0.08	16.9	371.8	4.65	16.33
	3	0.08	16.7	293.8	3.67	13.06
	4	0.08	16.75	267.95	3.35	
	5	0.08	15.96	319.85	4.00	
	6	0.08	16.9	306.82	3.84	
Compressive Strength Mean=3.81						

APPENDIX THREE

Property of Cement Result

PLACE	Walkite university
DEPARTMENT	Construction technology and management
LABORATORY	Construction materials laboratory

Consistency with 0% of fly ash

Trial	Weight of cement(gm)	Weight of fly ash	Percentage by water of dry cement (%)	Water added (ml)	Penetration
1	300	0	30%	90	33
2	300	0	28%	84	27
3	300	0	27%	81	10

Consistency with 10% of fly ash

Trial	Weight of cement	Weight of fly ash	Percentage by water of dry cement (%)	Water added (ml)	Penetration
1	270	30	33%	99	23
2	270	30	31%	93	19
3	270	30	28%	84	11

Consistency with 15% of fly ash

Trial	Weight of cement	Weight of fly ash	Percentage by water of dry cement (%)	Water added (ml)	Penetration
1	255	45	33%	99	18
2	255	45	32%	96	15
3	255	45	30%	90	9.5

Consistency with 20% of fly ash

Trial	Weight of cement	Weight of fly ash	Percentage by water of dry cement (%)	Water added (ml)	Penetration
1	240	60	34%	102	23
2	240	60	33%	99	16
3	240	60	32%	96	10

Consistency with 25 % of fly ash

Trial	Weight of cement	Weight of fly ash	Percentage by water of dry cement (%)	Water added (ml)	Penetration
1	225	75	36%	108	28
2	225	75	34%	102	19
3	225	75	33%	99	10.5

Consistency with 30% of fly ash

Trial	Weight of cement	Weight of fly ash	Percentage by water of dry cement (%)	Water added (ml)	Penetration
1	210	90	36%	108	16
2	210	90	34%	102	12.5
3	210	90	33%	99	9

SETTING TIME

Setting time with 0% of fly ash and w/c of 33%

Trial	Time(min)	Penetration
1	30	33
2	45	30
3	60	26
4	75	23

Setting time with 10% of fly ash and w/c of 33%

Trial	Time	Penetration
1	30	33
2	45	30
3	60	27.5
4	75	24

Setting time with 15% of fly ash and w/c of 33%

Trial	Time (min)	Penetration
1	30	35
2	45	31
3	60	27
4	75	25
5	90	23

Setting time with 20% of fly ash and w/c of 33%

Trial	Time (min)	Penetration
1	30	39

2	45	37
3	60	34.5
4	75	31
5	90	24.5
6	105	22

Setting time with 25% of fly ash and w/c of 33%

Trial	Time (min)	Penetration
1	30	47
2	45	44.5
3	60	39
4	75	31
5	90	27
6	105	23

Setting time with 30% of fly ash and w/c of 33%

Trial time	Time	Penetration
1	30	47
2	45	44
3	60	40
4	75	30
5	90	28
6	105	25.5
7	120	18

Appendix four
Significant Coal Deposits in Ethiopia

Locality	Thickness (m)	Surface area (km^2)	Reserve in tons($x10^6$)	Administrative region
Yayu			229[8]	
Moye	0.1-2.2	8-10	40-50	Illubabor
Dilbi	Varies from block to block(0.1-2.2)	4	20	Illubabor
Chilga	4.23 average	3.88	20	Gonder
Nejo	1.3	2.2	3	Wellega
Wuchale	0.5-1.5		3.3	Wollo
Mush Valley	1.75	0.15-0.26	0.8	Shoa

List of Localities Known for Coal Occurrences in Ethiopia

Location of Occurrence	Administration Region		Location of Occurrence	Administration Region
Arigo, Didessa, Nejo and Mendi	Wellega		Dessie, Merso and Wuchale	Wollo
Chida, Modjo, Meteso,Anchano, Soyoma, Sola, Jiren ,Lalo-Sapo and Waka	Keffa		Deridawa	Deridaw
Debrebrhan, debrelibanos, Fiche, Mojo, Muger and Ankober	Shoa		Halole	Sidamo
Kindo-Halale, Morka	Omo		Hunda , Dlesuma, Meiso	Hararge
Morka	Gamugofa		Adigrat	Tigray

The Appendix four Was Taken From Utilization Of Coal In Metal Industries.

(Case of AKaki Metal Products Factory) By Elfu Amare Demoze

PHOTO GALLERY





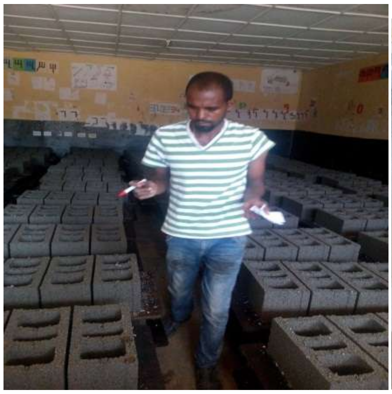

















Appendix 5

CHEMICAL ANALYSIS OF FLY ASH

Geological Survey of Ethiopia:Geochemical Laboratory Directorate

Geochemical Laboratory Complete Silicate Analysis Report Format   Form G0004

FILE ID ;1275/17 pvt   Originator; Murugeta Debela

Sample type;Coal ash   Date Submmitted;05/02/2017

Preparation : -200 MESH

Number of Sample: 1   Element to be determined Major Oxides & Minor Oxides

Analytical Method: LiBO2 FUSION , HFattack,GRAVIMETERIC,COLORIMETRIC and AAS

Analytical Results in PERCENT

FIELD NO	Lab No	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
M.D-01	1275/17	45.28	26.72	3.04	<0.01	0.88	2.00	0.48	0.03	0.18	0.54	5.60	16.53

Analysts	Checked by	Approved by	Quality Control	DATE REPORTED
Tirita Zemere				
Dessie Abebe				
Tinitra Beletkachew				
Tamiru Siraye	Gosa Hiile	Demisew Lemma	Awash Yirga	6/20/2017
Yohannes Getachew				