Jimma University

School of Graduate Studies

Jimma Institute of Technology

Faculty of Civil and Environmental Engineering

Department of Civil Engineering

Construction Engineering and Management Stream

INVESTIGATION ON THE PROPERTIES OF HOLLOW CONCRETE BLOCK USING RICE HUSK ASH AS A PARTIAL REPLACEMENT OF CEMENT

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

By: Tesfanesh Eshetu

April, 2018

Jimma, Ethiopia

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By: Tesfanesh Eshetu

Advisor: Engr. Elmer C.Agon.

Co-Advisor: Engr. Getachew Kebede. (M.Sc.)

April, 2018

Jimma, Ethiopia

DECLARATION

"I, the undersigned, declare that this research report entitled **" Investigation on the properties of HCB using rice husk ash as a partial replacement of cement "** is original work of my own, has not been presented for a degree of any other university and that all sources of material used for the thesis have been duly acknowledged."

Tesfanesh Eshetu __________________ _____/______/_________

Signature Date

This thesis has been submitted for the examination with my approval and university supervisors.

Name Signature Date

1. Eng. Elmer.C.Agon _______________ _______

/______/_______

Main advisor

2. Eng. Getachew Kebede _______________ _______

/______/_______

Co-advisor

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ABSTRACT

Hollow Concrete Blocks (HCB) are one of the most widely used walling materials in the construction industry. It is widely used in construction of residential buildings, factories and multi-storied buildings. Because of its low cost and speed of installation, it has been used all over the world [13].

The objective of this study is investigating the properties of Hollow concrete block using rice husk ash (RHA) as a partial replacement of cement.

A laboratory experimental study was conducted by preparing two types of HCB test samples. The first test samples of HCB was produced by using mix proportion 1:2:1:2 of cement, sand, gravel 00 and crushed aggregate 01 respectively as a control group and the second sample of HCBs are produced with the same mixing proportion but the partial replacement of cement with RHA is in different percentage,5% increment of RHA in volume. The properties of RHA, properties of HCB, optimum replacement of RHA and economical effect of RHA were investigated.

The chemical composition of RHA satisfies the requirement of ASTM pozzolan standard. The 28's day mean compressive strength of 0% RHA hollow concrete block is 5.01 N/mm^2 and 4.69 ,4.6 , 4.58 and 4.527 N/mm^2 of compressive strength were achieved by 5% ,10%,15% and 20% rice husk ash replacement respectively. The compressive strength of OPC and RHA concrete blocks increases with curing age and decreases as the percentage of RHA content increases. The optimum replacement was obtained at 20% replacement for the desired class B HCB. The higher replacement is slightly reducing the performance of the hollow concrete block. The material cost of all HCBs with RHA was found to be lower than the HCB without RHA. Replacing RHA with cement by 5% in volume can decrease the production cost by 1.65 birr.

general replacing of cement with rice husk ash for the production of Hollow Concrete Block can be applicable and the replacement can give us other comparable material without compromising the desired strength but the replacement percentage should not be greater than 20% in volume for class B HCB.

Keywords: Compressive Strength, Ordinary Portland cement (OPC), hollow concrete block (HCB) and rise husk ash (RHA).

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ASTM	American Society for Testing and Material
BS	British standard
Cm	Centimetre
CMU	Concrete masonry units
EBCS	Ethiopian Building Code Standard
ES	Ethiopian standard
GTZ	Deutsche Gesellschaft fuer Technische Zusammenarbei
HCB	Hollow concrete blocks
IS	Indian standard
Kg	Kilo gram
Kg/m3	Kilo gram per meter cube
L,W,H.	Length, Width and Height
Mpa	Mega Pascal
MHUPA	Ministry of House and Urban Poverty Alleviation
N/cm2	Newton per centimetre square
OPC	Ordinary Portland cement
PPC	Pozolana cement
RHPS	Rapidly hardening Portland cement
SSD	Saturated Surface Dry
W/C	Water cement ratio

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Hollow blocks are the most common type of Concrete block and walling materials that are made of natural sand or crushed rocks mixed in proportion with cement and water then compacted to mold into different shapes and sizes [14]. Hollow concrete blocks are being widely used in construction of residential buildings, factories , multi-storey buildings and compound walls due to its low cost , its light weight and ease of installation. 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.

Concrete is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as cement, well graded fine and coarse aggregates, water and admixtures (to produce concrete with special properties). In a concrete mix, cement and water form a paste which in addition to filling the voids of the fine aggregate, coats the surface of fine and coarse aggregates and binds them together. The molded concrete mix after sufficient curing becomes hard like stone due to chemical action between the water and binding material. The major factors responsible for wide usage of cement-concrete are mold ability, early hardening, and high early compressive strength, development of desired properties with admixtures to be used in adverse situations, suitability and durability. The simple reason for its extensive use in the construction of almost all civil engineering works is that the properties can be controlled within a wide range by using appropriate ingredients and by special mechanical, physical and chemical processing techniques [4].

Cement is the essential component of concrete which, when hydrated, binds the aggregates together to form the hard, strong and monolithic whole that is so useful. Well over 95% of the cement used in concrete throughout the world is Portland cement in its various forms [11]. It is by no means a simple material, and its complexities have an impact on the properties and behavior of concrete from mixing right through to the end of its life. It is therefore important to have some understanding of its manufacture, its composition, the processes involved in its hydration and of its final hardened structure if it is to be used effectively. The crucial components of Portland cement are calcium silicates, which in the manufacturing process are formed by heating a mixture of calcium oxide (CaO) and silicon dioxide (or silica, SiO2) to high temperatures. Both of these occur in the earth's crust. Cement production is a large scale operation requiring huge quantities of the raw materials, and the production plants [11].

In order to reduce the high cost of ordinary Portland cement need research into the use of some locally available materials that could be used as partial replacement for Ordinary Portland Cement (OPC) in Civil Engineering and Building Works. Supplementary cementitous materials have been proven to be effective in meeting most of the requirements of durable concrete and blended cements are now used in many parts of the world.Rice Husk Ash (RHA) which is an agricultural by-product has been reported to be a good pozzolan by numerous researchers [30].

This experimental study has investigated on the properties of hollow concrete block using rice husk ash as a partial replacement of ordinary Portland cement and evaluates optimum value of RHA to use as a partial substitute of cement for the production of hollow concrete block in order to get cost efficient and have the required strength products. Finally, comparison of the results with different standard specification had undertaken and then formulates a conclusion and recommendation.

1.2 STATEMENT OF THE PROBLEM

The construction industry is rapidly growing industry in the world and hollow concrete blocks are being widely used in the construction of residential buildings, factories and multi-storied buildings**.** Due to this the demand of HCB in the construction industry is increasing [4].The blocks are made out of mixture of cement, sand and stone chips. Cement is one of the major ingredients of concrete mix for hollow block production. The cost of cement is higher than other materials due to production, transportation and other related cost. To minimize the cost of cement in the hollow concrete production ,it needs to look suitable alternative material. The consumption and cost of cement have been increasing. So this research tried to find the way of using locally available and waste material, rice husk ash, as a partial replacement of cement and minimizing the consumption of cement in hollow concrete block. Improving the culture of using locally available material by showing one additional alternative, reduce the high cost of Ordinary Portland cement in the production of hollow concrete block and also enhance the economy of the firm.

1.3 RESEARCH QUESTIONS

This study will answer the following points while meeting its objectives:

- What are the properties of rice husk ash?
- What is the effect of rice husk ash partial replacement of cement on the properties of hollow concrete block?
- What is the optimum replacement of rice husk ash with cement in HCB production?
- What are the economical benefits of using rice husk ash for HCB production?

1.4 OBJECTIVE

1.4.1 General objective

The general objective of this research was to investigate the properties of hollow concrete blocks using rice husk ash as a partial replacement of cement.

1.4.2 Specific objectives

To directly address the main objective, the following specific objective will be sought.

- ✓ To determine the properties of rice husk ash.
- ✓ To determine the effect of using rice husk ash on the properties of hollow concrete block.
- ✓ To determine the optimum replacement of rice husk ash in hollow concrete block production.
- ✓ To analyze the economical effect of using rice husk ash as partial replacement of cement for hollow concrete block production.

1.5 SIGNIFICANCE OF THE STUDY

Implementation of waste rice husk save the consumption of cement. This study has tried to determine the ways of utilizing rice husk ash as a replacement of ordinary Portland cement for HCB production then compare the result with different standards and formulate a conclusion and recommendation depends on the result found therefore this provide helpful information to various stakeholders as follows;

- ✓ To the HCB manufacturing firms and to the contractors there is a possibility of using rice husk ash as a partial replacement of OPC for HCB production and minimize the cost.
- ✓ For the construction industry it helps the idea of investigating the possibility of using

locally available materials for construction purposes.

- ✓ For agricultural and investment firm there is the possibility of using their production waste (rice husk) for generating income by selling instead of other disposal.
- ✓ Other researchers will use the findings as a reference for further research on the utilization of rice husk ash as a partial replacement of cement.

1.6 SCOPE AND LIMITATION OF THE STUDY

The research also limited only on the mechanical properties of hollow concrete blocks such as compressive strength, density, moisture content and absorption capacity therefore the durability, fire resistance and sound insulation of hollow concrete block were not studied due to lack of laboratory for these test.

CHAPTER TWO

REVIEW OF RELATED LITERATURES

2.1 INTRODUCTION

The cement and concrete technology has shown various advancements during the past years. One of the best advancements is the use of by-product materials as a cement replacement to alleviate environmental and economical impact of cement production. These cement replacing materials were reported to improve different properties of the mortar and the concrete [3].

Rice husk is an agro-waste material. In Many parts of the world a large amount of rice husk could be obtained as an agricultural by-product Therefore, a large number of researchers have been directed toward the utilization of waste materials. Nowadays, waste materials or pozzolans from industrial and agricultural by-products such as fly ash and rice husk ash are receiving more attention since their uses generally improve the properties of the blended cement concrete, the cost, and the reduction of negative environmental effects [25].

A concrete block is primarily used as a building material in the construction of walls. It is sometimes called a concrete masonry unit (CMU). A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. Most concrete blocks have one or more hollow cavity, and their sides may be cast smooth or with a design. In use, concrete blocks are stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall [4].

This chapter dedicated in discussing about cement, different performance criteria of hollow concrete block and rice husk ash.

2.2 CEMENT

Cement is a fine grey powder which reacted with water hardens to form a rigid chemical mineral structure which holds the aggregates together acting as glue and gives concrete its strengths. The credit for its discovery is given to the Romans, who mixed lime ($CaCO3$) with volcanic ash, producing a cement mortar which was used during construction [5].

The cements are manufactured to produce the proper amount of expansion without adversely affecting the concrete quality and retaining the normal range of concrete shrinkage [10]. Cement is one of the most expensive components of concrete. Although cement paste is required to fill aggregate voids, bind them together and provide mobility to fresh concrete, it is also responsible for drying shrinkage, heat generation and porosity [1].

Nowadays, after several important technical improvements, concrete made with Portland cement is probably the most used manmade material in the world. In a concrete mixture the function of the cement is to react with the water forming a plastic mass when the concrete is fresh and a solid mass when the concrete is hard [2].

2.3 TYPES OF CEMENT

There are different types of cement depending on their composition, method of manufacturing (grinding, burning, etc.) and also the relative proportion of the different compounds. One of these types and the most commonly used one is Portland cement, which in turn is divided into many types. Among them the common type of cement is Portland pozzolana cement which contains some amount of pozzolanic materials.

2.3.1. Portland cement

Portland cement is one of the most widely used cement and is the most important hydraulic cement. It can also be used for mortar & plaster production. It is used in all types of structural concrete like walls, floors, bridges, tunnels, etc. It is further used in all types of masonry works like foundations, footings, dams, retaining walls, and pavements. When Portland cement is mixed with coarse aggregate and fine aggregate (sand) together with enough water, to ensure a good consistency, we get concrete. The origin of the name “Portland cement" is usually attributed to Joseph Aspdin, a brick mason in England who in 1824 took out a patent for making a powder made from mixed and ground hard limestone and finely divided clay. This forms into slurry and then is calcine in a furnace till the CO2 was expelled. He called the resulting material Portland cement because when the mortar made with it hardened it produced a material resembling the stone which was quarried near Portland, England [6].

2.3.1.1 Classification of Portland cement

The most common classification of Portland cement is that of ASTM. It classifies Portland cement mainly into five groups (non-air entrained) differing only on the relative amount of the compounds and the degree of fineness [4].

- ✓ ASTM type I cement is a general purpose Portland cement used when there is no special property required by the concrete.
- ✓ ASTM type II cement is Moderate Portland cement. It is also a general-purpose cement to be used when moderate sulphate resistance or moderate heat of hydration is desired.
- ✓ ASTM type III cement is High early strength Portland cement which is used when high early strength is desired, usually less than one week, it is usually used when a structure must be put into service as quickly as possible.
- ✓ ASTM type IV cement is Low -Heat of Hydration Portland cement which is used, when a low heat of hydration is required, like in mass concrete.
- ✓ ASTM type V is Sulphate -resisting Portland cement which is used when high sulphate resistance is desired.

2.3.1.2 Chemical composition of ordinary Portland cement

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 fuse and form clinker[8].Portland cement is made from materials which contain the proper proportions of lime (CaO), silica (SiO2), alumina (Al2O3), iron (Fe203) with minor amounts of magnesia and sulfur trioxide. A typical composition and the approximate limits of chemical composition in Ordinary Portland cement is shown in Table 2.1 [8].

Table 2.1 Approximate limits of oxide composition in cement

Oxide	Function	Percent (%)
CaO	Control strength and soundness. Its deficiency reduce setting time and strength	60-67
SiO_2	Gives strength. Excess of it causes slow setting	17-25
Al_2O_3	Responsible for quick setting, if excess, it lowers the strength	3-8
Fe_2O_3	Gives colour and helps in fusion of different ingredients	5-6
MgO	Impart colour and hardness, if excess it causes cracks in mortar and concrete and unsoundness	0.1 - 4.0
A1kalis	Those are residues, and if excess causes efflorescence and cracking	0.2 - 1.3
SO_3	Makes cement sound	1-3

2.3.1.3 Composition of cement clinker

The various constituents combine in burning and form cement clinker. The compounds formed in the burning process have the properties of setting and hardening in the presence of water. They are known as Bogue compounds after the name of Bogue who identified them. Le-Chatelier and Tornebohm have referred these compounds as Alite (C_3S), Belite (C_2S), Celite (C_3A) and Felite (C_4AF). The following Bogue compounds are formed during clinkering process [8]

Table 2.2 Composition of cement clinker

The principal minerals compounds in Portland cement	Formula	Name	Symbol
Tricalcium silicate:	$3CaO.SiO_2$	Alite	C_3S
Dicalcium silicate	$2CaO.SiO_2$	Belite	C_2S
Tricalcium Aluminate	$3CaO.Ai_2O_3$	Calite	C_3A
Tetracalcium Alumino Ferrite	$4CaO.A1_2O_3.Fe_2O_3$	Felite	C_4AF

The properties of Portland cement varies markedly with the proportions of the above four compounds, reflecting substantial difference between their individual behaviors.

2.3.1.4 Portland Pozzolana cement

Portland pozzolana cement (PPC) is manufactured by the intergrinding of OPC clinker with 15 to 35 % of pozzolanic materials [6]. Pozzolanic materials are siliceous or aluminous materials which by themselves posses little or no cementitious properties. But in the presence of water they react with calcium hydroxide which is liberated from the hydration of cement to form a compound possessing cementitious property. The reaction of the pozzolanic materials with calcium hydroxide results in many advantages of PPC over OPC. If these pozzolanic materials were not reacted with the calcium hydroxide, free calcium hydroxide would have been present in the concrete resulting in higher permeability of the concrete and susceptibility to other attacks. The pozzolanic reaction reduces the porosity of the concrete by producing cementitious compound. It also reduces the heat of hydration since its reaction is slower than that of OPC, which implies that it has slower rate of strength than OPC, making it suitable for mass concrete construction [4].

2.4 HYDRATION OF CEMENT

The chemical reaction between cement and water is known as hydration of cement. The reaction takes place between the active components of cement (C_4AF, C_3A, C_3S and C_2S) and water. The factors responsible for the physical properties of concrete are the extent of hydration of cement and the resultant microstructure of the hydrated cement. When the cement comes in contact with water, the hydration products start depositing on the outer periphery of the nucleus of hydrated cement. This reaction proceeds slowly for 2-5 hours and is called induction or dormant period. As the hydration proceeds, the deposit of hydration products on the original cement grain makes the diffusion of water to un hydrated nucleus more and more difficult, consequently reducing the rate of hydration with time. At any stage of hydration, the cement paste consists of gel (a fine-grained product of hydration having large surface area collectively), the un reacted cement, calcium hydroxide, water and some minor compounds. The crystals of the various resulting compounds gradually fill the space originally occupied by water, resulting in the stiffening of the mass and subsequent development of the strength. The reactions of the compounds and their products are as follows:

$C_3S + H_2O \rightarrow C–S–H^* + Ca(OH)_2$

$C_2S + H_2O \rightarrow C–S–H + Ca(OH)_2$ H* is H2O

$C_3A + H_2O \rightarrow C_3AH_6$ S is SO3

$C_3A + H2O + CaSO_4 \rightarrow CA\ C\ S\ H_{12}$

Calcium sulpho-aluminate

$C_4AF + H_2O \rightarrow C_3AH_6 + CFH$

The product C–S–H gel represents the calcium silicate hydrate also known as tobermorite gel which is the gel structure. The hydrated crystals are extremely small, fibrous, platey or tubular in shape varying from less than 2 mm to 10 mm or more. The C–S–H phase makes up 50–60% of the volume of solids in a completely hydrated Portland cement paste and is, therefore, the most important in determining the properties of the paste. The proposed surface area for C–S–H is of the order of 100–700 m2/g and the solid to solid distance being about 18 Å. The Ca(OH)2 liberated during the silicate phase crystallizes in the available free space. The calcium hydroxide crystals also known as portlandite consists of 20-25% volume of the solids in the hydrated paste. These have lower surface area and their strength contributing potential is limited. The gel must be saturated with water if hydration is to continue. The calcium hydroxide crystals formed in the process dissolve in water providing hydroxyl (OH–) ions, which are important for the protection of reinforcement in concrete. As hydration proceeds, the two crystal types become more heavily interlocked increasing the strength, though the main cementing action is provided by the gel which occupies two-thirds of the total mass of hydrate [8].

2.5 PHYSICAL PROPERTIES OF CEMENT

Tests of the physical properties of the cements should be used to evaluate the properties of the cement, rather than the concrete.

2.5.1 Fineness

The fineness to which cement is ground during its production can have a considerable effect on the behaviour of the cement during hydration. Although it is true that if a cement does meet normal specifications, changing the cement fineness alone with not solve concrete problem that arise in particle, the fineness is nonetheless an important parameter of greater important, the rate of hydration increase with increasing fineness .This leads to both higher rate of strength gain and a higher rate of evolution of heat. Since hydration takes place at the surface of the cement particles, and further hydration is hindered by the formation of reaction products, finer particles will be more completely hydrated than coarser particle. Larger cement particles probably never hydrate completely, increasing fineness tends to decrease the amount of bleeding but at high fineness the amount of water required for workability for non entrained concrete is increased which result in increased drying shrinkage .It is also worth nothing that high cement fineness requires a greater amount of gypsum for proper set control owing to the increased availability of C3A for reaction and reduces the durability of concrete to [9].

2.5.2 Consistency of cement paste

This test is carried out to determine the amount of water required to prepared a standard cement paste .The usual range of water –cement ratio for normal consistency is between 26%-33% [9].Many of the properties of concrete are affected by its water content. The physical requirements of cement paste like setting and soundness depends on the water content of the neat cement paste. Therefore it is necessary to define and study the water content at which to do these tests. This is defined in terms of the normal consistency of the paste which is measured according to ASTM C 187. The amount of water required to achieve a normal consistency as defined by a penetration of 10 ± 1 mm of the Vicat plunger (ASTM C 187) is expressed as a percentage by weight of the dry cement. The test is very sensitive to the conditions under which it is being carried out, particularly the temperature and the way the cement is compacted into the mould. The test does not correlate to the quality of the cement; it only measures the plasticity of cement paste.

2.5.3 Setting time

Setting is a process in which cementitious mixtures of plastic consistency is converted into a set material which has lost its deformability and crumbles under the effect of sufficiently great external force [19]. It is preceded by a stiffening of the paste in which the apparent viscosity of the material increases without losing its plastic character. There are two types of setting time i.e. initial and final setting times. The initial setting time indicates the time at which the paste begins to stiffen considerably and can no longer be molded; while the final setting time indicates the time at which the paste has hardened to the point at which it can sustain some load. Like normal consistency these tests are also used for quality control. Ethiopian standard recommends that the initial setting time for cement not to be less than 45 minutes and the final setting time not to exceed 10 hours [9].

2.6 RICE HUSK ASH

Rice husk ash (RHA), produced by burning rice husk under controlled Temperature, due to its high activity and high specific surface area, can be applied to concrete by replacing cement, such as in normal concrete and high-strength / high-performance concrete. In addition, its application in ultra-high strength concrete has also been reported. Many experimental studies have shown that, RHA improves the mechanical properties of concrete, decreases permeability properties and significantly ameliorates its durability. The adverse effect of reducing a slump of concrete can be resolved by increasing water reducing agent. RHA in concrete has a preferable application prospect in the future [18].

Rice husk can be fulfils the physical characteristics and chemical composition of mineral admixtures. Pozzolanic activity of rice husk ash (RHA) depends on (i) silica content, (ii) silica crystallization phase, and (iii) size and surface area of ash particles. In addition, ash must contain only a small amount of carbon.RHA that has amorphous silica content and large surface area can be produced by combustion of rice husk at controlled temperature. Suitable incinerator/furnace as well as grinding method is required for burning and grinding rice husk in order to obtain good quality ash [7].

Accordingly, the study of the application of RHA in concrete is a sustainable development strategy; not only to utilize agricultural waste materials but also to partly reduce the use of silicate cement. Compared with the improved ratio of RHA on the compressive strength, improving the durability of concrete has a significant better result. The reasons are concluded that RHA decreases Ca(OH)2 and clearly ameliorates the pore structure, a denser micro-structure can be achieved, penetrability is decreased, and accordingly a better durability is obtained. Several studies showed that, RHA noticeably improved the durability of concrete [16, 17, 18].

2.6.1 Properties of rice husk ash

Table 2.3 Physical properties of RHA [28]

item No	particulars	properties
1	Color	Gray
2	Shape texture	Irregular
3	Mineralogy	Non crystalline
4	Particle size	< 45micro
5	Oder	Odorless
6	Specific gravity	2.3
7	Appearance	Very fine

2.6.2 Chemical composition of rice husk ash

Due to type of rice husk, burning process, temperature used and different reason the chemical composition of rice husk ash had differences weight percentage of chemical proportion.

Table 2.4 Chemical composition of rice husk ash

Compound	**Weight percentage (%)**	
	Ghassan[36]	**G.L. Oyekan [30]**
Silicon oxide (SiO_2)	88.32	90
Aluminum oxide (Al_2O_3)	0.46	0.39
Ferum oxide (Fe_2O_3)	0.67	0.37
Calcium oxide (CaO)	0.67	0.46
Magnesium oxide (MgO)	0.44	0.88
Potassium oxide (K_2O)	2.91	3.1
Sodium oxide (Na_2O)		0.07
Phosphorus oxide (P_2O_5)		1.6
MnO		0.039
LOI	5.81	3.03

2.6.3 Effect of rice husk ash on the concrete or hollow concrete block

I. Effect of RHA on Compressive Strength

The compressive strength of the block is decreased when the percentage of rice husk ash is increased. This may be due to the reaction of the lime with silica (SiO_2). In the presence of moisture the lime in the cement reacts with the silica in the RHA to produce tricalcium silicate (C_3S) and dicalcium silicate (C_2S), the hydration products of these two compounds are tobermorite gel and calcium hydroxide. The tobermorite particles are responsible for the cementing properties as well as other important engineering properties such as strength and shrinkage.The decrease in strength may be attributed to the fact that the partial replacement of cement with the RHA caused a reduction in the quantity of cement in the mix available for the hydration process and hence a reduction in the formation of the stable strength producing cementitious compounds. Another possible reason for the low strength obtained is the type of burning used to produce the ash. The burning process has been known to affect the quality of the ash produced. Open field burning was used in the investigation and the ash obtained probably contained a high percentage of unburned carbon with a consequent reduction in the pozzolanic activity of the ash. High pozzolanic RHA is created by maintaining husk combustion temperatures between 500℃ and 700℃ [28, 29].

II. Effect on Porosity

Block units take in water due to their porous nature. The volume of water absorbed is an indication of the pore volume which depends on the interstitial arrangement of the particles of the constituent materials at micro level. When exposed to persistent flooding, a highly porous block will absorb and retain much water, become soaked and could eventually fail. All the blocks with rice husk ash are more porous than the control [30].

III. Effect on Permeability

Replacing cement with RHA increases the permeability of the block. This means that the inclusion of the admixture opens up the block in a way that encourages up flow of fluid [30].

IV. Effect on Thermal Conductivity

The value of thermal conductivity is fluctuating as the RHA content increases in different study. The value of the thermal conductivity of the block could be said to increase as the RHA content increases except that there was a drop in some percentage of RHA content. The low value of the thermal conductivity of the block makes it the most suitable when reduction of heat transfer into or heat loss from the enclosed space is desired. This minimizes the cooling/heating load necessary to provide a level of thermal comfort within the building over the annual climatic cycle. Consequently, there is reduction in the size of the air conditioning system required to cool or heat the space, reduction in the thickness of the thermal insulator, and extension of the period of human comfort without reliance on mechanical air conditioning. The above qualities reduce the annual energy cost in addition to other energy conservation and environmental effects.

V. Effect of RHA on Concrete

The percentage RHA content increased the compressive strength of the concrete cube specimens decreased. The initial increase in strength of the block could be attributed to the reaction of the lime (CaO) in the cement with the silica in the RHA resulting in the production of strength producing calcium silicate compounds. As the percentage RHA content in the mix increased, the amount of cement available for the hydration process decreased with a consequent reduction in the strength of the concrete cube specimens produced [30].

VI. Effects of RHA on the Workability of Concrete

RHA in concrete increases the water demand, decreases the slump of concrete and has a negative influence on the workability of concrete. Therefore, the application of RHA in concrete, especially which at a lower w/b, must take the necessary measures to assure the good workability of concrete, namely using large amounts of water reducing agent. However, the dosage of water reducing agent was restricted to be lower than its saturation dosage to avoid its segregation [18].

VII. Effects of RHA on the Durability of Concrete

Compared with the improved ratio of RHA on the compressive strength, improving the durability of concrete has a significant better result. The reasons are concluded that RHA decreases Ca(OH)2 and clearly ameliorates the pore structure, a denser micro-structure can be achieved, penetrability is decreased, and accordingly a better durability is obtained. Several studies showed that, RHA noticeably improved the durability of concrete [17, 33-35]

2.6.4 Availability of Rice husk ash

Rice husk ash (RHA) is an agricultural based pozzolanic material, generated by rice mills in huge quantities. Rice husk is an agricultural residue which accounts for 20% of the 649.7 million tons of rice produced annually worldwide. The chemical composition of rice husk is found to vary from one sample to another due to the differences in the type of paddy, crop year, climate and geographical conditions [26].

In order to assess the potential of Rice husk ash production in Ethiopia, it is very important to evaluate the Rice yield in the country. Rice is considered as the “Millennium Crop” to ensure food security in Ethiopia .The annual production capacity is about more than 713,160.65 quintal, the rice covering about 58,000 hectares of land. This annual production is not sufficient to satisfy the local demand so its needs more investment. The estimated potential areas of rice production in Ethiopia is 30 million hectares of which a total 5.6 million hectares highly suitable and 25 million hectares suitable. By preparing to Irrigation 3.7 million hectares are suitable to the production of rice husk ash [19]

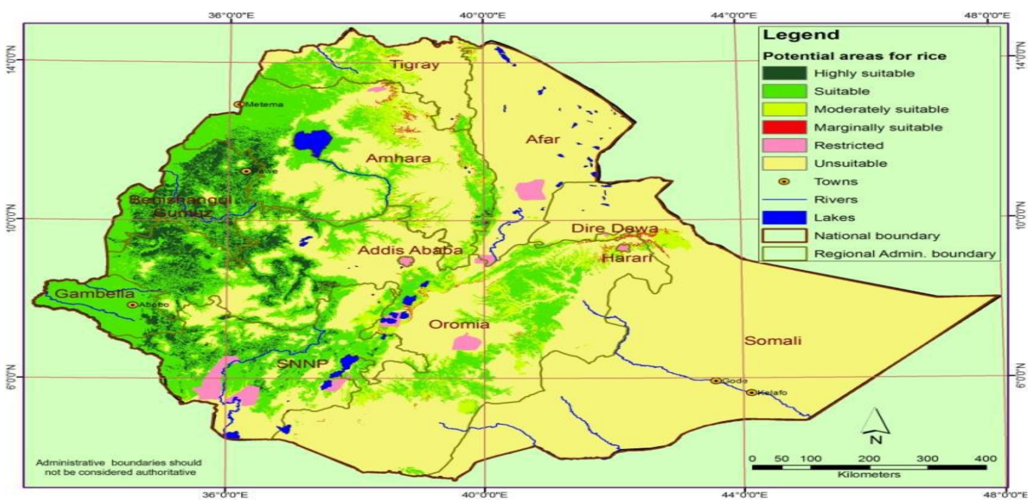

Figure 2.1: Rice Suitability Map: Rain-fed [31]

Agriculture is the mainstay of the Ethiopian economy. If government of Ethiopia increased the investment on infrastructure, rural finance, access to improved technologies and research and development for rice production, the country will have potential for rice husk production. Rice could suitably grow in many parts of the country is listed on Table 2.5.

Table 2.5 The predominant potential areas for rice husk ash production [19].

Predominant potential region	predominant potential areas
South Western Highlands of Oromia Region	Illuababora, East and West Wellega and Jimma Zone
West central highlands of Amhara Region	Fogera, GonderZuria,Dembia, Takusa and Achefer
Amhara and Benshangul Regions	Jawi, Pawi, Metema and Dangur
Gameblla regional	Abobo and EtangWoredas
South and South West Lowlands of SNNPR	Beralee, Weyito, Omorate, GuraFerda and Menit
Somali Region	Gode

2.7 HOLLOW CONCRETE BLOCK

Hollow concrete block is an alternative wall and floor, making material in the building construction having one or more large holes with the solid material between 50 and 75 percent of the total volume of the block calculated from the overall dimensions. Hollow concrete blocks are manufactured from a zero-slump mixture of Portland cement (and possibly other cementitious materials), aggregates, water and sometimes admixtures[Ethiopian standard (ES 596:2001)].

2.7.1 Hollow concrete blocks classification

Hollow concrete blocks used for wall construction classified as load bearing and non load bearing depends on their structural function [8].According to Ethiopian standards ES 596:2001 hollow concrete blocks shall conform four classes. Depends on their strength, as Class A, B, C and D and their requirements are defined .

Table 2.6 Classification of hallow concrete block according of ES

Types of hollow concrete block	**Class**
Load bearing	A B C
Non load bearing	D

Class A used for load bearing wall construction above or below ground level in damp proof course, in exterior walls that may or may not be treated with weather- protective coating and for interior walls and density of Class A blocks must conform between the range of 900 – 1200 kg/m3.

Class B and C are used for load bearing wall construction above ground level in damp proof course in exterior walls that are treated with suitable weather- protective coating and their density should be between 900 – 1200 kg/m3 but class C is recommended for non load bearing wall.

Class D are used for non load bearing interior walls and exterior panels walls in steel or Reinforced concrete framed construction when protected from weather by rendering or by some other efficient treatment and their density should be between 600 - 900 kg/m3.

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 on Table 2.7.

Table 2.7 Weight classification of HCB (ASTM C 90-10)

Classification of HCB	**Density (Kg/m^3)**
Light weight	Less than 1682
Medium weight	1682-2002
Normal weight	2002 or more

Addition to this ASTM shall conform two grades those are grade N and grade S. Grade N blocks are suitable for general use such as in exterior walls below and above grade level that may or may not be exposed to moisture penetration. But grade S blocks limited to use above grade level for walls not exposed to weather and for exterior walls with weather protective coating.

2.8 HOLLOW CONCRETE BLOCKS PRODUCTION PROCESS

2.8.1 Raw Materials

Portland cement (OPC or PPC), aggregates ,sand and water are commonly raw materials used to make concrete mixture for production of hollow concrete blocks. But concrete mixture used for blocks has a higher percentage of sand and a lower percentage of gravel and water than the concrete. Mixtures used for general construction purposes. This produces a very dry, stiff mixture that holds its shape when it is removed from the block mold. In addition to these, basic components various chemicals, called admixtures, can be used to modify curing time, increase compressive strength, or improve workability sometimes pigments may be added to give the blocks a uniform color throughout. Aggregates should be passing through a sieve of nominal aperture of 9.5 mm in addition to this the size of aggregate should not exceed two–third of the thickness of the thinnest part of the shell or web unit [20].

2.8.1.1 Aggregate

Aggregates are the materials basically used as filler with binding material in the production of mortar and concrete. They are derived from igneous, sedimentary and metamorphic rocks or manufactured from blast furnace slag, etc. According to size aggregates are classified as coarse aggregate, fine aggregate and all-in- aggregate [8].

2.8.1.2 Sand

Sand is used widely as a constituent of masonry in mortar, in concrete units and sand lime units, and in grouts and renders. It is a mixture of rock particles of different sizes from about 10 mm diameter down to 75 μm diameter. Most sand is a naturally occurring rock powder derived from recent naturally occurring alluvial deposits such as the beds of rivers and sea beaches or from older deposits formed by alluvial or glacial action. In some areas it may be derived from dunes or by crushing quarried rocks [10].

2.8.1.3 Water

The water used is fresh, colorless, odorless and tasteless potable water that was free from organic matter of any kind. The amount of water must therefore be limited to produce quality concrete required for a job. For instance excess water weakens bond between the successive lifts of concrete. Contrary lesser water makes it difficult to work with concrete [13].Potable water is acceptable for the concrete mix such water needs no testing but water that is unsuitable for drinking must be tested.

2.8.1.4 Cement

Ordinary Portland (Type-I) cement is suitable for general concrete construction. Most widely used cement for hollow concrete production are ordinary Portland cement (OPC), Portland pozzolana cement (PPC) and special cements. Type I, or ordinary cement, is used where extended curing periods are no handicap, or where blocks can be yarded for 7 to 28 days, allowing time for the blocks to attain specification strength [2].

2.8.2 Batching

Aggregates can be batches by volume or by weight, but the latter is more accurate. For this reason, cement should only be batches by weight, or preferably by using only whole bags of 50 kg. In backyard block production, with less stringent quality standards, batching by volume using buckets, tins, wooden boxes or wheelbarrows is quite acceptable, if done with care to ensure uniform proportions of mix [MHUPA].

2.8.3 Mixing

Before starting production the different materials used to produce the HCB will be dry-mixed thoroughly on a clean and dry ground by hand or the mixture will be put in the mixing machine with the appropriate amount of water required. According to GTZ Water to cement ratio of hollow concrete block is 0.49 – 0.55.The quality of concrete blocks depends largely on the type of mixer and period of mixing. The free fall, revolving drum type mixers are not suitable, because of the semi-dry nature of the mix. Pan mixers have a quick moving action and are thus recommended [Ministry of Federal Affairs 2003].The following mixing proportions for the production of hollow concrete blocks are used in accordance to ESC D3.301.

Table 2.8 Material proportion of hollow concrete block production by volume

Class	Proportions by volume of				
	Sand	Gravel 00 5mm-0.15mm	Gravel 01 10mm -2.36 mm	Redash or pumice	Cement
A	2	1	1		1
	2	1		1	1
B	2	1	2		1
	2	1		2	1
C	3	1	2		1
	3	1		2	1

2.8.4 Molding

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

Figure 2.2 Casting machine

2.8.5 Curing

Shelter the blocks from sun and draying winds .After 24 hours they should be watered and kept damp. Once molded blocks have sufficiently hardened to permit removal of the supporting wooden pallet they may be carefully turned on side or edge and the pallet removed, the pallet oiled and reused. Keep blocks damp for several days to permit the cement to hydrate completely. The longer the curing time the better is the strength. The blocks should thereafter be completely dried prior to placing in the wall [4].

2.9.SURFACE TEXTURE AND FINISH

Textures may also be developed by treating the face of the units while still green by wire brushing or combing, by slightly eroding the surface by playing a fine spray of water upon it, and by splitting (split block) such surface must provide adequate adhesion for plaster or other finish as stated in Ethiopian standard ES 596:2001.

2.10. PHYSICAL REQUIREMENTS OF HOLLOW CONCRETE BLOCK

All units shall be sound and free of cracks or other defects which interfere with the proper placing of the unit or damage the strength or performance of the construction. Minor chipping resulting from the customary methods of handling during delivery, shall not be deemed grounds for rejection. Where units are to be used in exposed wall construction, the face or faces that are to be exposed shall be free of chips, cracks, or other imperfections [13].

Table 2.9 Nominal dimensions of hollow concrete blocks [ES 596:2001]

Length (L)mm	Breadth (b) mm	Height (h) mm
400	100	200
	150	
	200	
500	100	100
	120	150
	150	200
	200	250
600	100	100
	120	150
	150	200
	200	250

2.11. HOLLOW CONCRETE BLOCK PROPERTIES

2.11.1. 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).

The density of a block can only be obtained after the casting process. Three blocks taken randomly from the selected samples and then dried to constant mass in a suitable oven heated to approximately 105°C. After cooling the blocks to room temperature, the dimensions of each block shall be measured in centimeters (to the nearest millimeter) and the overall volume computed in cubic centimeters. According to Ethiopian standard ES 596:2001 three blocks shall be taken for average density and it should conform to the requirements specified in Table 2.10 below.

Table 2.10.Density classification of concrete masonry units [ES 596:2001]

Class of Hollow concrete block	**Ethiopian standard ES 596:2001 (Kg/m3)**
A	900-1200
B	900-1200
C	900-1200
D	600-900

2.11.2. Compressive Strength

The strength of hollow concrete is closely related to the specimen size and shape, method of pore formation, direction of loading, age, water content, water-cement ratio, degree of compaction, and cement content characteristic of its ingredients used, method of curing, size and number of holes created. Both hollow structure of the air holes and mechanical condition of the pore shells have a great influence on the compressive strength of hollow concrete block. It is also been found that a reduction in density due to formation of holes will results in a significant drops in strength. Generally, compressive strength increases linearly with density of structural concrete
The minimum compressive strength at 28 days being the average of six units, and the minimum compressive strength at 28 days of individual units should be tested. Compressive strength of a concrete masonry unit shall be taken as the maximum load in Newton divided by the gross cross sectional area of the unit in square millimeters finally the results of the nearest 0.1 N/mm^2, separately for each unit and as the average for the six units will be recorded [20] The following table are the minimum compressive strength requirements for blocks at the age of 28 days. The mix proportions of the material components are to be adjusted as required to obtain the required compressive strength according to Ethiopian standard, listed on the Table 2.11.

Table 2.11. Compressive strength of hollow concrete blocks at 28 days [ES 596:2001]

Type of hollow concrete block	Class	Minimum comprehensive strength (N/mm2)
		Average of 6 units
Load bearing	A	5.5
	B	4.5
	C	3.5
Non load bearing	D	2

2.11.3. Water Absorption

It is a measure of the voids (reachable pore volume) within the net volume of the concrete, including the voids within the aggregate itself. According to ASTM C140-70, the water absorption determined from five full-size units by completely immersed in water at room temperature for 24 hours and they shall be removed from the water and allowed to drain for one minute by placing them on a 10 mm or coarser wire mesh, visible surface water being removed with a damp cloth, and immediately weighed and then all specimens shall be dried in a ventilated oven at 100 °C to 115 °C for not less than 24 hours and until two successive weightings at intervals of 2 hours show an increment of loss not greater than 0.2 percent of the last previously determined mass of the specimen. Ethiopian standard [ES 596:2001] specify water absorption 290 kg/m3 (25%) for load bearing hollow concrete block and 320 kg/m3 (30%) for non load bearing hollow concrete block.

2.11.4. Drying Shrinkage

The drying shrinkage is defined as the change in linear dimension of test specimen due to drying from saturated condition to an equilibrium weight and length under specified accelerated drying condition. Dimensional changes of units has a significant effect on cracking that may be takes place during the early curing and drying which leads to a reduction in volume due to loss of moisture. The amount of drying shrinkage that occurs depends on the properties of the materials used for production, for instance units produced with normal weight aggregates tend to shrink less than units produced with lightweight aggregates and high strength units, with the corresponding high cement content, will shrink more. In addition to this the weather conditions at the job site also contribute to the dimensional changes in concrete masonry. Clearly, there will be more shrinkage in hot, arid climates as the amount of moisture lost to the atmosphere is greater than in cooler, humid climates. Units when unrestrained being the average of three units shall not exceed 0.1 percent [IS: 2185:1979]. The 'drying shrinkage' shall be calculated for each specimen as the difference between the 'original wet measurement' and the 'dry measurement' expressed as a percentage o f the 'dry length [21]

2.11.5. Moisture content

Moisture content requirement of concrete block masonry units is related to their linear shrinkage characteristics. Concrete loses or absorbs moisture with changes in the moisture content or relative humidity of the surrounding air. The cement paste may gain moisture and hence "swell", or lose moisture and "shrink" before it attains an air dry equilibrium condition. It will undergo no dimensional change when the moisture content of the concrete is in equilibrium with the relative humidity of the surrounding so that masonry units are never delivered to a construction site in a saturated condition, and moreover, could not be laid in this condition. If unacceptably moist units are laid in a wall at the time of construction, and this inherent shrinkage is restrained in-service, stresses are developed within the masonry that may cause cracking. ASTM C90-70 specifies this.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 STUDY AREA

The study was conducted in Jimma Zone, Southwestern Ethiopia, which is located at 345km in southwest of Addis Ababa. Its geographical coordinates are between 7° 13'- 8° 56N latitude and 35°49'-38°38'E longitude with an estimated area of 19,305.5 km^2. It has an area of average altitude of about 5400 ft. (1780 m) above sea level. The climatic zone locally known as Woyna Daga which is considered for agriculture as well as human settlement. The rice husk was found in jimma Zone at the specific area of, kishea ,Shebe Shambo woreda.

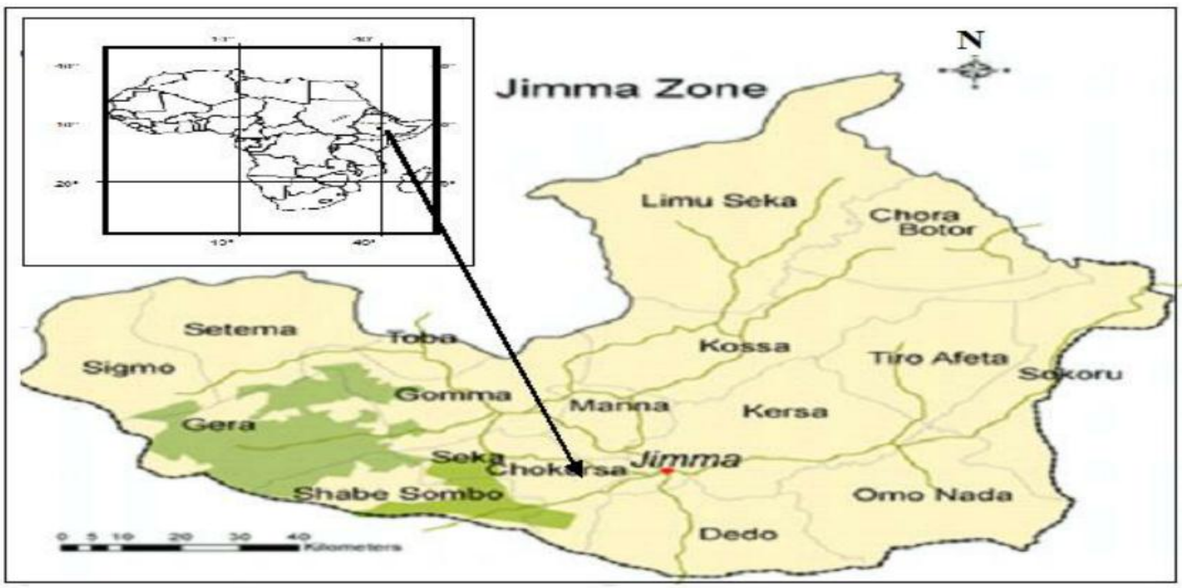

Figure 3.1 Map showing the geography of study districts [32].

3.2 STUDY DESIGN

The study was conducted in different steps. These include material preparation, determining engineering property of materials, production of hollow blocks with a mixing proportion of class B hollow concrete block and determining the properties of hollow concrete block. In this study the amount and kind of aggregate and sand was constant, but quantity of cement, water and rice husk ash was varied.

3.2.1 Material preparation

3.2.1.1 Water

In this study potable water was used.

3.2.1.2 Cement

Ordinary Portland Cement (OPC) of 42.5 Grade was used to conduct this experimental work.

3.2.1.3 Sand

The sand used for the study was purchased from local supplier and their sources are Gambela. Those fractions from 4.75 mm to 150 microns are termed as sand.

3.2.1.4 Crushed aggregate (01) and fine aggregate (00)

The crushed aggregate (01) and crushed fine aggregate (00) used for the study was purchased from local supplier in Jimma.

I. Crushed aggregate (10mm – 2.36mm or 01)

Maximum crushed aggregate size used in this research was 10mm and obtained from local supplier.

II. Fine aggregate (5mm-0.15mm)

Aggregate passing through 4.75 mm sieve are defined as fine aggregate. It was found from local suppliers. The fine aggregate size was used in this research are 5mm up to 0.15mm.

3.2.1.5 Rice husk ash

Figure 3.2.Rice husk [ ]

3.2.1.5.1 Preparation of rice husk ash

For this research the rice husk was collected from kishea found in Shebe Shambo woreda and Jimma Zone . It used after sieving and identifying small particle size of rice from the husk. It was then burned in the laboratory by using burning machine. The rice husk ash was burn for 6 -7 hours in the burning machine and it is controlled burning process. The temperature was in the range of 500-600℃. The ash was left inside the machine to cool down and its takes more time to cool down therefore using some external area to cooling the ash with normal temperature before it was collected. Both burring and grinding process was takes place in Jimma agricultural and veterinary college.

Figure 3.3 Rice husk burning process

3.2.1.5.2 Grinding process of rice husk ash

The burning ash after cooling was coarse and it needs grinding machine to make the size distribution of the rice husk ash is fine. But there is a limitation in this part since there is no standard grinding machine. This research used the maize’s grinding machine which is shown in the figure 3.4 to minimize the coarse distribution of ash.

Figure 3.4 Grinding of rice husk ash

3.2.2 Experimental work procedures of material

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

3.2.2.1 Properties of crushed Aggregate (10mm – 2.36mm)

1. **Sieve Analysis**

The grading is determined in accordance with ASTM C 136, "Sieve or Screen Analysis of Fine and Coarse Aggregates." A sample of the aggregate is shaken through a series of sieves nested one above the other in order of size, with the sieve having the largest openings on top and the one having the smallest openings at the bottom. The gradations of aggregate were selected by considering the ASTM C-33 standard gradation specifications. The laboratory samples of aggregate for the property test were taken by using quartering method and sample splitter. The results for the tests are presented in the Appendix one.

Figure 3.5 Sampling techniques for aggregate

2. Specific Gravity & Absorption (ASTM C 127-01 and ASTM C 128-01)

Tests for the specific gravity and absorption characteristics of aggregates have long been used to aid in determining batch quantities for concrete. Reject all material passing 4.75mm sieve. Test methods for finding specific gravity of aggregates are described in ASTM C-127, "Specific Gravity and Absorption of Coarse Aggregate," are the generally accepted test procedures. The specific gravity and water absorption are calculated according to the following equation provided in the standard: The bulk specific gravity and bulk specific gravity SSD are calculated as follows;

$$\text{Bulk Specific Gravity} = \frac{A}{B-C}$$

$$\text{Bulk Specific Gravity (SSD)} = \frac{B}{B-C}$$

$$\text{Apparent Specific Gravity} = \frac{A}{A-C}$$

$$\text{Absorption, \%,} = \frac{B-A}{A} * 100$$

Where

A = Weight of oven-dry sample in air;

B = Weight of saturated surface-dry mass in air; and

C = Weight of saturated sample in water

Figure 3.6 specific gravity and water absorption

3. Bulk density (unit weight)

The bulk density of the aggregate was determined according to ASTM C-29. In the test, a test cylinder of known volume is used and the mass of aggregate required to fill the cylinder is determined from the difference in mass between filled and empty cylinder.

Figure 3.7 The Bulk Density of the Coarse Aggregate Test

The bulk density, unit weight, of an aggregate is the mass of the aggregate divided by the volume of particles and the voids between particles. The method most commonly used requires placing three layers of oven-dry aggregate in a container of known volume, rolling each layer 25 times with a tamping rod, leveling off the surface, and determining the mass of the container and its contents. The mass of the container is subtracted to give the mass of the aggregate, and the bulk density is the aggregate mass divided by the volume of the container**.**

The bulk density is calculated for each test specimen from the equation,

$$\text{Unit Weight (Kg/m3)} = \frac{B-A}{C}$$

Where A = Weight of Container (Kg)

B = Weight of Container + Sample (Kg)

C = Volume of container

3. Moisture Content

Moisture Content of coarse aggregate was determined in accordance with ASTM C 566, “Total Moisture Content of Aggregate by Drying,” by measuring the mass of a sample of the aggregate representative of the moisture content in the supply being tested, drying the sample and obtaining the mass again. In the test, about 2 kg of aggregate sample is oven dried at 105’C for

24 hours and from the difference in weight before and after drying, the moisture content is determined. The moisture content is calculated from the equation,

$$\text{Total Moisture Content, \%} = \frac{A-B}{B} * 100$$

Where A = Weight of the original Sample

B = Weight of the dry sample.

Figure 3.8 Moisture content of coarse aggregate test

3.2.2.2 Properties of fine Aggregate

1. **Sieve Analysis; Gradation ASTM C136**

The grading was determined in accordance with ASTM C136/C136M, “Sieve Analysis of Fine and Coarse Aggregates.” A representative sample of the aggregate that has been properly prepared is shaken through a series of sieves nested one above the other in order of size, with the sieve having the largest openings on top and the one having the smallest openings at the bottom.

Figure 3.9 Sieve Analysis test

2. **Fineness Modulus**

Fineness modulus is often computed using the sieve analysis results. The fineness modulus is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100. The specified sieves are the 4.75 mm, 2.36 mm, 1.18 mm, 600 µm, 300 µm, and 150 µm (No. 4, 8, 16, 30, 50, and 100). Note that the lower limit of the specified series of sieves is the 150 mm (No. 100) sieve and that the actual size of the openings in each larger sieve is twice that of the sieve in the following.

$$FM=\sum \frac{\%\ \text{retained}}{100}$$

3. **Specific gravity and Water Absorption**

This test was conducted in accordance with ASTM C128, "Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate." Fine aggregate is dried to a constant mass at 100 to 110°C (212 to 230°F), cooled in air, and immersed in water for 24 hours. The sample is stirred frequently until it approaches a free flowing condition and then a portion is placed in a mould and tamped. If surface moisture is still present, the fine aggregate will retain its molded shape after the mould is lifted. Drying is continued with testing at frequent intervals until the tamped fine aggregate slumps slightly upon removal of the mold. This indicates that it has reached an saturated surface dry basin (SSD) condition. The mass of fine aggregate sample is determined in SSD, oven dry and submerged states. These values are then used to calculate bulk specific gravity, bulk SSD specific gravity, apparent specific gravity and absorption. Relative density (specific gravity) is computed from the equation

Bulk Relative Gravity= $\frac{A}{B+C-D}$ Bulk Relative Gravity (SSD) = $\frac{B}{B+C-D}$

Where A = is the mass of the oven-dry sample in air

B = is the mass of the SSD sample in air

C = is the mass of the jar or flask filled with water; and.

D= is the mass of the jar or flask with specimen and water to the Calibration or filling mark

4. Absorption and surface moisture

The various moisture conditions in which an aggregate may exist have been described previously. Two of these, oven-dry and saturated surface-dry (SSD), are used as the basis for relative density calculations. Aggregates stockpiled on the job, however, are seldom in either of these states. Absorption is a measure of the total pore volume accessible to water and is usually calculated using the results from a relative density determination (ASTM C127; ASTM C128). Absorption is computed as a percentage by subtracting the oven-dry mass from the saturated surface-dry mass, dividing by the oven-dry mass, and multiplying by 100.

$$\text{Absorption } \% = \frac{WSSD-WOD}{WOD} * 100$$

Total moisture content

Total moisture content is measured in accordance with ASTM C566, “Total Moisture Content of Aggregate by Drying,” by measuring the mass of a sample of the aggregate representative of the moisture content in the supply being tested, drying the sample, and obtaining the mass again.

$$\text{Total moisture content } \% = \frac{A-B}{B} * 100$$

Where A = Weight of the original sample

B = weight of the dry sample

3.2.2.3 Properties of cement

1. **Consistency of cement with different percentage of cement**

To determine the quantity (%age) of mixing water required for preparing cement paste of standard consistency (satisfactory workability) test were needed .Cement sets and hardens in to a solid mass up on hydration when mixed with water .It Binds two or more non adhesive substances together for various test of cement, neat cement paste of normal ,standard, consistence has to be made by mixing the cement with the correct amount of water .It is determined by using vicat apparatus ,which measure the resistance of the paste to the penetration of a plunger of 300gm released at the surface of the paste. The determination of the correct amount of water is required for the reason that the rate of hydration and setting of cement are affected by the w/c ratio .The water requirement for various tests of cement depends up on the normal consistency of the cement ,which itself depends up on the compound ,composition & fineness of the cement. Percentage of water (P) in the cement paste of standard consistency varies from cement to cement & from batch to Bach .Therefore it is recommended that this quantity be taken as under for various tests. The usual rage of w/c ratio for normal consistency is between 0.26 to 0.33. The consistency test analysis is occurred as follow ;

$$P = \frac{W}{C} * 100$$

Where C = Weight of cement taken (gm)

W = weight of water for desired penetration

P = % age of water for normal consistency

Figure 3.10 Consistency of cement with different percentage of cemen

2. Fineness of cement with different percentage of cement

To determine the fineness of cement by sieving through sieve, of standard size, finer cement will increase the rate of hydration. This leads to higher rate of beat evolution & strength gain. Finer cement will decrease the amount of bleeding but it increase gypsum requirement ,which control proper setting , and water requirement for workability (which leads to higher drying shrinkage & cracking) Therefore the fineness of cement has to be balanced with amount of coarseness in the cement . Finer cement decreases amount of bleeding. The test is used to check proper grinding of cement .And it can be determined by using standard size sieve IS 90 micron (9) sieve. Sieve should be cleaned gently only with bristle brush to avoid damage to the mesh and sieving must be carried out gently and continuously for 15 minutes. The calculation of fineness percentage is;

$$Fineness\,\% = \frac{W2}{W1} * 10$$

Where W_1 (gm) = weight of the cement before sieving

W_2 (gm) = weight of the cement residue after sieving

Figure 3.11 Fineness of cement with different percentage of cement

3.2.2.4 Properties of rice husk ash

Chemical composition, sieve analysis, specific gravity and color of rice husk ash are carried out in Addis Abeba with in mineralogy & geotechnical laboratory of geological survey of Ethiopia. Determine the percentages of these oxides as required in accordance with the applicable sections of Test Methods C 114 for materials having an insoluble residue greater than 1 %. Analysts performing sodium oxide and potassium oxide determinations shall observe the precautions outlined in the applicable section of C 1157 .These test methods are used to develop data for comparison with the requirements of Specification C 618.

3.2.3 Mix Design

Each mix of concrete is composed of crushed aggregate (01) and fine aggregate (00), natural sand, ordinary Portland cement, and water. Mix designs were created for each of eight different percentage of rice husk ash. The summarised mix design was according to Table 2.10 ESC D3.301 and GTZ low cost hosing manual volume I.

1. Cement to aggregate ratio

After the materials were tested, the material was selected for proportioning for class B HCB, Prepared cement aggregate ratio. According to ESC D3.301 on Table 2.8 cement to aggregate ratio is 1:5 by volume for class B hollow concrete block production. The maximum aggregate size of this proportion is 10mm for production of hollow concrete.

2. Water cement ratio

Depending on the workability of the concrete test and according to GTZ Low Cost Housing Manual Volume I water cement ratio for hollow concrete block is between (0.49 - 0.55) was recommended. On this research 0.49 water cement ratio were selected for zero percent rice husk ash mix .When the amount of rice husk ash increase the amount of water was increased.

Table 3.1 Water to cement ratio

Percentage of RHA replacement	**Amount of cement in Kg**		**W/C Ratio**	**Amount of water in m^3**
	RHA	**Cement**		
0	0	0.048	0.49	0.0235
5	0.0024	0.0456	0.5	0.0240
10	0.0048	0.0432	0.51	0.0245
15	0.0072	0.0408	0.52	0.0250
20	0.0096	0.0384	0.53	0.0254
25	0.012	0.036	0.54	0.0259
30	0.0144	0.0336	0.55	0.0264
35	0.0168	0.0312	0.56	0.0269

3. Material proportions for HCB production

Volume batching was used for the proportioning of materials. Two box were prepared for measuring materials, the first was the conventional box used to proportioning material that have the volume of $0.036m^3$ or 50cm*40cm*18cm (L, W and H) and the other one is $0.0024m^3$ or 24cm*10cm*10cm in dimension used to measure quantity of rice husk ash 5% of the total quantity of cement in one mix. To produce 24 hollow concrete block sample from one mix the following proportion and two boxes were used.

Table 3.2 Quantities of Materials for 24 sample HCB of one Mix.

% RHA	Quantities (m3)						Moisture content (m3)			WATER NEED FOR MIX= A-B-C-D
	Crushed aggregate 01 (V_1)	Fine aggregate 00(v2)	Sand (V3)	Cement	RHA	Water (A)	sand (B)=1.84 v3	FA (C) =1.99v2	CA (D)=0.89 v1	
0	0.096	0.048	0.096	0.048	0	0.0235	0.00177	0.0010	0.0009	0.0199
5	0.096	0.048	0.096	0.046	0.0024	0.024	0.00177	0.0010	0.0009	0.0204
10	0.096	0.048	0.096	0.043	0.0048	0.0245	0.00177	0.0010	0.0009	0.0209
15	0.096	0.048	0.096	0.041	0.0072	0.025	0.00177	0.0010	0.0009	0.0214
20	0.096	0.048	0.096	0.038	0.0096	0.0254	0.00177	0.0010	0.0009	0.0218
25	0.096	0.048	0.096	0.036	0.012	0.0259	0.00177	0.0010	0.0009	0.0223
30	0.096	0.048	0.096	0.034	0.0144	0.0264	0.00177	0.0010	0.0009	0.0228
35	0.096	0.048	0.096	0.031	0.0168	0.0269	0.00177	0.0010	0.0009	0.0233

The first sample was prepared by replacing 0% of cement with rice husk ash that was used as a control mix and the other sample mixes was prepared by increasing the percentage of rice husk ash replacement and decreasing the cement with the same percentage of replacement. The replacement was continued up to 35% of rice husk ash at 5% increment.

Figure 3.12 Box for proportion of ingredients

3.2.4 Tests on Fresh Concrete

1. Slump

The test was performed by following ASTM C 143/C Standard Test Method for Slump of Hydraulic-Cement Concrete. A 30cm tall slump cone was filled with concrete in 3 equal layers. Each layer was rolled 25 times by a 5/8-in tamping rod. After the cone was filled, all excess concrete was stricken from the top. The cone was then lifted straight up and the vertical displacement of the concrete was measured from the original top of the cone.

Figure 3.13 measuring slump of fresh concrete mix

3.2.5 Production of hollow concrete block

3.2.5.1 Mixing process

The mixing process was conducted in two steps. The first step was dry mix of aggregates and cement on the floor by hand and the second step was wet mixing of aggregates and cement inside electrically operated mixer.

Figure 3.14 batch mix

3.2.5.2 Casting process

The next step was casting of sample HCB by using a block production machine which use vibration and pressure to form the block within the conventional dimension of 40cm x 20cmx 20cm (L, W, and H).

Figure 3.15 Moulding Machine of hollow concrete block

3.2.5.3 Curing

After the HCB was molded they were kept for 24 hours under the shade to prevent moisture loss due to sunlight before start curing. Then the curing was done for 14 days as recommended on GTZ Low Cost Housing Manual Volume I also the method of curing used was spraying water.

3.2.6 Laboratory test Hardened hollow concrete block

After material laboratory test and hollow concrete production there were laboratory tests on the properties of HCB.

I. Compressive strength of hollow concrete block

According to Ethiopian standard (ES 596: 2001) the 7^{th}, 14^{th} and 28^{th} days of hollow concrete block was tested in the laboratory. A total of one hundred forty four (144) samples for each age and for different percentage of rise husk ash HCB were prepared for this test

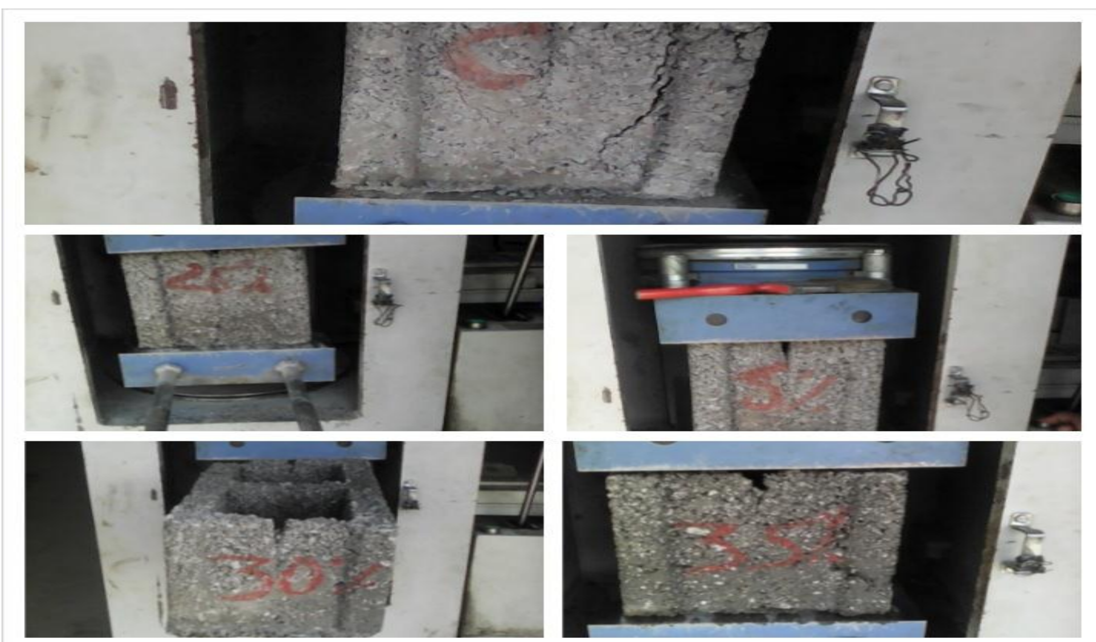

Figure 3.16 Compressive strength test of HCB with different % of rice husk ash

II. Water absorption ,Moisture content and Density

At 28th day density, moisture content and absorption test for the HCB has been carryout. Then comparison is made between HCB with and without RHA.

Figure 3.17 Water absorption, Moisture content and Density

Moisture content of HCB

Moisture content requirement of concrete block masonry units is related to their linear shrinkage Characteristics. Concrete loses or absorbs moisture with changes in the moisture content or relative humidity of the surrounding air. The cement paste may gain moisture and hence “swell”, or lose moisture and “shrink” before it attains an air dry equilibrium condition. It will undergo no dimensional change when the moisture content of the concrete is in equilibrium with the relative humidity of the surrounding so that masonry units are never delivered to a construction site in a saturated condition, and moreover, could not be laid in this condition. If unacceptably moist units are laid in a wall at the time of construction, and this inherent shrinkage is restrained in-service, stresses are developed within the masonry that may cause cracking. ASTM C90-70 specifies three moisture content requirements

According to ASTM C140-11a to calculate the moisture content .

Moisture Content, % of total absorption = $\frac{Wr - Wd}{Ws - Wd}$ x 100

Where: W_r = received weight of unit, kg,

W_d = oven-dry weight of unit, kg, and

W_s= saturated weight of unit, kg

Water absorption

Water absorption test was carried out to investigate the water absorption property of hollow concrete block, in which RHA was used as partial replacement for cement. Three samples of both cement blocks and RHA based cement blocks were used for the water absorption test. First, the samples were kept in an oven at a temperature of 100-105 °C for a period of 24 hours and the dry weight of the blocks was measured. Then the same blocks were immersed in water for a period of 24 hours and the wet weight of blocks was measured. Water absorption was quantified as percentage of ratio of the reduction in weight to the dry weight of block. According to ASTM 140-11a Water absorption of individual blocks was determined and the average value was calculated

Water absorption (Kg/m3) = $\frac{(\mathbf{Ws-Wd})}{(\mathbf{Ws-Wi})} * 1000$

Water absorption % = $\frac{(\mathbf{Ws-Wd})}{(\mathbf{Wd})} * 100$

Where:

W_i = immersed weight of specimen (kg),

Wd = oven-dry weight of unit (kg),

And Ws= saturated weight of unit (kg)

Density

According to ASTM C140 calculate oven-dry density as follows:

$$\textbf{Density, (D), kg/m3} = \frac{(Wd)}{(Ws - Wi)} * 1000$$

Where: *Wd* = oven-dry weight of specimen, kg,

Ws= saturated weight of specimen, kg, and

Wi = immersed weight of specimen, kg

3.3 SAMPLING PROCEDURE AND SAMPLE SIZE

Figure 3.18 Hollow concrete block samples on the production place

The sampling procedure was purposive sampling, therefore the sample size was determined accordingly to the test specimen number required to conduct compressive strength, density, and moisture content and absorption test for HCB. According to Ethiopian standard (ES 596:2001) taking a sample of 12 hollow concrete blocks . Out of the 12 blocks, 6 blocks to the test for compressive strength of each age, 3 blocks shall be subjected to the test for block density and water absorption and the remaining 3 blocks shall be reserved for retest purpose.

Table 3.3 Total number of hollow concrete blocks sample required

% of Rice husk ash	Number of sample					
	For compressive strength test			For Absorption , Density & moisture content	For reserved	Total sum
	7th day	14th day	28th day	28th day		
0%	6	6	6	3	3	24
5%	6	6	6	3	3	24
10%	6	6	6	3	3	24
15%	6	6	6	3	3	24
20%	6	6	6	3	3	24
25%	6	6	6	3	3	24
30%	6	6	6	3	3	24
35%	6	6	6	3	3	24
GRAND TOTAL OF SAMPLES						192

3.4 STUDY VARIABLES

3.4.1 Dependent Variable:

- Properties of hollow concrete block with rice husk ash.

3.4.2 Independent Variable:

- Compressive strength of hollow concrete block
- Water absorption of hollow concrete block
- Production cost of hollow concrete block
- Properties of rice husk ash

3.5 DATA COLLECTION PROCESS

Quantitative data was collected from both Jimma zone agricultural office and Shebe woreda agricultural office and jimma institute of technology laboratory results.

3.6 EXPERIMENTAL OR LABORATORY TESTS

The data were obtained from the results of experimental procedures in the laboratory recorded with proper format and the data are becoming input for the analytical analysis and the result tell as some outputs of the findings.

3.7 DATA PROCESSING AND ANALYSIS

The data were collected from laboratory test and analyzed based on the experimental results found from the compressive strength, density, moisture content and absorption test results to meet these research objectives. The result and findings were presented in table, chart, graph or other methods as required.

3.8 ETHICAL CONSIDERATION

The data's are only collected after ethical permission given from and Jimma university civil engineering department and all concerned bodies like HCB manufacturing firm.

3.9 DATA QUALITY ASSURANCE

In order to assure the quality of data collected the following activities were done.

- The proportioning for different samples was conducted properly.
- All parameters that should be kept constant were checked.
- The curing and production processes were followed up continuously by the researcher.
- The test results was filled and checked properly.

3.10 DISSEMINATION PLAN

Since this research is for the fulfillment of degree of masters in construction engineering and management, the research findings will be presented by using power point presentation to advisors, examiners and interested parties by the researcher and the thesis will be printed and will be submitted both in hard copy and soft copy to examiner, advisors and to the department. Once the research is approved and signed by advisors and examiner, the paper will be uploaded to internet for other interested parties about the title of the paper.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1 Crushed fine aggregate (5mm to 0.15mm)

1) Grain size of aggregate

The gradation of the fine aggregate sample was determined in accordance with ASTM C 136 and the test results are shown on Figure 4.1.

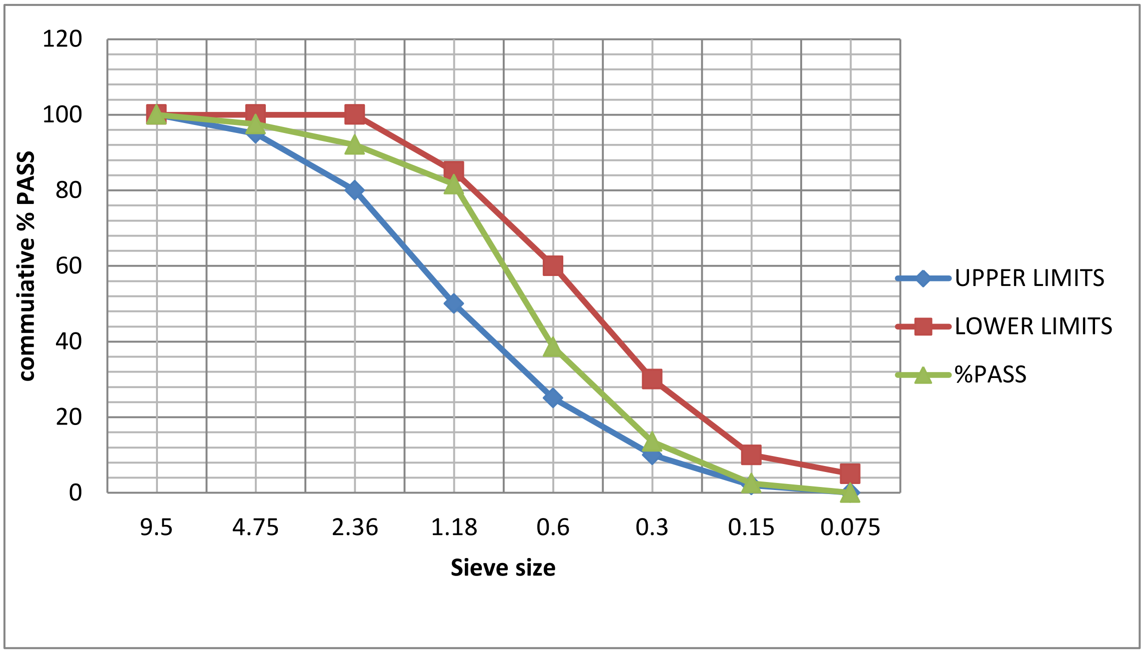

Figure 4.1 Average Grading Curve Test for Fine Aggregates

The grading curve for the aggregates falls within the lower and upper limit of the grading requirement for aggregate ASTM C 33 and ES C.D3.201. This implies that the aggregates are suitable for construction work.

2) Fineness Modulus

Table 4.1 Fineness modules of fine aggregate

Sieve size Total	Cumulative % retaining (Y)
9.5 mm (3/8 in.)	0
4.75 mm (No. 4)	2.5
2.36 mm (No. 8)	7.95
1.18 mm (No. 16)	18.4
600 mm (No. 30)	61.45
300 mm (No. 50)	86.9
150 mm (No. 100)	97.5
Sum = ∑ Y	274.7
FM= ∑ Y /100 = 2.74	

According to the requirement of ASTM C33 the fineness modulus of Fine aggregate shall not be less than 2.30 and more than 3.1 and also ES C.D3.201 fineness modulus shall be between 2 up to 3.5. Fineness modulus was computed using the sieve analysis results. The result of the fineness modulus of the fine aggregate which is presented in Table 4.1 is 2.74 under the limit of ASTM and ES.

3) Specific gravity and absorption, silt content, moisture content and unit weight of fine aggregate

According to the test method of ASTM C 128, ASTM C-117 , ASTM C-566 and ASTM C29 /C29M specific gravity and absorption , silt content, moisture content and bulk unit weight of crushed fine aggregate (5mm-0.15mm) was carried out and the test result are shown below on the table 4.2.

Table 4.2 Test result for crushed aggregate 00

No	**Description**	**Method**	**Test result**	**Allowable limit**	**Standard**
1	Absorption	ASTM C-128	1.83	0.2 -2	ASTM C-128
2	Relative density (specific gravity)				
	Apparent Specific Gravity	ASTM C-128	2.79	2.4-2.9	ASTM C-128
	Bulk Specific Gravity (SSD basis)	ASTM C-128	2.7	2.4-2.9	ASTM C-128
	Bulk Specific Gravity	ASTM C-128	2.65	2.3-2.9	ASTM C-128
3	Mean of silt content	ASTM C-117	2.97	≤ 6%	ASTM C33
4	Moisture content	ASTM C-566	1.99	0% - 10%	ASTM C-33
5	Unit weight(kg/m^3)	ASTM C-29	1433.6	1200-1760	ASTM C-33

The values of the saturated surface dry specific gravities (SSD) of the fine aggregates are ranges from 2.40 to 2.90 in accordance with the specifications of ASTM C 128.These values are showed in table 4.2 reveals the relative Density or Specific Gravity of fine aggregates used in the investigation were 2.54, which indicates that the fine aggregate is suitable for construction work. Table 4.2 reveals the Absorption of Fine Aggregate in accordance with ASTM C 128-97, “Standard Test Method for Specific Gravity and Absorption of Fine Aggregate”. The Table shows that the crushed aggregate used for the experiment was conforming ASTM C 128-97 standard with values 1.63%. According to ASTM C 33, silt content should not be greater than 3%.for concrete subjected to abrasion and 6% for all concrete. Therefore the materials are satisfying ASTM standard. ASTM C-566 specified the moisture contents of fine aggregate are between 0% to10 percent. The result shown from the table 4.2 is within the limits therefore it is applicable for use of concrete work.According to ASTM C-33 the bulk unit weight of aggregates used for normal weight concrete generally ranges from 1200 to 1760kg/m3. The value of the unit weight of fine aggregate is within the specified limit as shown in table 4.2.This indicates that the fine aggregate is suitable for concrete work.

4.2.2. Crushed aggregate (10mm – 2.36mm or 01 aggregate)

1) Size Gradation

According to the test method of ASTM C.136 sieve analysis of crushed aggregate was carryout and the test results are shown on Figure 4.2.

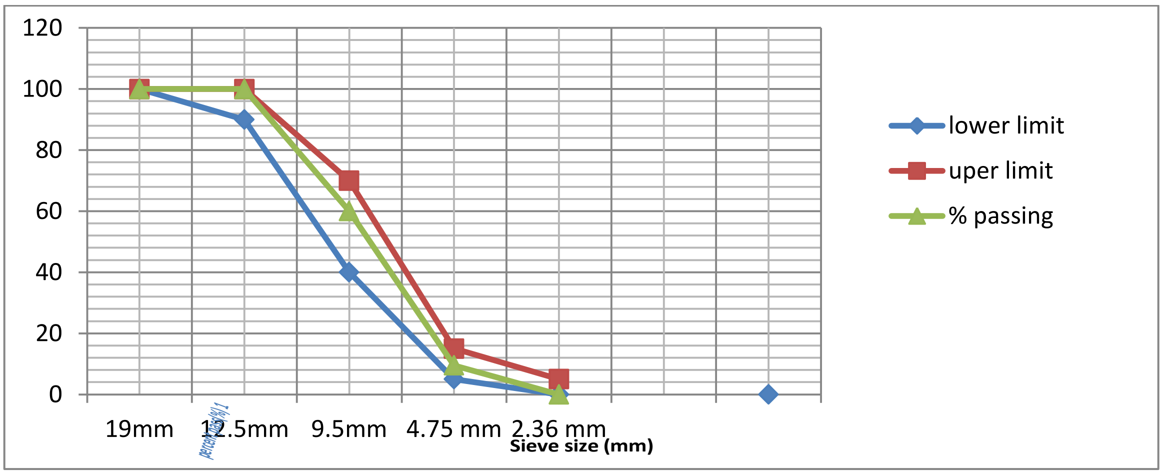

Figure 4.2 average grading curve test for aggregates 01

The above figure result show that the aggregate are within the upper and lower limit of ASTM standard. Therefore we can use this aggregate for construction purpose.

2) Specific gravity and absorption, silt content, moisture content and unit weight of crushed aggregate

According to ESC.D3-201 the limitation for bulk specific gravity (SSD) is from 2.4 to 3.0 the aggregates are within Ethiopian standard .According to ASTM C 128 absorption is at the rage 0.2% to 4% and specific gravity is between 2.3-2.The moisture contents should be within 0.5% to 2%. Aggregates are within the limits. ASTM C-33 limits the bulk unit weight from 1250 – 1460kg/m3, as it is shown from Table 4.3 the unit weights are within the limits. Therefore, the aggregates fulfill specification.

Table 4.3 Test result for crushed aggregate 01

No	Description	Method	Test result	Allowable limit	Standard
1	percentage Absorption	ASTM C-127	0.47	0.2 - 4	ASTM C-127
2	Relative density (specific gravity)				
	Apparent Specific Gravity	ASTM C-127	2.78	2.4-2.9	ASTM C-127
	Bulk Specific Gravity (SSD)	ASTM C-127	2.76	2.3-3.0	ESC.D3-201& ASTM 127
	Bulk Specific Gravity	ASTM C-127	2.74	2.3 -2.9	ASTM C-127
3	Moisture content	ASTM C-117	0.84	0.5%-2%	ASTM C-566
4	Unit weight(kg/m^3)	ASTM C-29	1444.5	1250-1460	ASTM C-33

4.3.3. Sand

1) Size Gradation

According to the test method of ASTM C-136 sieve analysis was carryout and the test result are shown in the Figure 4.3.

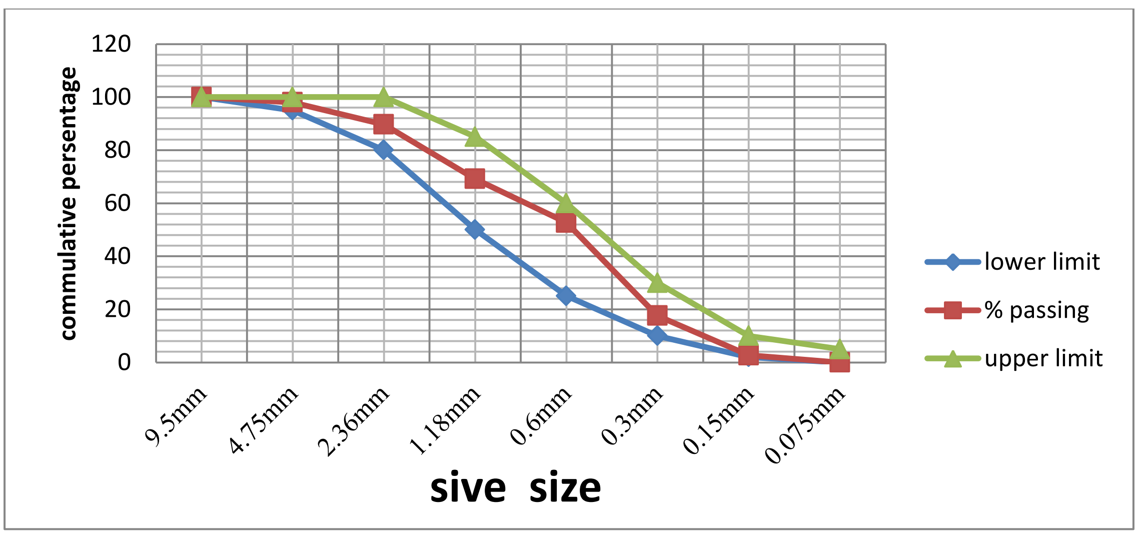

Figure 4.3 Average grading curve test for sand

The results for average particle size distribution of sand are summarized and presented in figure 4.4.The sand used in this research has fineness modules of According to ASTM C - 33 Therefore the cumulative percentage passing of the sand within the ASTM limits.

2) Fineness Modulus

According to the requirement of ESC-D3-201 the fineness modulus of sand shall not be less than 2.30 and more than 3.5. Fineness modulus is often computed using the sieve analysis results. The fineness modulus is the sum of the total percentages coarser than each of a specified series of sieves, divided by 100. The result of the fineness modulus of the fine aggregate which is presented in Table 4.4 is 2.7under the limit.

Table 4.4 Fineness modules of sand

Sieve size Total	Cumulative retaining (Y)
9.5 mm (3/8 in.)	
4.75 mm (No. 4)	2
2.36 mm (No. 8)	10.35
1.18 mm (No. 16)	30.85
600 mm (No. 30)	47.35
300 mm (No. 50)	82.4
150 mm (No. 100)	97.3
Sum = ∑ Y	270.25
FM = ∑ Y /100 = 2.7	

3) Specific gravity and absorption, Silt content, Moisture content and Bulk unit weight

According to ASTM C -128 the absorption limit is between 0.2 % to 2 % .The result found from this test is lies on the limit. According to ASTM C -128 the bulk specific gravity limit is between 2.3 to 2.9 and bulk specific gravity of saturated surface dry basis is between 2.4 – 2.9 . The table and the chart are describe both results are in the limit of ASTM standard. Silt is one of the harmful things that reduce the bond strength of the concrete by covering the particles and preventing them from forming a bond with the cement. As a result it decreases the strength of concrete or mortar. Because of this reason based on Ethiopian standard the silt content of sand should be kept less than 6 % and if it is greater than 6 % it should be washed. The amount of silt content for the sand used is 2.89%. According to the test method of ASTM C-566 moisture content of sand was carryout and the test result are shown below on Table 4.5.The moisture contents should be within 0.5% to 2%. The sand used to produce the HCB is within the limits.

Table 4.5 Test result for sand

No	Description	Method	Test result	Allowable limit	Standard
1	Absorption	ASTM C-128	2	0.2 -2	ASTM C-128
2	Relative density (specific gravity)				
	Apparent Specific Gravity	ASTM C-128	2.57	2.4-2.9	ASTM C-128
	Bulk Specific Gravity (SSD)	ASTM C-128	2.52	2.4-2.9	ASTM C-128
	Bulk Specific Gravity	ASTM C-128	2.57	2.3-2.9	ASTM C-128
3	Mean of silt content	ASTM C-117	2.89	≤ 6%	ASTM C33
4	Moisture content	ASTM C-566	1.84	0%- 10%	ASTM C-33
5	Unit weight(kg/m^3)	ASTM C-29	1527.33	1200-1760	ASTM C-33

According to the test method of ASTM C29 bulk unit weight of fine aggregate was carryout and the test result are shown on table 4.5.According to ASTM C-33 limits of the bulk unit weight of sand is between 1320 – 1680kg/m3 and the results are within the limits. Therefore, the sand is acceptable for concrete and also HCB production.

4.3.4 Rice husk ash and Cement test

1) Sieve analysis of rice husk ash

Table 4.6 Sieve analysis of rice husk ash

Sieve opening (mm)	Sample weight retaining (gm)	Weight % of Retaining	Cumulative weight percent oversize	Cumulative weight percent undersize
> 2	0	0	0	0
2 - 1.18	0	0	0	0
1.18 - 0.6	0	0	0	0
0.6 - 0.3	6.270	3.135	3.135	100
0.3 - 0.16	112.741	56.37	59.51	96.86
0.16-0.063	64.286	32.14	91.64	40.49
< 0.063	16.703	8.35	100	8.35

The grain size of Rice husk ash is described in the above table and its show more ash was retained 0.16 mm and above sieve its mean the rice husk ash is coarser.

2) Specific gravity rice husk ash

Table 4.7 Specific gravity of rice husk ash

Description	Measurement	
	Trial 1	**Trial 2**
Mass of picnometer in = (M_2) (g)	28.578	28.069
Mass of test solution in the picnometer without test sample in = (M_3) g	78.449	78.01
Density of test solution in = Q_2 g/cm3	1	1
mass of picnometer + test sample in = (M_4)(g)	38.65	36.63
mass of test sample in (g) = M_4-M_2	10.072	8.566
Mass of picnom+test sample and test solution in = (M_5)g	84.86	83.54
M_3+M_4+M_5 = volume of test sample in g.cm3	3.6595	3.039
specific gravity in g/cm3	**2.75**	**2.81**
Average of specific gravity		**2.78**

It was found that specific gravity of Rice Husk Ash was very less when compared to the specific gravity of cement. It was also noted that bulk density of Rice Husk Ash was less when compared to that of the cement. Because of low bulk density the volume occupied for a given mass was more and hence the RHA fills the pores in concrete making it impermeable.

3) Consistency test of cement

Determining consistency of the cement is used for different tests. Consistency of the cement is the determining the amount of water needed to form a paste with measured penetration of 10±1 in the Vicat needle apparatus. The amount of water determined in the consistency test is used for other tests like setting time. When the storage time of cement increases it may lose its fineness Property. As a result of this the amount of water needed for consistent cement pastes are decreased. For most cement pastes the percentage by water of dry cement lies between 26% and 33%.The results are shown in the table 4.8 for each percentage of rice husk ash with cement increase but the value of penetration decreased. As it is shown in the table below the consistency percentage of 0% and 5% are lead between the limit. But when the percentage of rice husk ash increased water needed for mixing is increased.

Table 4.8 penetration test 1

% of RHA	% by water of dry cement	Amount of water (ml)	penetration test
0	32.75%	131	9.3
5	32.75%	131	8.33
10	32.75%	131	7.33
15	32.75%	131	6.33
20	32.75%	131	5.33
25	32.75%	131	4.33
30	32.75%	131	3.33
35	32.75%	131	3

The usual range of water to cement ratio for normal consistency is between 26% and 33% but the result obtained shown in table 4.6 indicate that maximum percentage of 32.75% were taken and the penetration depth of the mix is out of the standard of limit except zero percent mix.In additional to this the penetration depth of the sample decreases in constant amount of depth difference with the same water to cement ratio. Therefore its need more water.

Table 4.9 penetration test 2

% of RHA	W/C ratio	Amount of water (ml)	penetration taste
0	0.4875	195	11
5	0.4975	199	11
10	0.5075	203	11
15	0.5175	207	10
20	0.5275	211	10
25	0.5375	215	9
30	0.5475	219	9
35	0.5575	223	9

Depending of the penetration test 1 result there is another trial and error according to GTZ Low cost Housing Manual Volume I water cement ratio for hollow concrete block is between (0.49 - 0.55) was recommended. As shown in the Table 4.9 the penetration depth of the mortar with rice husk ash is in the limit but the amount of water is increased. Its help us to select water to cement ratio on the limitation of GTZ Low cost Housing Manual Volume I

4) Fineness of cement

Table 4.10 Fineness of cement with different percentage of rice husk ash

% of RHA	Weight of cement and ash	% Mean fineness retaining
0	100	1.38
5	100	1.94
10	100	2.12
15	100	2.49
20	100	3
25	100	5.75
30	100	8.5
35	100	10.53

According to IS the percentage of cement fineness not exceeds 10% for the ordinary Portland cement and 5% for Portland-Pozzolan cement (PPC). The percentage of fineness 0% up to 30 % of RHA replacement in the percentage limit but 35% it's not in the limit.

Table 4.11 Fineness of cement and rice husk ash

Trial	Weight of cement or Ash (Kg)	Fineness % of cement	Fineness % of RHA
1	100	1.041	9.03
2	100	1.0315	11.05
3	100	2.0711	10.81
Mean Fineness % of cement = 1.38			
Mean Fineness % of RHA = 10.30 %			

The fineness, expressed as the percentage of sample retained after passing through 90μ sieve was 10.3% where as the standard fineness of cement is 1.3% and hence the fineness of RHA was slightly increased acceptable limits. According to the above table 4.11 rice husk ash is coarser then cement.

5) WORKABILITY TEST

The slump value of the concrete made using rice husk ash and without rice husk ash are listed in Table 4.12 with the same water to cement ratio were used.

Table 4.12 The results of workability tests are presented

% of RHA	W/c ratio	Slump (mm)
0%	0.4875	35
5%	0.4975	29
10%	0.5075	26
15%	0.5175	25
20%	0.5275	24
25%	0.5375	24
30%	0.5475	23
35%	0.5575	20

The results are decreasing when the amount of RHA in the sample is increasing which means by the workability is decreasing. RHA has high specific surface area and will increase the water demand of the concrete mixture to produce a workable concrete. RHA have finer particles which have higher surface area compared to cement particle. The water absorbing characteristics of RHA increase the demand of water with the increasing amount of RHA in the mixture.

6) Chemical Composition of Cement and RHA

Table 4.13 shows the approximate oxide composition of ordinary Portland cement and rice husk ash were used in the study.

Table.4.13 Chemical composition of cement and rice husk ash

Sr.No.	Parameters	RHA result in %	Cement result in % [30]
1	SiO_2	70.24	18.86
2	Al_2O_3	1.16	1.50
3	Fe_2O_3	0.60	11.26
4	CaO	1.44	52.51
5	MgO	1.68	1.48
6	Na_2O	1.04	1.42
7	K_2O	2.00	
8	MnO	0.08	
9	P_2O_5	3.83	
10	TiO_2	0.04	
11	H_2O	6.74	
12	LOI	11.24	0.2
	$SiO_2 + Fe_2O_3 + Al_2O_3$	72.01	

For RHA to be used as pozzolan in concrete production, it should satisfy requirements for chemical composition of pozzolans as per ASTM C618. The combined proportion of silicon dioxide (SiO2), aluminum oxide ($A1_2O_3$) and iron oxide (Fe_2O_3) in the ash should be not less than 70% and LOI should not exceed 10% as stipulated in ASTM requirement .The use of class F pozolan containing up to 12% of loss on ignition.

According to ASTM C 618 the available alkalis, Na_2O, supplementary optional chemical requirement is not greater than 1.5% . Its chemical composition is less than the limit.

The percentage of MgO in cement which is come from Magnesia compounds in raw material is about (0.1- 4)% and 5% as maximum range to control expansion from hydration of this oxide in hard concrete. . Crack in mortar comes from excess amount of MgO but this percent found from the laboratory report was not excess. The weight loss of the sample due to heating is then determined. A high loss on ignition can indicate pre hydration and carbonation, which may be caused by improper and prolonged storage. ASTM limits is 12% as maximum for normal and rapid hardening Portland cement. The result of LOI is 11.24% it's lower than the ASTM limit.

4.3.5 Hollow concrete block test result

1) Compressive strength with different percentage of rice husk ash

Table 4.14 Compressive strength of HCB with different percentage of RHA

COMPRESSIVE STRENGTH OF HOLLOW CONCRETE BLOCK									
	% OF RICE HUSK ASH	0%	5%	10%	15%	20%	25%	30%	35%
	7th day of compressive strength	2.93	2.5	2.38	2.36	2.3	2.18	1.8	1.71
	14th day compressive strength	3.57	3.4	3.33	3.15	3.1	2.98	2.6	2.2
compressive strength	28th day of compressive strength	5.01	4.699	4.6	4.58	4.527	4.38	3.9	3.7

According to Ethiopian standard (ES 596: 2001) minimum compressive strength for load bearing class B hollow concrete block type is 4.5 N/mm^2 an average and 4 N/mm2 for individual unit. From 7th day up to 28th day compressive strength test result of Hollow concrete block are summarized on Table 4.14. Compressive strength of hollow concrete block up to 20% rice husk ash is under limitation of Ethiopian standard but 25%, 30% and 35% of hollow concrete block are failed to meet the standard. In this study, the blocks containing RHA achieved lower values of compressive strength compared to the control mixture between the period of 7 to 28 days. The high compressive strength was due to the lower water-cement ratio of the mix.

The compressive strength of unit with different replacement level exceeds the specified minimum requirement compressive strength of 4.5 N/mm2 as stated in ES. The average data for strength against curing age is shown in Table 4.15. Every block types of compressive strength increased with time. It can be seen that HCB with RHA 20 % reaches the optimum values of strength at 28 days. At 28 days, RHA 0% which consist of 0 % RHA replacement obtained the highest strength value followed by RHA 5% and RHA10%. The next thing from the result is that, the relationships between the 7th day and 28th day compressive strength within different %

of RHA replacement. In any concrete structure, the 7th day compressive strength should be 50 – 75% of the desired compressive strength at 28th day.

Table 4.15 Percentage of compressive strength test result

% of rice husk ash	**7th days of compressive strength**	**28th days of compressive strength**	**Desired strength for class B HCB in MPa at the 28th day**	**% Of strength achieved at the 7th day**
0	2.93	5.01	4.5	58
5	2.5	4.699	4.5	53
10	2.38	4.6	4.5	52
15	2.36	4.58	4.5	51.5
20	2.3	4.527	4.5	51
25	2.18	4.38	4.5	49
30	1.8	3.9	4.5	46
35	1.71	3.7	4.5	46

From the above table we can see that in the first five consecutive replacements from (0% - 20%) the result gained at the 7th day was greater than 50% and from the rest replacement, lower percentage of strength was gained. As the percentage of RHA increased the percentage strength gain decrease.

2) Moisture content, Absorption and Density

According to Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units ASTM C-140 laboratory test was conducted to determine the moisture content, absorption and density of HCB. There were three (3) samples in each percentage replacement and the results are described be

I) Moisture content

Table 4.16 Percentage moisture content of HCB

% of rice husk ash	Sample weight in Kg (Wr)	Sample weight in water in Kg (Wi)	Sample SSD weight in Kg (Ws)	oven Dry weight in kg (Wd)	Moisture content % = (Wr – Wd) / (Ws – Wd) x 100
0%	14.2	7.7	14.7	13.53	57.91
5%	14.4	7.7	14.8	13.53	68.75
10%	14.9	7.6	15.2	13.87	73.53
15%	14.7	7.5	14.9	13.47	76.15
20%	14.9	7.7	15.1	13.51	96.91
25%	15.0	7.7	15.2	13.51	98.21

ASTM C90-70 specifies three moisture content requirements corresponding to linear shrinkage as listed in Table 4.16. As we see from the above table the moisture content % of total absorption slightly increased when the amount of RHA increase.

II) Water absorption

Table 4.17 Water absorption of hollow concrete block

% of rice husk ash	Sample weight in Kg (Wr)	Sample weight in water in Kg (Wi)	Sample SSD weight in Kg (Ws)	oven Dry weight in kg (Wd)	% of water absorption (ws-wd /wd)*100	water absorption (Kg/m3)= (Ws-Wd)/(Ws-Wi)*1000
0%	14.2	7.73	14.7	13.53	8.9	172.9
5%	14.4	7.68	14.8	13.53	9.5	178.0
10%	14.9	7.63	15.2	13.87	9.9	178.0
15%	14.7	7.53	14.9	13.47	10.9	198.0
20%	14.9	7.70	15.1	13.51	12.1	218.8
25%	15.0	7.67	15.2	13.51	12.8	227.5

From the Table 4.17 above it was found that, the percentage of water absorption increases as the percentage of RHA increased. This may be due to the fact that as RHA is more porous water fills the pores which increase the water absorption rate.

According to ASTM C90-70 water absorption requirement of load bearing hollow concrete block is 240 kg/m3.On the other hand Ethiopian standard [ES 596:2001] specify water absorption 290 kg/m3 (25%) for load bearing hollow concrete block and 320 kg/m3 (30%) for non-load bearing hollow concrete block. It was seen from the above table all the results are fulfill the standards requirement. Therefore with respect to absorption, the Rice husk ash has no major effect.

III) Density

Table 4.18 Density of hollow concrete block

% of rice husk ash	Sample weight in Kg (Wr)	Sample weight in water in Kg (Wi)	Sample SSD weight in Kg (Ws)	oven Dry weight in kg (Wd)	Density (kg/m3) =(Wd/Ws-Wi)*1000
0%	14.2	7.73	14.7	13.53	1933.8
5%	14.4	7.68	14.8	13.53	1900.3
10%	14.9	7.63	15.2	13.87	1837.7
15%	14.7	7.53	14.9	13.47	1823.7
20%	14.9	7.70	15.1	13.51	1820.1
25%	15.0	7.67	15.2	13.51	1787.5

Table 4.18 illustrate the relationship between amount of RHA and density of the block. The average Density of hollow concrete block decreases when the percentage of rice husk ash increase.

Table 4.19 Density classification of hollow concrete block [ASTM C90-70]

Grade	Oven dry density classification (kg/m3)		
	Light weight	Medium weight	Normal weight
N-I & II	1362 - 1682 (kg/m3)	1682 - 2002 (kg/m3)	<2002 (kg/m3)
S-I & II	>1362 (kg/m3)		

ASTM C 90-70 specifies density of hollow concrete block limit and the result density was obtained on study is lines with the limit.

3) Production cost comparison

The production cost for both type of HCB contain direct and indirect cost and in the direct cost there are material cost, labor cost and equipment cost. In indirect cost there is an overhead cost. The major cost that makes deference in my study was the material cost but both labor and equipment costs are remain constant because the replacing of sand with sawdust didn't affect both labor cost and equipment cost only affect material cost.

4.3.6 Material cost

The HCBs are produced by using a mix ratio of 1:2:1:2 of cement, sand, crushed sand, crushed aggregate.

Table 4.20 Material cost needed for one mix 0% rice husk ash replacement

MATERIAL REQUIRED	UNIT	Qty	PURCHASEING COST	RATE /M3
Cement	m3	0.048	1086.75	52.164
Sand	m3	0.096	825	79.2
Fine crushed aggregate	m3	0.048	690	33.12
Coarse crushed Aggregate	m3	0.096	825	79.2
Total grand cost for 0% HCB				243.684

Table 4.21 Cost of rice husk ash preparation

Cost of RHA preparation				
Rice husk cost	Burning cost	Gridding cost	Transport cost	Total cost
150	140	70	40	400

Table 4.22 Cost of materials with 5% rice husk ash mix

MATERIAL REQUIRED	UNIT	Qty	RATE (ETB)	AMOUNT IN (ETB)
Cement	m3	0.0456	1086.75	49.5558
RHA	m3	0.0024	400	0.96
Sand	m3	0.096	825	79.2
Fine crushed aggregate	m3	0.048	690	33.12
Coarse crushed Aggregate	m3	0.096	825	79.2
Total grand cost for 5% HCB				242.0358

Table 4.23 Total production cost for different % of rice husk ash

% RHA	TOTAL Material cost	Labor cost	Transport cost	Total cost	Rate for each HCB	Production cost difference
0%	243.68	30	11.25	284.93	11.40	
5%	242.04	30	11.25	283.29	11.33	1.6482
10%	240.39	30	11.25	281.64	11.27	3.2964
15%	238.74	30	11.25	279.99	11.20	4.9446
20%	237.09	30	11.25	278.34	11.13	6.5928
25%	235.44	30	11.25	276.69	11.07	8.241

As we see from the above tables when the percentage of rice husk ash increase by different percentage , the total cost of hollow concrete block production decreases by an average 4.9 birr. As a result shows that we can produce economical products by replacing cement with Rice husk ash in different percentage.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

From the chemical properties made, the combination of silicon oxide, Aluminum oxide and iron oxide is greater than 70%. Therefore RHA can be used as replacement material of cement because of its pozzolanic properties. The finding of the study also show the workablity of the concrete reduces with increase of the RHA percentage.

The compressive strength results were compared with Ethiopian standard ESC D3 301 and the result fulfill class B HCB up to 20% rice husk ash and class C HCB up to 35%. The moisture content, absorption and density of the 28th day HCB result also fulfill the standard specification ASTM C 90-70 and ASTM C 129 for class B HCB. The moisture content and water absorption values are increased when the percentage of rice husk ash is increased. Replacing of cement with rice husk ash to produce HCB can increase the water cement ratio due to high moisture absorption properties of rice husk ash and can increases the absorption capacity of class B HCB. This decreases the required strength of HCB due to low compressive strength properties of rice husk ash after 20% of rice husk ash.

Depending on the compressive strength of hollow concrete block result the optimum rice husk ash replacement of cement lays on 20 percentages replacement.

Percentage of rice husk ash increase by different percentage, the total cost of hollow concrete block production decreases by an average 4.9 ETB. The result shows that we can produce economical products by replacing cement with Rice husk ash in different percentage.

In general replacing of cement with rice husk ash for the production of Hollow Concrete Block can be applicable and the replacement can give us other comparable material without

Compromising the desired strength but the replacement percentage should not be greater than 20% in volume for class B HCB.

5.2 RECOMMENDATION

After the study was carryout depending on the result found the recommendation was formulated for concerned body therefore the recommendation provides helpful information to various stakeholders as follow.

- In order to decrease the water absorption of hollow concrete block the rice husk ash user needs to improve the properties of RHA.
- The construction industry are highly dependent on natural resources, cement , and this can leads us to the depletion of natural resources therefore the culture of using locally available materials for the construction industry as an input should be improved
- Using of rice husk ash for partial replacement of cement for the production of HCB can give us low cost and strong product therefore they should consider that, using of rice husk ash for HCB production to make their products more economical.
- Ethiopian agricultural firm can get support to increase the rice husk product with different alternative.
- Researchers can use this finding as a reference and it will help as a motivation for deep digging about rice husk ash properties and different chemical for the manufacturing of RHA to improve compressive strength of HCB. And researchers pay a close attention to environmental-friendly concrete materials.
- It is very important to prepare superior quality RHA with high quantity. However, according to currently available combustion equipment and technology, it is difficult to singly produce high quantity of RHA under the proper control conditions. Thus, related new technology is needed.

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APPENDIX ONE

Laboratory data sheet for material property test
Place: Jimma institute of technology

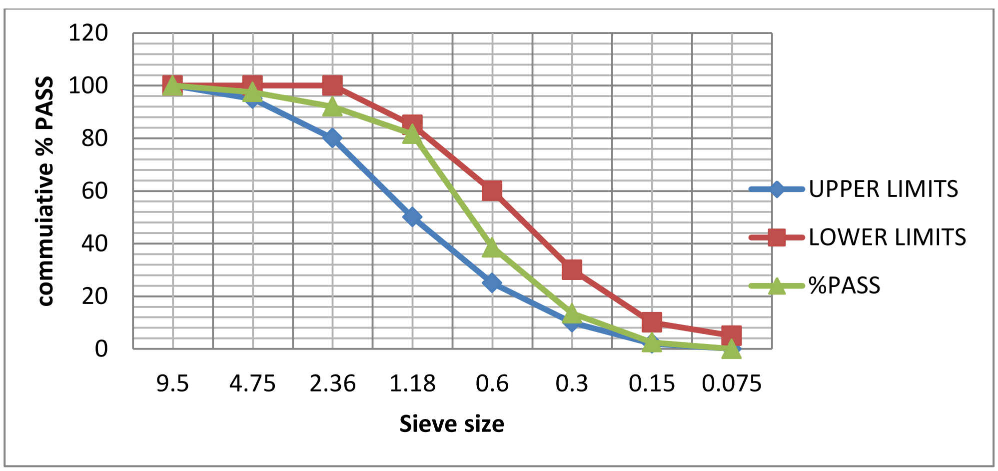
Department :Civil engineering department

Laboratory : Construction material laboratory

1. **Crushed fine aggregate (5mm-0.15mm)**

I. Sieve analysis

Sieve sample	Sieve Dia	Mass of retaining(Kg)	% of retaining	Cumulative retaining	Cumulative % passing	ASTM C 33 & ES standard upper and lower limit	Remark
	9.5	0	0	0	100	100	ok
4	4.75	0.05	2.5	2.5	97.5	95 - 100	ok
8	2.36	0.109	5.45	7.95	92.05	80 - 100	ok
16	1.18	0.209	10.45	18.4	81.6	50 - 85	ok
30	0.6	0.861	43.05	61.45	38.55	25 - 60	ok
50	0.3	0.509	25.45	86.9	13.1	10- 30	ok
100	0.15	0.212	10.6	97.5	2.5	2 -10	ok
200	0.075	0.05	2.5	100	0	0-5	ok
pan		0	0				



Grain Size Analysis of Fine Aggregate

II. **Specific gravity and absorption test result for crushed aggregate 00**

Description	Measurement in (kg)			Mean of the result
	sample 1	sample 2	sample 3	
D. Mass of Oven Dry Sample in Air	0.492	0.489	0.492	_
A .Mass of Saturated Surface dry sample in air	0.5	0.5	0.5	_
B. Mass of Flask + Water	1.5	1.5	1.5	_
C. Mass of Flask + Water + Sample	1.82	1.83	1.79	_
Absorption = (0.5-D)/D)*100	1.63	2.25	1.63	1.83
Apparent Specific Gravity =D/(B+D-C)	2.86	3.08	2.44	2.79
Bulk Specific Gravity = D/B+0.5-C	2.73	2.88	2.34	2.65
Bulk Specific Gravity (Saturated surface dry basis) = 0.5/B+0.5-C	2.78	2.94	2.38	2.7

III. Silt content of fine aggregate

Description	Measurement (Kg)		
	sample 1	sample 2	sample 3
A. Weight of sample	1	1	1
B. weight of oven dry sample after washing	0.973	0.968	0.97
Silt content % = (A-B)/A*100	2.7	3.2	3
MEAN OF SILT CONTENT	**2.97**		

IV. Moisture content

Description	Measurement (Kg)		
	sample 1	sample 2	sample 3
A. weight of original sample	0.5	0.5	0.5
B. weight of oven dry sample	0.482	0.491	0.498
moisture content % (w%)= ((A-B)/B)*100	3.73	1.83	0.40
MEAN MOISTURE CONTENT	**1.99**		

V. Bulk unit weight test result for crushed fine aggregate (5mm-0.15mm)

Description	Measurement		
	sample 1	sample 2	sample 3
D. Weight of sample = B-A (Kg)	7.219	7.23	7.055
A. Weight of container	1.6	1.6	1.6
B. Weight of container + sample	8.819	8.83	8.655
C Volume of container (m^3)	0.005	0.005	0.005
Unit weight = D/C	1443.8	1446.0	1411.0
Mean unit weight (Kg/m^3)	**1433.60**		

2. COARSE AGGREGATE (10mm-2.36mm)

I. Specific gravity and absorption test result for crushed course aggregate

Description	variable	weight of sample in kg			Mean
		sample 1	sample 2	sample 3	
Weight in water of the saturated aggregate (Ww) = Wa-Wb	Mw	1.2	1.3	1.3	
weight in air of the saturated surface dry aggregate	MSSD	2	1.99	1.99	
weight in air of oven dried aggregate	MD	1.988	1.979	1.985	
Apparent specific gravity	MD /(MD-MW)	2.52	2.91	2.90	2.78
Bulk specific gravity (oven dry basis)	MD/(MSSD-Mw)	2.49	2.87	2.88	2.74
Bulk specific gravity (sat. surf, dry basis)	MSSD/(MSSD-Mw)	2.50	2.88	2.88	2.76
% water Absorption	((MSSD-MD)/MD)*100	0.60	0.56	0.25	0.47

II. Moisture content test result for crushed fine aggregate (10mm-4.75mm) (01)

Description	**Measurement**		
	sample 1	**sample 2**	**sample 3**
A. weight of original sample	2	2	2
B .weight of oven dry sample	1.985	1.98	1.985
moisture content % (w%)= ((A-B) / B) *100	0.76	1.01	0.76
MEAN MOISTURE CONTENT	**0.84**		

III. Bulk unit weight test result for crushed aggregate(10mm – 2.36mm)

Description	weight of sample in kg		
	sample 1	sample 2	sample 3
A .weight of container	1.695	1.695	1.695
B. weight of container + weight of sample	16.1	16.31	16.01
Weight of sample = B - A	14.405	14.615	14.315
C. volume of container m3	0.01	0.01	0.01
unit weight (kg/m3) = (B-A)/c	1440.5	1461.5	1431.5
Mean unit weight	**1444.5**		

3. Sand

I. Sieve analysis of sand

Sieve sample	Sieve Dia (mm)	Mass of retaining(Kg)	% of Retaining	Cumulative retaining	Cumulative % passing	ASTM standard	Remark
s1	9.5	0	0	0	100	100	ok
s2	4.75	0.04	2	2	98	95 - 100	ok
s3	2.36	0.167	8.35	10.35	89.65	80 - 100	ok
s4	1.18	0.41	20.5	30.85	69.15	50 - 85	ok
s5	0.6	0.33	16.5	47.35	52.65	25 - 60	ok
s6	0.3	0.701	35.05	82.4	17.6	10 - 30	ok
s7	0.15	0.298	14.9	97.3	2.7	2 - 10	ok
S8	0.075	0.054	2.7	100	0	2-5	ok
Total mass = 2kg							
Fm= 2.703							

II. Fineness modules of sand

Sieve size Total	Percent retained (X)	Y =100-X
9.5 mm (3/8 in.)	0	
4.75 mm (No. 4)	98	2
2.36 mm (No. 8)	89.65	10.35
1.18 mm (No. 16)	69.15	30.85
600 mm (No. 30)	52.65	47.35
300 mm (No. 50)	17.6	82.4
150 mm (No. 100)	2.7	97.3
Sum = ∑ Y		270.25
FM= ∑ Y /100 = 2.7		
ASTM C-33		

III. Specific gravity and absorption test of sand result

Description	weight of sample in kg			Mean of the result
	sample 1	sample 2	sample 3	
D. Mass of Oven Dry Sample in Air	0.49	0.487	0.493	–
A. Mass of Saturated Surface Dry Sample in Air	0.5	0.5	0.5	–
B. Mass of Flask + Water	1.5	1.5	1.5	–
C . Mass of Flask + Water + Sample	1.79	1.83	1.79	–
Absorption = (0.5-D)/D)*100	2.04	2.67	1.42	2
Apparent Specific Gravity =D/(B+D-C)	2.45	3.10	2.43	2.66
Bulk Specific Gravity = D/B+0.5-C	2.33	2.86	2.35	2.52
Bulk Specific Gravity (Saturated surface dry basis) = 0.5/B+0.5-C	2.38	2.94	2.38	2.57

IV. Silt content of sand result

DESCRIPTION	MESURMENT (ml)		
	Sample 1	**sample 2**	**sample 3**
V1. volume of sample (silt+ sand)	75	75	75
V2. volume of silt after 3hr	2.5	2	2
% silt content by volume =(v2/v1)*100	3.33	2.67	2.67
MEAN % OF SILT CONTENT	2.89		

3 Cement

Penetration test .1

Trial	% of RHA	weight of sample		Weight of cement + Ash (C)	Quantities of water add (W) (gm)	W/C RATIO	Penetration (mm) ITS ±10mm	Average	REMARK
		Weight of cement	Weight of ash						
1	0%	400	0	400	110	0.275	9		OK
2	0%	400	0	400	120	0.3	10		OK
3	0%	400	0	400	130	0.325	11	10	OK
4	5%	380	20	400	110	0.275	7		NOT OK
5	5%	380	20	400	120	0.3	9		NOT OK
6	5%	380	20	400	130	0.325	9	8.33333	NOT OK
7	10%	360	40	400	110	0.275	8		NOT OK
8	10%	360	40	400	120	0.3	8		NOT OK
9	10%	360	40	400	130	0.325	9	8.33333	NOT OK
10	15%	340	60	400	110	0.275	6		NOT OK
11	15%	340	60	400	120	0.3	8		NOT OK
12	15%	340	60	400	130	0.325	8	7.33333	NOT OK
13	20%	320	80	400	110	0.275	6		NOT OK
14	20%	320	80	400	120	0.3	6		NOT OK
15	20%	320	80	400	130	0.325	7	6.33333	NOT OK
16	25%	300	100	400	110	0.275	5		NOT OK
17	25%	300	100	400	120	0.3	4		NOT OK
18	25%	300	100	400	130	0.325	7	5.33333	NOT OK
19	30%	280	120	400	110	0.275	4		NOT OK
20	30%	280	120	400	120	0.3	5		NOT OK
21	30%	280	120	400	130	0.325	5	4.66667	NOT OK
22	35%	260	140	400	110	0.275	4		NOT OK
23	35%	260	140	400	120	0.3	4		NOT OK
24	35%	260	140	400	130	0.325	5	4.33333	NOT OK

4 penetration test 2

Trial	% of RHA	weight of sample		Weight of cement + Ash (C)	Quantities of water add (W) (gm)	W/C RATIO	Penetration (mm) ITS ±10mm	Average	REMARK
		Weight of cement	Weight of ash						
1	0%	400	0	400	180	0.45	10		OK
2	0%	400	0	400	195	0.4875	11		OK
3	0%	400	0	400	220	0.55	12	11	OK
4	5%	380	20	400	195	0.4875	10		OK
5	5%	380	20	400	199	0.4975	11		OK
6	5%	380	20	400	220	0.55	11	10.66	OK
7	10%	360	40	400	199	0.4975	10		OK
8	10%	360	40	400	203	0.5075	11		OK
9	10%	360	40	400	220	0.55	10	10.33	OK
10	15%	340	60	400	203	0.5075	9		OK
11	15%	340	60	400	207	0.5175	10		OK
12	15%	340	60	400	220	0.55	10	9.66	OK
13	20%	320	80	400	207	0.5175	9		OK
14	20%	320	80	400	211	0.5275	10		OK
15	20%	320	80	400	220	0.55	9	9.33	OK
16	25%	300	100	400	211	0.5275	9		OK
17	25%	300	100	400	215	0.5375	9		OK
18	25%	300	100	400	220	0.55	9	9	OK
19	30%	280	120	400	215	0.5375	8		NOT OK
20	30%	280	120	400	219	0.5475	9		NOT OK
21	30%	280	120	400	220	0.55	9	8.66	NOT OK
22	35%	260	140	400	219	0.5475	8		NOT OK
23	35%	260	140	400	223	0.5575	9		NOT OK
24	35%	260	140	400	220	0.55	8	8.33	NOT OK

5 Fineness of cement with different percentage of rice husk ash

Trial	% of ash	Weight of cement +ash (gm)			WEIGHT OF CEMEN (after sieving) (W2)	Fineness % = (w2/w1)*100	Mean Fineness % = (w2/w1)*100
		Weight of cement (gm)	Weight of Ash(gm))	WEIGHT OF CEMEN (before sieving) (W1)			
1	0%	100	0	100	0.041	0.041	
2	0%	100	0	100	0.0315	0.0315	
3	0%	100	0	100	0.0711	0.0711	0.05
4	5%	95	5	100	0.2	0.2	
5	5%	95	5	100	1.7031	1.7031	
6	5%	95	5	100	0.9031	0.9031	0.94
7	10%	90	10	100	1.12	1.12	
8	10%	90	10	100	1.25	1.25	
9	10%	90	10	100	1.0043	1.0043	1.12
10	15%	85	15	100	2.904	2.904	
11	15%	85	15	100	1.43	1.43	
12	15%	85	15	100	2.14	2.14	2.16
13	20%	80	20	100	3.13	3.13	
14	20%	80	20	100	2.99	2.99	
15	20%	80	20	100	2.87	2.87	3
16	25%	75	25	100	7.005	7.005	
17	25%	75	25	100	5.7	5.7	
18	25%	75	25	100	4.53	4.53	5.75
19	30%	70	30	100	8.68	8.68	
20	30%	70	30	100	7.73	7.73	
21	30%	70	30	100	9.1	9.1	8.5
22	35%	65	35	100	10.73	10.73	
23	35%	65	35	100	11.05	11.05	
24	35%	65	35	100	9.8	9.8	10.53

APPENDIX TWO

Laboratory data sheet for hollow concrete block property test

Place: Jimma inistitut of technology

Department :Civil engineering department

Laboratory : Construction material laboratory

1. **Compressive strength test result**

I. 0% Rice husk ash hollow concrete block

The 7th day compressive strength test result

Casting date								
Testing date 7th day for 0% of rice husk ash								
Sample	**Dimension (cm)**			**Area(m2)**	**Volume (m3)**	**Weight**	**load**	**Comprehensive strength**
	L	**W**	**H**	**L*W**	**Total (L*W*H)**			
1	40.5	19.5	20	0.07897	0.0158	14.3	130.3	3.7
2	40	19	20	0.076	0.0152	14	199.8	3.1
3	39	19.5	19.5	0.076	0.0148	15.01	159	2.793
4	40	20	20	0.08	0.016	15.17	171.2	2.608
5	39.5	19.5	19.5	0.077	0.015	13.11	149.2	2.546
6	39.5	19	19.5	0.075	0.0146	14.9	160.1	2.88
Mean comprehensive strength = 2.94								

The 14th day compressive strength test result

Casting date								
Testing date 14th day for 0% of rice husk ash								
sample	**dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40	19	20	0.076	0.0152	13.6	181.7	3.9
2	40	20	20	0.08	0.016	15.701	155.33	3.917
3	39.5	19.5	19.5	0.077	0.0150	12.87	183.9	3.406
4	39.5	20.5	20	0.081	0.0162	11.08	116.2	3.783
5	39.5	19.5	19.5	0.077	0.0150	12.79	109.5	3.997
6	40	20	20	0.080	0.016	16.731	162.1	3.52
Mean comprehensive strength = 3.75								

The 28th day compressive strength test result

Casting date								
Testing date 28th day for 0% of rice husk ash								
sample	**dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19	20	0.077	0.01539	13.014	228.1	4.904
2	40	19.5	20	0.078	0.0156	13.507	163.5	5.003
3	39.5	19.5	20	0.077	0.015405	13.87	163.9	4.629
4	39.5	19.5	20	0.077	0.015405	12.69	121.2	5.829
5	39.5	19.5	19.5	0.077	0.015019875	12.701	149	4.899
6	40.5	20	20.5	0.081	0.016605	13.731	128.1	4.799
mean comprehensive strength = 5.01								

II. 5 % Rice husk ash hollow concrete block

The 7th day compressive strength test result

Casting date								
Testing date 7th day for 5% of rice husk ash								
Sample	Dimension (cm)			Area(m2)	volume(m3)	Weight	load	comprehensive strength
	L	W	H	L*W	(L*W*H)			
1	39.5	19.5	19.5	0.07703	0.0150	14.2	212.8	2.317
2	40.5	19.5	20	0.07898	0.015795	12.9	142.1	2.99
3	39.5	19.5	19.5	0.0771	0.0150	15.2	129.3	2.245
4	40	20.5	20	0.082	0.0164	12.95	144.6	2.313
5	39	19.5	19.5	0.07605	0.01482975	14.4	150.7	2.229
6	39.5	19	20	0.07505	0.01501	14.1	156.3	2.98
Mean comprehensive strength = 2.51								

The 14th day compressive strength test result

Casting date								
Testing date 14th day for 5% of rice husk ash								
Sample	Dimension (cm)			Area(m2)	volume (m3)	Weight	load	comprehensive strength
	L	W	H	L*W	(L*W*H)			
1	40.5	19	20.5	0.0770	0.01577	13.6	147.o	2.801
2	38	20.5	20	0.0779	0.01558	13.701	116.2	3.23
3	40	19.5	19.5	0.0780	0.01521	12.87	121.2	3.94
4	39	19.5	19.5	0.0761	0.01483	11.08	116.7	3.302
5	40	20	20	0.0800	0.01600	12.79	137.1	3.09
6	40	18.5	20	0.0740	0.01480	13.731	167.0	3.74
Mean comprehensive strength = 3.35								

The 28th day compressive strength test result

Sample	Dimension (cm)			Area(m2)	volume (m3)	Weight	load	Comprehensive strength
Casting date								
Testing date 28th day for 5% of rice husk ash								
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19	20	0.077	0.015	13.014	181.7	5.78
2	40	19.5	20	0.078	0.016	13.507	155.33	4.603
3	39.5	19.5	20	0.077	0.015	13.87	183.9	4.329
4	39.5	19.5	20	0.077	0.015	12.69	116.2	4.429
5	39.5	19.5	19.5	0.077	0.015	12.701	109.5	4.801
6	40.5	20	20.5	0.081	0.017	13.731	162.1	4.25
Mean comprehensive strength = 4.699								

III. 10 % Rice husk ash hollow concrete block

The 7th day compressive strength test result

Sample	Dimension (cm)			Area(m2)	Volume (m3)	Weight	load	Comprehensive strength
Casting date								
Testing date 7th day for 10% of rice husk ash								
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	39.5	19.5	19.5	0.0770	0.0150	14.2	179.03	2.097
2	40.5	19.5	20	0.0790	0.0158	12.9	134.1	2.904
3	39.5	19.5	19.5	0.0771	0.0150	15.2	157	2.22
4	40	20.5	20	0.0820	0.0164	12.95	157.4	2.84
5	39	19.5	19.5	0.0761	0.0148	14.4	111.02	2.001
6	39.5	19	20	0.0751	0.0150	14.1	104.9	2.203
Mean comprehensive strength = 2.3775								

The 14th day compressive strength test result

Casting date								
Testing date 14th day for 10% of rice husk ash								
Sample	**Dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**Comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19	20.5	0.07695	0.01577475	13.6	107.0	3.05
2	38	20.5	20	0.0779	0.01558	13.701	152.1	4
3	40	19.5	19.5	0.078	0.01521	12.87	150	3.54
4	39	19.5	19.5	0.07605	0.01482975	11.08	156.31	3.303
5	40	20	20	0.08	0.016	12.79	124.24	3.1
6	40	18.5	20	0.074	0.0148	13.731	130.11	3.01
Mean comprehensive strength = 3.33								

The 28th day compressive strength test result

Casting date								
Testing date 28th day for 10% of rice husk ash								
sample	**dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19	20	0.0770	0.0154	13.014	181.7	4.505
2	40	19.5	20	0.0780	0.0156	13.507	155.33	4.207
3	39.5	19.5	20	0.0770	0.0154	13.87	183.9	4.41
4	39.5	19.5	20	0.0770	0.0154	12.69	116.2	4.833
5	39.5	19.5	19.5	0.0770	0.0150	12.701	109.5	4.73
6	40.5	20	20.5	0.0810	0.0166	13.731	162.1	4.9
Mean comprehensive strength = 4.6								

IV. 15 % Rice husk ash hollow concrete block

The 7th day compressive strength test result

Casting date								
Testing date 7th day for 15% of rice husk ash								
	dimension (cm)			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
sample	**L**	**W**	**H**	**L*W**	**(L*W*H)**			
1	39.5	19.5	19.5	0.077	0.015	14.2	199.7	2.64
2	40.5	19.5	20	0.079	0.016	12.9	228.3	2.04
3	39.54	19.5	19.5	0.077	0.015	15.2	146.7	2.299
4	40	20.5	20	0.082	0.0164	12.95	130.6	2.504
5	39	19.5	19.5	0.076	0.0148	14.4	148.23	2.4
6	39.5	19	20	0.075	0.015	14.1	183.67	2.3
mean comprehensive strength = 2.36								

The 14th day compressive strength test result

Casting date								
Testing date 14th day for 15% of RHA								
	dimension (cm)			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
sample	**L**	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19	20.5	0.0769	0.0158	13.6	173.3	3.01
2	38.9	20.5	20	0.0797	0.0159	13.7	138.3	3.02
3	40	19.5	19.5	0.078	0.015	12.87	141.6	3.54
4	39.5	19.5	19.5	0.077	0.015	11.08	162.3	3.203
5	40.5	20	20	0.081	0.0162	12.79	126.56	3.1
6	40	18.5	20	0.074	0.0148	13.731	163	3.01
Mean comprehensive strength = 3.15								

Casting date								
Testing date 28th day for 15% of RHA								
sample	**dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19.5	20	0.079	0.016	13.014	185.7	4.405
2	40	19.5	20	0.078	0.016	13.507	133.34	4.8
3	39.5	19	20	0.075	0.015	13.87	139.9	4.31
4	39.5	19.5	19.5	0.077	0.015	12.69	110.2	4.833
5	39.5	19.5	19.5	0.077	0.015	12.701	119.5	4.404
6	40.5	19	20.5	0.077	0.016	13.731	126.3	4.75
Mean comprehensive strength = 4.58								

V. 20 % Rice husk ash hollow concrete block

The 7th day compressive strength test result

Casting date								
Testing date 7th day for 20% of RHA								
sample	**dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weigh t**	**load**	**comprehensi ve strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	39.5	19	19	0.075	0.014	14.2	199.7	2.03
2	40.5	19.5	20.5	0.0789	0.0162	12.9	228.3	2.15
3	39.54	19.5	19.5	0.077	0.015	15.2	146.7	2.399
4	39	20.5	20	0.0799	0.01599	12.95	130.6	2.704
5	40	19.5	19.5	0.078	0.0152	14.4	148.23	2.41
6	40	19	20	0.076	0.0152	14.1	183.67	2.05
mean comprehensive strength = 2.29								

14th

Casting date								
Testing date 14th day for 20% of RHA								
sample	**dimension (cm)**			**Aream2**	**volume m3**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40	20	20	0.080	0.016	13.6	173.3	3.3
2	38	20.5	20	0.078	0.016	13.701	138.3	3.32
3	40	20	20	0.080	0.016	12.87	141.6	3.048
4	39	19.5	19.5	0.076	0.015	11.08	162.3	3.02
5	40	20	20	0.080	0.016	12.79	126.56	3.009
6	40	19	19	0.076	0.014	13.731	163	3.003
mean comprehensive strength = 3.12								

The 28th day compressive strength test result

Casting date								
Testing date 28th day for 20% of RHA								
sample	**dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19.5	20	0.079	0.016	13.014	185.7	4.006
2	39.4	19.5	20	0.077	0.015	13.507	133.34	4.501
3	40	19.5	19.5	0.078	0.015	13.87	139.9	4.7
4	39.5	19.5	20	0.077	0.015	12.69	110.2	4.67
5	39.5	19.5	19.5	0.077	0.015	12.701	119.5	4.99
6	40	20	20.5	0.080	0.016	13.731	126.3	4.3
mean comprehensive strength = 4.53								

VI. 25 % Rice husk ash hollow concrete block

The 7th day compressive strength test result

Casting date								
Testing date 7th day for 25% of RHA								
sample	**dimension (cm)**			**Area m2**	**volume m3**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	39	19.5	19.5	0.0761	0.0148	14.2	120.4	2
2	40	20	20	0.0800	0.0160	12.9	111.7	2.02
3	40	20	20	0.0800	0.0160	15.2	146.01	2.27
4	40	20.5	20	0.0820	0.0164	12.95	151	2.501
5	39	19.5	19.5	0.0761	0.0148	14.4	173.8	2.02
6	40	20	20	0.0800	0.0160	14.1	113.8	2
Mean comprehensive strength = 2.18								

The 14th day compressive strength test result

Casting date								
Testing date 14th day for 25% RHA								
Sample	**dimension (cm)**			**Area(m2**	**volume m3)**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40	20	20	0.08	0.016	13.6	126	2.9
2	38	20.5	20.5	0.078	0.016	13.70	105.3	3.01
3	39.6	19.5	19.5	0.077	0.015	12.87	141.6	2.99
4	39.7	19.5	19.5	0.077	0.015	11.08	124.56	3.02
5	40	20	20	0.080	0.016	12.79	162.5	2.87
6	40	18.5	20	0.074	0.015	13.73	153.7	3.1
Mean comprehensive strength = 2.98								

The 28th day compressive strength test result

Casting date								
Testing date 28th day for 25% of RHA								
sample	**dimension (cm)**			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**L*W*H**			
1	39.8	19.5	19.5	0.078	0.015	13.014	131.02	4
2	40	19.5	20	0.078	0.016	13.507	113.71	4.89
3	39.5	19.5	20.5	0.077	0.016	13.87	143.9	4.1
4	39.5	19.5	20	0.077	0.015	12.69	111.2	4.59
5	40	19.5	19.5	0.078	0.015	12.701	129	4.61
6	40.5	20	20.5	0.081	0.017	13.731	136.21	4.9
Mean comprehensive strength = 4.38								

VII. 30 % Rice husk ash hollow concrete block

The 7th day compressive strength test result

Casting date								
Testing date 7th day for 30% of RHA								
sample	**dimension (cm)**			**Area m2**	**volume m3**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**L*W*H**			
1	39.5	19.5	19.5	0.077	0.01502	14.2	120.4	2.1
2	40.5	19.5	20	0.079	0.015795	12.9	111.7	1.99
3	39.54	19.5	19.5	0.077	0.015	15.2	146.01	2.03
4	40	20.5	20	0.082	0.0164	12.95	151	2.01
5	39	19.5	19.5	0.07605	0.01483	14.4	173.8	1.96
6	39.5	19	20	0.07505	0.01501	14.1	113.8	1.87
Mean comprehensive strength = 1.8								

The 14th day compressive strength test result

Casting date									
Testing date 14th day for 30% of RHA									
sample	**dimension (cm)**			**Area(m2)**	**volume (m3**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**L*W*H**			
1	40.5	19	20.5	0.07695	0.015775	13.6	126	2.78
2	38	20.5	20	0.0779	0.01558	13.701	105.3	2.601
3	40	19.5	19.5	0.078	0.01521	12.87	141.6	2.54
4	39	19.5	19.5	0.07605	0.01483	11.08	124.56	2.37
5	40	20	20	0.08	0.016	12.79	162.5	2.63
6	40	18.5	20	0.074	0.0148	13.731	153.7	2.67
Mean comprehensive strength = 2.60								

The 28th day compressive strength test result

Casting date								
Testing date 28th day for 30% of RHA								
sample	**dimension (cm)**			**Area m2**	**volume m3**	**Weight**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**L*W*H**			
1	40.5	19	20	0.077	0.015	13.014	131.02	3.6
2	40	19.5	20	0.078	0.0156	13.507	113.7	3.35
3	39.5	19.5	20	0.0775	0.0154	13.87	143.9	3.5
4	39.5	19.5	20	0.07725	0.015	12.69	111.2	3.67
5	39.5	19.5	19.5	0.0775	0.01502	12.701	129	3.29
6	40.5	20	20.5	0.081	0.016605	13.731	136.2	3.2
Mean comprehensive strength = 3.9								

VIII. 35 % Rice husk ash hollow concrete block

The 7th day compressive strength test result

Casting date								
Testing date 7th day for 35% of RHA								
	dimension (cm)			**Area(m2)**	**volume (m3)**	**Weigh t**	**load**	**comprehensive strength**
sample	**L**	**W**	**H**	**L*W**	**(L*W*H)**			
1	40	20	20	0.08	0.016	14.2	120.4	1.83
2	40	20	20	0.08	0.016	12.9	111.7	2
3	40	20	20	0.08	0.016	15.2	146.01	1.87
4	40	20	20	0.08	0.016	12.95	151	1.34
5	39.5	19.5	19.5	0.077	0.0150	14.4	173.8	1.35
6	39.5	19	20	0.075	0.015	14.1	113.8	1.87
Mean comprehensive strength = 1.71								

The 14th day compressive strength test result

Casting date								
Testing date 14th day for 35% of RHA								
sample	**dimension (cm)**			**Area(m2**	**volume (m3)**	**Weigh t**	**load**	**comprehensive strength**
	L	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19.5	20.5	0.079	0.0162	13.6	126	2
2	38	20.5	20	0.0779	0.01558	13.701	105.3	2.32
3	40	20	20	0.08	0.016	12.87	141.6	2.22
4	39	19.5	19.5	0.07605	0.0148	11.08	124.6	2.36
5	40	20	20	0.08	0.016	12.79	162.5	2.099
6	40	20	20	0.08	0.016	13.731	153.7	2.202
Mean comprehensive strength = 2.20								

The 28th day compressive strength test result

Casting date								
Testing date 28th day for 35% of RHA								
	dimension (cm)			**Area(m2)**	**volume (m3)**	**Weight**	**load**	**comprehensive strength**
sample	**L**	**W**	**H**	**L*W**	**(L*W*H)**			
1	40.5	19	20	0.07695	0.01539	13.014	131.0	2.57
2	40	19.5	20	0.078	0.0156	13.507	113.7	3.71
3	39.5	19.5	20	0.07702	0.015405	13.87	143.9	3.64
4	39.5	19.5	20	0.07702	0.015405	12.69	111.2	2.88
5	39.5	19.5	19.5	0.07702	0.0150198	12.701	129	3.91
6	40.5	20	20.5	0.081	0.016605	13.731	136.2	3
Mean comprehensive strength = 3.7								

II Moisture content ,water absorption and density of Hollow concrete block

% of rice husk ash	Sample weight in Kg (Wr)	Sample weight in water in Kg (Wi)	Sample SSD weight in Kg (Ws)	oven Dry weight in kg (Wd)	Moisture content % = (Wr – Wd) / (Ws – Wd) x 100	**% of water absorption (ws-wd /wd)*100**	water absorption (Kg/m3)= (Ws-Wd)/(Ws-Wi)*1000	Density (kg/m3) =(Wd/Ws-Wi)*1000
0%	14.21	7.73	14.73	13.53	57.91	8.94	172.92	1933.81
5%	14.37	7.68	14.81	13.53	68.75	9.46	178.00	1900.35
10%	14.94	7.63	15.24	13.87	73.53	9.85	178.02	1837.73
15%	14.69	7.53	14.92	13.47	76.15	10.87	197.98	1823.67
20%	14.94	7.70	15.13	13.51	96.91	12.08	218.75	1820.13
25%	15.01	7.67	15.23	13.51	98.21	12.85	227.51	1787.54

III Cost calculation for production of hollow concrete block

RHA percentage	QTY BY VOLUME					QTY BY BIRR						
	Cement	RHA	FA	CA	SAND	PURCHASING COST	Cement	RHA	FA	CA	SAND	Material cost
0	0.048	0	0.048	0.096	0.096	CEMENT= 1086.75 SAND =825 FA = 690 CA= 825 RHA=400	52.16	0	33.12	79.2	79.2	243.68
5	0.0456	0.0024	0.048	0.096	0.096		49.56	0.96	33.12	79.2	79.2	242.04
10	0.0432	0.0048	0.048	0.096	0.096		46.95	1.92	33.12	79.2	79.2	240.39
15	0.0408	0.0072	0.048	0.096	0.096		44.34	2.88	33.12	79.2	79.2	238.74
20	0.0384	0.0096	0.048	0.096	0.096		41.73	3.84	33.12	79.2	79.2	237.09
25	0.036	0.012	0.048	0.096	0.096		39.12	4.8	33.12	79.2	79.2	235.44

Total cost for hollow concrete block production

% RHA	TOTAL Material cost	Labor cost	Transport cost	Total cost	Rate for each HCB	Production cost difference
0%	243.68	30	11.25	284.93	11.40	
5%	242.04	30	11.25	283.29	11.33	1.6482
10%	240.39	30	11.25	281.64	11.27	3.2964
15%	238.74	30	11.25	279.99	11.20	4.9446
20%	237.09	30	11.25	278.34	11.13	6.5928
25%	235.44	30	11.25	276.69	11.07	8.241

APPENDIX THREE

Laboratory data sheet for rice husk ash test
Geological survey of Ethiopia: Geochemical laboratory directorate

Geochemical Laboratory complete silicate analysis report format

Geological Survey of Ethiopia:Geochemical Laboratory Directorate
Geochemical Laboratory Complete Silicate Analysis Report Format Form G0004
FILE ID ;2982/17 pvt Originator;Tesfanesh Eshetu Fetene
Sample type;powder Date Submmitted;08/09/2017
Preparation :-200 MESH
Number of Sample: 1 Element to be determined Major Oxides & Minor Oxides
Analytical Method: $LiBO_2$ FUSION , HFattack,GRAVIMETERIC,COLORIMETRIC and AAS
Analytical Results in PERCENT

FIELD	Lab No	SiO_2	Al_2O_3	Fe_2O_4	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
T-01	2982/17	70.24	1.16	0.6	1.44	1.68	1.04	2.00	0.08	3.83	0.04	6.74	11.24

Analysts
Tizita Zemene
Dessie Abebe
Tihitna Beletkachew
Tamiru Siraye
Yohannes Getachew
Nigist Fikadu

Checked by
Tamiru Siraye

Approved by
for Demisew Lemma

Quality Control
Awash Yirga

DATE REPORTED
8/23/2017

Geological Survey of Ethiopia Central Geological Lab.

Page 1 of 1

Geological Survey of Ethiopia
Mineralogy & Geotechnical Laboratory Directorate
Result Form

Case Team: - Chemical: Lab Section: - Silicate ☐ Gold & Base metal ☐
Water ☐ Hydrocarbon ☐

Case Team: - Mineralogical: Lab section: - Mineralogy ☐ Physical ☒
Client /Originator Name:- Tesfanesh Eshetu Fetene (Jimma University)

Client Category:- Survey ☐ Gov. ☒ Pvt. ☐
File name:- 3492/17GOV Area Ref: - No of Samples:- 1 Sample No.
Sample Type:- Soil Lab No:-
Type of Analysis:- Colour Preparation required:- Date Submitted:- 2/12/09

Coll. No.	Lab. No.	Colour
T-01	3492/17	Munsel Color Name Diagram 1 For gley 2.5/ Black

Described By / Analysts:- Misrak Tefera Checked by:- Date Completed :- 29/8/17

Geological Survey of Ethiopia
Mineralogy & Geotechnical Laboratory Directorate
Result Form

Case Team: - Chemical: Lab Section: - Silicate ☐ Gold & Base metal ☐ Water ☐ Hydrocarbon ☐

Case Team: - Mineralogical: Lab section: - Mineralogy ☐ Physical ☒

Client /Originator Name:- Tesfanesh Eshetu Fetene(Jimma University)

Client Category: - Survey ☐ Gov. ☒ Pvt. ☐

File name:- 3493/17PVT Area Ref:- No of Samples:- 1 Sample No.

Sample Type :- Lab No: -

Type of Analysis :- Specific gravity Preparation required: - Date Submitted :- 2/12/09

Coll.No.	Lab. No.	Pycnometer No.	m_2 Mass of picnometer in g	m_3 Mass of test solution in the picnometer without test sample in g	Q_2 Density of test solution in g/cm³	m_4 Mass of picnom.plus test sample in g	m_4-m_2 mass of test sample in g	m_5 mass of picnom. test sample and test solution in g	m_3+m_4 - m_5 volume of test sample in g/cm³	Specific Gravity in g/cm³	Average
T-01	3493/17	51/51	28.578	78.4488	1 g/cm³	38.6502	10.0722	84.8615	3.6595	2.75	2.78
		29/29	28.069	78.0108	1 g/cm³	36.6346	8.5656	83.5378	3.0386	2.81	

Described By / Analysts :- Abayneh Begashaw Checked by :- Misrak Tefera Date Completed 29/8/17

Geological Survey of Ethiopia

Mineralogy & Geotechnical Laboratory Directorate

Result Form

Case Team: - Chemical: Lab Section: - Silicate ☐ Gold & Base metal ☐ Water ☐
Hydrocarbon ☐

Case Team: - Mineralogical Lab section: - Mineralogy ☐ Physical ☒
Client /Originator Name:- Tesfanesh Eshetu Fetene (Jimma University)

Client Category: - Survey ☐ Gov. ☒ Pvt. ☐
File name:- 3494/17PVT Area Ref:- No of Samples:- 1 Sample No. T-01
Sample Type :- Lab No:- 3494/17
Type of Analysis:- Sieve Analysis Date Submitted:- 2/12/09

Sieve Opening mm	Sample weight retained gm	Weight % Retained	Cumulative weight percent oversize	Cumulative weight percent undersize
>2	0	0	0	0
2-1.18	0	0	0	0
1.18-0.6	0	0	0	0
0.6-0.3	6.2701	3.13505	3.13505	100
0.3-0.16	112.7409	56.37045	59.5055	96.86495
0.16-0.063	64.2857	32.14285	91.64835	40.4945
<0.063	16.7033	8.35165	100	8.35165

Described By / Analysts: Abayneh Begashaw
Checked by: Misrak Tefera
Date Completed 29/8/17