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WASTE TO ENERGY INCINERATOR'S BOTTOM ASH AS A POTENTIAL SUBSTITUTION OF CEMENT IN BRICK BLOCK PRODUCTION, REPPIE, ETHIOPIA

A MASTER'S THESIS

BY YIHEYIS

HAGOS

DEPARTMENT OF ENVIRONMENTAL ENGINEERING

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APPROVAL PAGE

This is to certify that the thesis prepared by **Mr. Yiheyis Hagos** entitled **"Waste to Energy incinerator's Bottom Ash as a Potential Substitution of Cement In Brick Block Production, Reppie, Ethiopia"** and submitted as a partial fulfillment for the Degree of Master of Science complies with the regulations of the University and meets the accepted standards with respect to originality, content and quality.

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Addis Ababa Science and Technology University College of Biological and Chemical Engineering

DECLARATION

I hereby declare that this thesis entitled "**Waste to Energy incinerator's Bottom Ash as a Potential Substitution of Cement In Brick Block Production, Reppie, Ethiopia**" was prepared by me, with the guidance of my advisor. The work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted, in whole or in part, for any other degree or professional qualification.

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ABSTRACT

Bottom ash is a byproduct from incinerated municipal solid waste (MSW) to produce electric power and reduced the volume of the solid waste damped in open land fill that is serious problem to the environment is used to produce bricks. Primary data was collected from *Reppie* waste to energy plant using a sack by going to the plant and secondary data sources from literatures review. The tastes that are take place during the research are include; chemical contents of the municipal solid waste incinerated bottom ash (MSWIBA) analysis, fineness of grinded bottom ash, Loss on ignition (LOI), consistency of blended mortar paste, setting time blended mortar paste, workability of fresh blended mortar, Compressive Strength of mortar and brick compressive strength and water absorption of cementitious brick block for the percentage replacement of 10 %, 15 %, 20 % and 25 % of bottom ash in weight. The chemical contents of sample are different than ordinary Portland cement because of organic contents of the bottom ash and the physical characteristics of the sample are not fall in the range of the ordinary Portland cement. The compressive strength of brick is attained clay brick standards and categories of classes A except 20% bottom ash replacement. In the research replacement of bottom ash is recommended in production of brick for construction and addition of gypsum for workability, setting time and fast strength gain is also recommended for blended mortar.

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Contents

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ABBREVIATION AND ACRONYMS

MSWI ……………………………………...Municipal solid west incineration

IEA ……………………………………...…. International Energy Agency

UCS ……………………………………...…. Universal compressive strength

Tph……………………………………….. Tone per hour

USD……………………………………...…. United States Dollar

NCV ……………………………………Net Calorific Value

EBCS ……………………………………Ethiopian building code of standards

BA ………………………………………...…Bottom ash

FA ………………………………………...…Fly ash

LL ………………………………………….Limit state

PL ……………………………………….…Plastic Limit

E-waste ………………………………….…Electronic waste

MSW …………………………………...... Municipal solid waste

OPC……………………………………...Ordinary port land cement

MPa ……………………………………...Mega Pascal

LOI …………………………………….…...Loss on ignition

MSWIBA ……………………...………. Municipal solid waste incineration bottom ash

MW ………………………………….....…Mega watt

AAS …………………………...……….…Automatic absorption spectrometry

ASTM…………………….……………..... American Society for Testing and Materials

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CHAPTER ONE
INTRODUCTION

1.1 Back Ground of the Study

Huge amount of municipal solid waste is generated now time due to consumer society, mass production and consumption of goods that leads high amount of solid wastes so incineration is used in terms of mass reduction, volume reduction, that are play a key role in environmental protection and waste management. Incineration is results 70% reduction in mass and 90% reduction in volume this is the most effective treatments for waste management and land fill conservation[1]. Municipal solid waste incineration (MSWI) is also the major energy generation method in modern civilization. Reppi waste to energy incineration plant would design to produce 25 MW per day. The Reppie waste to energy project built at the cost of 95 million USD on 37 hectares of land in outskirts of the capital of Addis Ababa [2]. During incineration the municipal solid waste, bottom ash would be produced that is disposed back to the open land as a waste if not used for other uses.

But manufacturing of brick from bottom ash buy substituting the cement as a recovery is that are important to overcome the impact of bottom ash to the environment. Bottom ash conversion to any construction material has an economical importance in terms of cement production and electric power production. The municipal solid waste generated from the plant is not has a well manageable disposal land fill place and the way the byproducts disposed back to the open land fill is unsatisfactory but simply back to the existing land fill. Bottom ash generated from waste to energy power plants has become an important environmental and economic objective.

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1.2 Statement of the Problem

About 14,00 tons of Municipal solid waste per day generated in Addis Ababa, this amount of wastes are a series problem for the environment[3]. To convert this municipal solid waste to energy Addis Ababa City Administration and Ethiopia Electric Power has established waste to energy plant to generate 25-MW- 50MW electricity power per day. From total weight of the municipal solid waste incinerated the percentage of bottom ash generates are 25%-30% of the total weight of the MSW feed by the plant, this show that about 40 tons of bottom ash are generated per day. Currently this huge amount of bottom ash would be disposed back to the open land fill layer cover as a waste. The bottom ash has been returning to the landfill this trend has been a problem for the environment. However, some researchers already found ash as potential source of building constructing materials by partially substituting cement and this important in mitigation of environmental pollution also economic since waste is cheaper than virgin material. The availability of ash in *reppie* waste energy incinerator, the effect of the ash to the environment and method of conversion enhance to propose and do this experimental research.

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1.3 Objective

1.3.1 General Objective

The general objective of the study is to evaluate the potential possibility of bottom ash as a substitution of cement in brick block production.

1.3.2 Specific Objective

- To characterize the physiochemical characteristics of *reppi* waste to energy Incinerator's bottom ash.
- To optimize or evaluate the substituent *reppi* waste to energy incinerated bottom ash in brick block production.
- To measure and compare the brick produced from the substituent bottom ash against the standards.

1.4 Significant of the Study

This research mainly deals with the conversion of incinerator's bottom ash to brick that used as building construction material. The research signifies directly and indirectly for the environment and society. Few of the many significant of this research are: 1, environmentally, this research mitigates the exhaust gas for cement clinker one ton of greenhouse gases for each ton of cement created and requires the equivalent of a barrel of oil per ton [4] and also because bottom ash is a collection of different cementitious contents and other environmentally pollutant constituents. This state has a negative influence on the ecology and future of human beings[5]Redirecting the residues of incinerated bottom ash that disposed back to the open land fill as a waste into construction material are secures the safety of the environment. 2, economically, this research will build a brick by substituting parts of the cement. Cement is very costly and if portion of the cement are replaced, the cost of brick will be reduced addition to that energy consumption to grind the bottom ash due to material size. This helps for those who use brick as primary building construction material. 3, academically, this research also helps for academician who refer and research on this area. Since this research will conduct characterization, the scientific community will get some insight about the chemical and physical composition of the waste. Therefore, this signifies in different aspect.

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1.5 Scope of the Study

The scope of this research is limited to generally to Addis Ababa municipal solid waste managements. When *Koshe* became active, the surrounding area was sparsely populated and beyond the municipal master plan for Addis Ababa [3, 6]. The landfill hosts about 500 scavengers who sell recovered materials from the waste to businesses and farmers *Wikipedia*. The scope of the research conducted the physiochemical characterization of bottom ash, and determine the bottom ash as potential substitution of cement in brick production, optimization of the products in terms of cement to bottom ash ratio, mixing manner vibration and compaction and also measurement of the produced brick block

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CHAPTURE TWO

LITERATURE RIVIEW

2.1 Impacts of Bottom Ash from Reppie Waste to Energy Incineration Plant

The recycling of these materials are of increasing interest worldwide, due to the high environmental impact of the cement and concrete industries. Producing cement involves many steps, including grinding and blending raw ingredients (such as limestone, shells or chalk, and shale, clay, sand, or iron ore), heating those ingredients to very high temperatures in a kiln, cooling and mixing those ingredients with gypsum, then grinding down the mixture to form cement powder. This energy-intensive process typically emits nearly one ton of greenhouse gases for each ton of cement and requires the equivalent of a barrel of oil per ton. This state has a negative influence on the ecology and future of human beings[5]. [7] Civil engineers have been challenged to convert waste to useful building and construction material. Recycling of such waste as raw material alternatives may contribute in the exhaustion of the natural resources; the conservation of not renewable resources; improvement of the population health and security preoccupation with environmental matters and reduction in waste disposal costs[8]. The effects of those wastes on the bricks properties as physical, mechanical properties will be reviewed and recommendations for future research as out comings of this review will be given [9]. Incineration significantly reduces the volume of solid waste in need of disposal, destroys the harmful organic compounds that arc present in MSW, and provides an attractive source of alternative energy. Disposing the MSW ash in landfills may not always be an environmentally or an economically feasible solution and also various issues associated with MSW ash and its possible use in construction applications [10].

2.2 Quality of Solid Cementitious Brick Block of Bottom Ash to Cement Ratio

The compressive strength of concrete replacement of cement with bottom ash with initially three mix proportions were prepared by replacing the 5%, 10% and 15% cement with bottom ash by weight. The mix proportion for the preliminary tests was a nominal mix of 1: 2: 4 where 1-part cement, 2 parts of fine aggregates and 4 parts of coarse aggregates by weight. From the results of tests conducted on these specimens the final proportions of 7.5%, 11% and 12.5 % (all ranging around 10%) for replacement of cement by weight were selected for further testing. Results the 28days compressive strength of concrete with 10% replacement of cement with bottom ash gave higher strength. Hence, percentages of cement replacements close to 10.0% (i.e., 7.5%, 11.0% and

12.5%) were chosen for the final mixes. As expected the 7-day compressive strength of the concrete specimen is less than expected 70% of characteristic mean strength. This can be attributed to the reduction in quantity of cement binder material which has been replaced by bottom ash [11].

The result it can be seen that in both FA and BA treated samples, the Liquid Limit (LL) decreases with the increase in the ash content. The increase of the plastic limit and the decrease of the plastic index are mainly due to the flocculation of the clay particles and due to the increasing number of coarse particles in the mix. E-waste material becoming too much problem in India, such as: CD/ DVD / chips / LED and etc. manufacturing of fly ash brick by using e-waste & sculptures waste material result of compressive strength of fly ash brick is increased by using e-waste material by replacing stone dust is 113.30kg/cm2. Result compressive strength of fly ash brick is also increased by using combination of both waste materials like e-waste or sculptures waste of river & pond are 107.33 kg/cm^2[12].

[2] In this paper author investigate the Compressive Strength and Flexural strength test of the concrete at different ages i.e. 7, 14, 28 and 56 days. Bottom Ash is replaced 10%, 20%, 30%, 40% and 50% in the place of fine aggregate. Maximum compressive strength of mix proportion is 32.14 N/mm^2, 34.85 N/mm^2, 36.20 N/mm^{2}and 39.16 N/mm^2 at 7 days, 14 days, 28 days and 56 days respectively at 30% replacement of bottom ash and for flexural test beams of 150×150×700 cubic mm size were adopted[2]. The reduction of the workability is the highest; this may due to the finer particle size compared with the other treated bottom ashes. The influence of the workability can also be due to the particle shape of the treated bottom ashes, which are irregular and porous [2].

2.3 Characteristics of Municipal Solid Waste Incineration Bottom Ash

The chemical characteristics of bottom ash are mainly determined depending on the type and quality of the MSW source, not by pulverized fineness, and by the operating conditions of the power plant. Bottom ash primarily consists of silica (SiO_2), alumina (Al_2O_3), and ferric oxide (Fe_2O_3), which account for more than 80% of the total components. Bottom ash produced from lignite or sub-bituminous coal has higher proportions of calcium oxide (CaO), magnesium [2].

The chemical and physical properties of the treated bottom ash are characterized, and the metallic aluminum content is determined. The treated bottom ash is used in mortar as cement replacement by 30% weight. The bottom ash also contains higher amount of chloride and sulphate, which mainly come from household residues and industrial wastes. Thermal treatment on the raw bottom

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ash particles at 550 ˚C, and then mill the treated bottom ash, this has a lower SiO_2 content and higher CaO, chloride and sulphate than other treated bottom ashes, this may be due to the higher absorption of element of the dust-like layer on the coarse bottom ash particles which is removed during milling. The specific densities of cement and treated bottom ashes show that the bottom ash has lower density than OPC.

The flexural and compressive strengths of mortar with treated bottom ash after different curing ages are tested. The strengths of the reference after 1, 3, 7 and 28 days are tested in MPa, utilization of treated bottom ashes as cement replacement decreases the strength of mortars at all curing ages for all the mixes. However, the decrease of the flexural strength is lower than that of compressive strength for all the mixes. For mortar with BA, the decrease of strengths at all curing age is very high; this could be due to the high content of organic matter and lower pozzolanic properties of raw bottom ash because of the burning of organic matter, resulting in higher pozzolanic properties than BA [10]. From literature review the main chemical compositions of cement accordance with the methods given in IS 4032, ordinary Portland cement, 42.5 grade shall comply with the chemical requirements given in table-2 below. [13]

Table 1 Chemical analysis of grade 42.5 OPC cement

Elements	**Weight (%)**
SiO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6
CaO	60-65
MgO	0.5-4
Na_2O	0.5-1
K_2O	0.5-1
MnO	6

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2.4 Composition of Addis Ababa Municipal Solid Waste

Different individuals and institutions in different times showed that about 60-70 percent of Addis Ababa City's solid waste composition is organic waste (kitchen waste) mainly composed of vegetable and food wastes. These solid wastes contain high moisture and such wastes with high moisture content are not suitable for incineration [3]. Majority of the waste in Addis Ababa was of plant origin while the animal and the industrial origin was almost none in most of the households. When considering the solid organic waste production across different origin/nature (plant, animal and industrial), the plant origin was found to be higher (94%). While percentage composition for animal origin is 1% and 5% accounts for industrial origin [14].

Oxide composition

The main oxides present in MIBA are SiO_2, CaO and Al_2O_3, with others such as Fe_2O_3, Na_2O, MgO, SO_3, Cl, P_2O_5, ZnO and CuO present in smaller amounts. The oxide composition of MIBA is comparable to certain recognized pozzolanic and latent hydraulic cementitious materials and as such, in soil stabilization or cement bound mixtures, the potential pozzolanic properties of the material may be beneficial [15].

Mineralogy

The most abundant minerals reported in MIBA are quartz, calcite, hematite, magnetite and gehlenite. There are also more than 30 additional silicates, aluminates, aluminosilicates, sulfates, oxides and phosphates that have been less commonly identified in the material [15]. When exposed to environmental conditions and weathering, the mineralogy of MIBA will undergo change.

Organic contents

Residual organic matter remaining in MSWIBA after the combustion process can potentially lead to negative impacts on density, stiffness and increased risk of degradation over time [16]. Loss on ignition (LOI) tests is used to provide a measure of the organic fraction by comparing the difference in mass of samples before and after ignition [2].

2.5 The Effects of Bottom Ash on the Moisture Content

Condensation of water vapor within the body of a material emerges as perspiration on the surface and as hidden condensation in the body itself. This phenomenon might cause significant issues

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such as fall of plaster and fungal growth if necessary precautions are taken especially in the regions where hot and humid climates prevail. Moisture content decreases with the increasing temperature of firing at all ash ratios. Samples with 45% bottom ash ratio were measured to have 0.02% moisture content while those with 0.00% bottom ash ratio were measured to have 0.06% moisture content at 1150ºC firing temperature. This is presumed to have sourced from the reaction between the silica content of clay and carbon content of bottom ash to produce a vitreous structure [17].

2.6 The Effects of Bottom Ash on the Loss of Ignition

The samples without bottom ash additive have the minimum loss of ignition at all firing temperatures. However, there is a linear increase in values of loss of ignition for all the ash-added samples starting from 10% additive. The samples with 45% bottom ash additive exhibited the maximum loss of ignition with a value of 0.18%, at 1150ºC firing temperature [17].

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CHAPTER THREE

MATERIAL AND METHODOLOGY

To address the objectives of this study data were collected from different government organizations; bottom ash from *Reppie* waste to energy incinerator plant and analysis of major oxide and minor oxide determination for the elements of MSWIBA using $LiBO_2$ FUSION, HF and GRAVIMETRIC analytical method by AAS instrument from Ethiopian geotechnical and survey institute investigations and also another materials are purchased from non-governmental organizations(shops) to implement the research like ordinary Portland cement, sand (fine aggregate) collected from river, potable water, specimen molds etc. Additional data to implement the research were collected from secondary sources. To collect the primary data; samples like MSWIBA, OPC, fine aggregate, moulds are collected physically and bring to the laboratory then prepare for specific purpose of the research. The secondary data like chemical composition of OPC material, different standard determination (i.e. standards for workability of fresh mortar, compressive strength of mortar pastes, flexural strength of mortar pastes, compressive strength of (cementitious block) common bricks, physical properties of fine aggregate, fineness of cement and etc. were collected from different literatures reviews.

3.1 Study Area or Sampling Site

The project area is defined by the limit of Addis Ababa City Administration. The proposed development site is located at the *Reppie* open dump site or commonly known as “Koshe Site” which is located in *Kolfe Keraniyo subcitiy worda 01*. The *Reppie (Koshe)* site was established 50 years ago and is located 13km from the center to the Eastern part of the city. Currently the waste has a surface area of 37 hectares and 40-meter height. This made it the largest single waste disposal site in the country. At its commencement the *Reppie (Koshe)* site was at remote site from business and residential communities but currently due to expansion of the city it become surrounded by of residential community and community service centers.

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3.2 Materials

The main materials and tools required in the progress research work during brick production are listed below with their respective meaning and uses.

3.2.1 Ordinary Portland cement (OPC)

OPC cement is the most common type of cement in general use the world as a basic ingredient for concrete, mortar as a binding pastes which is known as hydraulic binding. Ordinary Portland cement 42.5 grade in one lot is produced and stored in air light container and it is very fresh cement (i.e. manufacture within three month).[18].Cement is a finely ground inorganic material powder of chemically combined argillaceous materials (silica, alumina) and calcareous materials (lime) with iron oxide, gypsum and small amounts of other ingredients. When mixed with water, cement forms a paste which sets and hardens by means of hydration reactions and processes and which, after hardening, retains its strength and stability even under water [19].

The paste binds two or more non-adhesive substances together. In this research municipal solid waste incinerated bottom ash are replacing the National OPC products. The OPC have compressive strength value of 42.5MPa that attained after 28 days [20]. Cements consist of different materials and are statistically homogeneous in composition resulting from quality assured production and material handling processes.

3.2.2 Municipal Solid Waste Incinerated Bottom Ash (MSWIBA)

MSWIBA used in this study obtained from *Reppi* municipal solid waste to energy incinerator plant. Municipal solid wastes from the city of Addis Ababa are disposed to the open land fill called *koshe* this is made the environment polluted and polish the surrounding society so the incinerator plant are burn the municipal solid waste instead of disposing to the open land fill to produce electric power energy but bottom ash are produced as a by-product during burning. The sizes of the material are coarse, angular and porous surface texture predominantly sand-sized [21]. Totally100 kg bottom ash is sampled and some debris and metals removed from the bottom ash before homogenization and further tests and analysis. The physical characteristics of bottom ash vary depending on the source of municipal solid waste and pulverized fineness [21].

Figure 1 *Reppie* Waste to Energy MSWIBA residues

3.2.3 Sand

The sand shall consist of natural sand, crushed stone, or crushed gravel sand or a combination of any of these. It shall be hard, durable, clean and free from adherent coatings and organic matter and shall not contain the amount of clay, silt and fine dust more than a specified amount that not contain any harmful impurities such as iron pyrites, alkalis, salts, coal or other organic impurities, mica, shale or similar laminated materials, soft fragments, sea shells in such form or in such quantities as to affect adversely the hardening, strength or durability of the mortar. The required grading may often be obtained by screening and/or by blending together either natural sands or crushed stone screenings, which are, by them unsuitable.

For the research sand is collected from locally purchased sectors that are loaded from river side. Therefore, for each specimen of brick the quantity of sand is similar. It is generally known that, building good quality of mortal is highly depending up on the good quality of sand (fine aggregates). Good quality of mortal for cementitious brick block production is also produced by carefully mixing of water, cement and fine aggregate (sand) combining add mixture as needed to obtain the optimum product in quality and economy for any use. Other essential properties include permeability, durability, minimum amount of shrinkage, and cracking [22]. Sand is the most common and loosely packed mineral on the earth's surface smaller than gravel and larger than silt and clay. Sand particles mostly range from 0.02 mm to 2.00 mm in diameter [23]. Sand is naturally produced material resulting from the mechanical and chemical breakdown of rocks. Sand accumulates in areas where sediments are transported and deposited such as in desert, beach, and river environments [23].

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3.2.4 Water

In this research, potable water was used for each trial of mixes. The sample was taken with bucket that can carry 10L. For each mix the amount of potable water found at the production site tap has been determined by the water cement ratio used. When water mixed with cement it forms a paste that binds the aggregate together and it causes the hardening of concrete through the process of hydration. The amount of water that is mixed with cement affects both the compressive strength and the durability of the concrete [24].

The ratio between water and cement is called the water cement ratio (w/c) which is calculated from the amount of water in the mixture divided by the amount of cement. It has been shown that the w/c ratio correlates to the compressive strength of the mortal; a higher ratio gives a lower compressive strength. Potable water was generally acceptable for concrete mixing and curing PH with less value conformed to the required of water for concreting and curing.

3.2.5 Mixer and mixing of mortar

The mixer is consisting of essentially a stainless steel bowl in relation to the blade and, to some extent, the gap between blade and bowl can be finally adjusted and fixed. The mixer is revolving about its own axis as it is driven in a planetary movement around the axis of the bowl by an electric motor at controlled uniform speeds [20].

With the mixer in the operating position pour the sand into the bowl and add the cement and percentage replaced MSWIBA then start the mixer immediately at the low speed for a minute called dry mix and add the water steadily and continue the mixing for an additional time by adding required quantities of water until workable mortar paste is obtained then stop the mixer. After that dropout the fresh mortar pastes by revolving down the mixer out late out to the container conveyance; remove all the mortar paste left and adhering to the wall and bottom part of the bowl by means of a rubber scraper [20].

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3.2.6 Moulds

The moulds for flexural taste are consists of three horizontal compartments so that three prismatic specimens 40 mm × 40 mm in cross section and 160 mm in length can be prepared simultaneously. The moulds are made of steel with walls at least 10 mm thick [20]. The mould shall be constructed in such a manner as to facilitate the removal of moulded specimens without damage because of the specimens for flexural strength taste is small length and width dimensions that are sensitive to break during de molding. Each mould shall be provided with a machined steel or cast iron baseplate. When assembled, moulds shall be positively and rigidly held together and fixed to the baseplate. The assembly is no distortion of leakage flow fresh mortar between the joint of the assembled moulds. The baseplate shall make adequate contact with the table of the compacting apparatus and be rigid enough not to induce secondary vibrations [20].

The standard brick dimension is one of the most crucial parameters that need to be considered during the selection of the moulds. Brick in different construction have a different dimension but there are many standards are established by different countries. In this research for compressive strength test of cementitius brick block moulds with a dimension 60mm*120mm*240mm cross section are used.

3.2.7 Flexural strength testing machine

This machine used to carry out the transverse flexural strength taste of mortar that have 40mm*40mm*160mm cross sectional dimension. It is a motorized and mechanical unit operation; the speed is adjusted with the increased load on the specimens. The machine consists two supporting rollers having a diameter of 10mm and apart 11 mm each other and a third roller with similar diameter that are transmitted the applied load to the opposite direction vertically down at the middle. The testing machine for the determination of flexural strength shall be capable of applying loads up to 10 KN. The three vertical planes through the axes of the three rollers shall be parallel and remain parallel, equidistant and normal to the direction of the specimen under test. One of the supporting rollers and the loading roller shall be capable of tilting slightly to allow a uniform distribution of the load over the width of the specimen without subjecting it to any torsional stresses [20].

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3.2.8 Mortar Compressive strength testing machine

The testing machine for the determination of compressive strength shall be of suitable capacity for the test. To perform the tastes on the machine prism portion of the sample 40mm*40mm*160mm cube side are used. The specimens are tasted after 3,7 and 28 curing days gradually the load are applied at the rate of 2.4KN/s until the specimens are fails. It shall be fitted with an indicating device which shall be so constructed that the value indicated at failure of the specimen remains indicated after the testing machine is unloaded. This can be achieved by the use of a maximum indicator on a pressure gauge or a memory on a digital display. Manually operated testing machines shall be fitted with a pacing device to facilitate the control of the load increase. [20] Furthermore, the resultant of the forces shall pass through the center of the specimen and the surface of the lower machine platen shall be normal to the axis of the machine and remain normal during loading.

3.3 Methodology

3.3.1 Chemical characterization of materials

Chemical composition of municipal solid waste incinerated bottom ash (MSWIBA)

The MSWI bottom ash provided by the waste-to-energy plant (*Reppi*, Ethiopia) is firstly dried, and the fraction of the dried bottom ash particles are selected to be investigated in Composition of Municipal solid waste incinerated bottom ash (MSWIBA) throughout the study of this research. According to Ethiopian geotechnical and surveying institute analysis the major and minor chemical composition and oxides of elements of the total MSWIBA samples determination by $LiBO_2$ FUSION methods this is temperature decomposition by using furnace at 950C^o using AAS instrument that determine Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O and MnO. Hydrophloric acid attack (HF) method is acid decomposition by using AAS instrument to determine silicon dioxide (SiO_2) percentage composition in the sample.

a **b**

Figure 2 a, Grinding machine and b, grinded MSWIBA up to cement fine

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3.3.2 Physical characterization of materials

i. Specific gravity of MSWIBA

The specific gravity of MSWIBA is defined as the ratio between the weight of a given volume of material and weight of an equal volume of water. The MSWIBA particles have pores or particles that contain water within a percentage replaced bottom ash of specific gravity a nominal mix is prepared with a bottom ash specific gravity that will affect the mix design. This is used to know the behavior of the material in the water that may sink or float when mixed with water. Hence it is necessary to determine the specific gravity of the percentage replace bottom ash before mix. Le chaterlier flask apparatus is used to determine the specific gravity of the sample in this research.

Experimental Procedure

A 50gm.of percentage replaced MSWI bottom ash was prepare weigh a dry and cleaned flask apparatus that was emptied and assigned it as W_1 after that the flask was filled with the 50gm. of MSWIBA and close the flask then weight the flux with the sample and assign as W_2. Kerosene was added up top of the bottle and weighed as W_3 this is because of not react with bottom ash then mix the mixture thoroughly and remove air bubble the emptied flask is and filled with kerosene up to top and then the weigh is called W4. Finally, the specific gravity of the bottom ash is calculated using $\frac{W2-W1}{(W2-W1)-(W3-W4)*0.1}$

ii. Bulk density of MSWIBA

The bulk density can be determined by dividing the mass of MSWIBA particle and voids between particles by the total volume of bottom ash sample. This is done by using graduated cylinder tool to mix the sample with water. It is considering the weight of the municipal solid waste incinerated bottom ash after drying that moist in the water to prevent fire ignition that happen at the exhaust bottom of the plant. The bulk density considers both the solid and the pore space of the particle of the sample. The organic contents, bottom ash texture, the density of the grind sample (i.e. too fineness or coarser) are affecting the bulk density of the sample. Bulk density indicates how much weight of bottom ash is used to the mix design of the blended mortar paste.

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Procedure

The sample was prepared and filled in to the funnel apparatus then freely flow the sample in to measuring cylinder and Weigh cylinder apparatus filled with the sample and took as W1 and the volume of the sample is then measured asV1. The calculation for density, volume and bulk density of the sample was calculated using the following question.

Density of MSWIBA $=$ specific gravity of MSWIBA $*$ density of reference (kerosene)…....1

Total volume of sample (V1) = $\frac{\text{weigth of MSWIBA (W1)}}{\text{Density of MSWIBA}}$ ……………………………………..…..2

Bulk density of MSWIBA (Sg) = $\frac{W1}{V1}$=…………………………………………………………3

iii. Loss of Mass on Ignition for MSWIBA

Loss of Mass on Ignition test is inorganic analytical chemistry used in analysis of mineral and chemica0l makeup of material. *Wikipedia*

In this test method, the MSWIBA is ignited in a muffle furnace at a controlled temperature. The loss in mass is assumed to represent the total moisture and CO_2 in the MSWIBA. Loss on ignition is the process of measuring the weight loss change of the sample after highly heating temperature that leads burning and volatile of the sample contests. In the analysis of the sample the chemical makeup of MSWIBA with a variant of the tests in which mass change is continually monitored as the temperature is changed is it consists of strongly heating (igniting)a sample of the material at a specified temperature, allowed volatile substances to escape until mass change and constant weight is obtained. *Wikipedia*

Experimental Procedure

Weigh empty crucible that the sample was placed in and inserted in to the oven and weigh the bottom ash sample with a tarred platinum crucible then cover and ignite the crucible with it content to constant weight in a muffle furnace at a temperature of 900 to 1000°C and allow a minimum of 20 min for heating period finally leave the sample from the muffle furnace after desired length of time and weighed it again.

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The calculation for the percentage weight loss of the sample due to heating furnace is calculated using the formula of loss on ignition (LOI) which is $\frac{W2-W3}{W2-W1} * 100$ w_1,w_2 and w_3 are represented weight of empty crucible that the sample was placed in, weight of the bottom ash sample with a tarred platinum crucible and weight of the sample after oven dry respectively.

Figure 3 Muffle Furnace or Carbonation to decompose BA sample

iv. Fineness of OPC Cement Vs. MSWIBA by 150 µm Sieves

The fineness to which cement is ground during its production can have a considerable effect on the behavior of the cement during hydration which is responsible for the rate of strength gain during curing. The smaller the particle size the grater the surface area to the volume ratio, this determine more area is available for water cement reaction per unit volume.

The rate of hydration increases with increasing fineness; this leads to both higher rate of strength gains 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 the reaction products, finer particles will be more completely hydrated than coarser particles. Increasing fineness tends to decrease the amount of bleeding, but at high fineness the amount of water required for workability is increased, which results in increased drying shrinkage.

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Procedure using construction material laboratory manual [19] place a 50 g sample of the cement on the clean, dry 150 µm (No. 200) sieve with the pan attached and gentle wrist motion until most of the fine material has passed through and the residue looks fairly clean this is requiring 3 to 4 min. Then gently tap the side of the sieve with the handle of the brush used for cleaning the sieve. Continue the sieving without the cover as described above for 5 or 10 min, depending on the condition of the cement and municipal solid waste incinerated bottom ash. Continuously rotate the sieve throughout the sieving. This open sieving may usually be continued safely for 9 min or more. Return any material escaping from the sieve or pan and collecting on the paper to the sieve. After every 25 strokes, turn the sieve about one sixth of a revolution, in the same direction. Continue the sieving operation until not more than 0.05 g of the material passes through in 1 min of continuous sieving. Transfer the residue (Rs) on the sieve to the balance pan, taking care to brush the sieve cloth thoroughly from both sides to ensure the removal of the entire residue from both sides to ensure the removal of the entire residue from the sieve. The fineness of the material is finally calculated using fineness $(F) = 100 - \left[\frac{Rs*100}{W}\right]$ where, Rs is residue left on sieve and W is represents weight of the sample.

Figure 4 Fineness taste for OPC and MSWIBA AASTU lab.

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v. Determination of Soundness of municipal solid waste incinerated bottom ash.

Soundness refers to the ability of a hardened cement and substituted percentage of MSWIBA paste to retain its volume after setting or prevent excessive volume change (expansion) after setting by using Le Chatelier's apparatus.

Procedure for soundness

Prepare cement and substituent bottom ash of normal consistency and fill the paste in the cylinder mould placed on glass plate that covered with another piece of glass and then submerge the whole thing in water at a temperature of 20 ± 1 °C for 24 hrs and measure the distance between the indicator needles taking the mould out and submerge it again into heat water up to its boiling point in 30 minutes and continue boiling for one hour and name it as L_1 and finally measure the distance between the needles after removing the mould from the water and allow it to cool called L_2. Thus the Expansion of the sample after setting is calculated using the formula of L_2-L_1 that determine the soundness of the pastes.

vi. Consistency tests for ordinary port land cement verses incinerated bottom ash

This test is carried out to determine the amount of water required to prepare a standard cement paste by vicant apparatus [19].

Experimental procedure

Measures a 500 gm of cement sample and mix with a measured quantity [19] of clean water by means of a trowel and quickly form the cement paste in the approximate shape of ball and introduce in to the vicant apparatus then lower the plunger gently and bring it in contact with the surface of the paste. Tighten the crew setting the movable indicator to the upper zero mark of the scale and release the plunger immediately after thirty second of releasing the plunger record its penetration of the needle inserted in to the paste thus the paste is said to be of normal consistency when the rod settles 10±1 mm below the original surface within thirty seconds. This is repeated the above procedures varying the proportion of water until a paste of normal consistency is obtained then finally the amount of water required for normal consistence is expressed as a percentage by weight of the dry cement. are catagorised under class A.

The calculation of the amount of water required to make a consistent is founded by using the formula percentage (%)of weight of water in gram divided to the weight of cement in gram and multiplied by 100.

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Figure 5 Consistency taste of blended mortar paste AASTU laboratory

vii. Setting time for blended ordinary port land cement with incinerator bottom ash

Initial setting time is when the cement percentage loses its plasticity and stiffness considerably and final setting time is the point when the paste hardens and can sustain some miner load. The objective of this test is to determine the Initial Setting time and Final Setting time of cement paste and substituted blended municipal solid waste incinerated bottom ash with normal consistency.

Setting time test procedure

Prepare ordinary Portland cement (OPC) and percentage of bottom ash paste of normal consistency and introduced the paste in to the conical ring mold. The test specimen is placed in the moist room and allowed it to remain there after immediate molding and placed. Allowed the specimen to remain in the moist cabinet for 30 minutes after molding without disturbing and lower the needle until it rests on the surface of the specimen. Took initial reading by releasing the rod quickly and allowed the needle to settle for 30 seconds.

The penetration of the 1mm (diameter) needle at every 10min until a penetration of 25mm or less is obtained and record the results of all penetration tests are determined and finally Interpolated between the results obtained to determine the initial setting time when a

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penetration of 25mm is obtained and the final setting time is when the needle does not sink visibly in to the paste.

viii. Silt Contents of fine aggregate (Sand)

Sand is a product of natural or artificial disintegration of rocks and minerals obtained from glacial, river, lake, marine, residual and wind-blown (very fine sand) deposits. These often contain other materials such as dust, loam and clay that are finer than sand. The presence of such materials in sand tends to make concrete or mortar decreases the bond between the materials to be bound together and hence the strength of the mixture and quality of the mixture produced resulting in fast deterioration. The test is therefore, to determine the silt in natural sand (finer than No.200 sieve) [19]. content in sand and checks the silt content against permissible limits by using a graduated cylinder or jar apparatus.

Procedure

A graduated cylinder or jar having a capacity of greater than a volume of 100ml was selected and a natural river sand that has a volume of 30ml are poured into the cylinder and approximated percentage of the cylinder was filled with a potable water then the cylinder was shake vigorously for about a minute. The cylinder was leaved for about an hour to allow the silt to settle on the top layer of the sand then the amount of fines forming a separate layer on the top of the washed sand was measured. To calculate the percentage silt contents of the sands, divide the amount of silt deposited on the top to that of the amount of clear sand in the cylinder.

Figure 6 Silt content tastes of fine aggregate taste (sand) AASTU laboratory

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ix. Sieve Analysis for fine aggregate (sands)

Sieve Analysis is a procedure for the determination of the particle size distribution of aggregates using a series of square or round openings starting with the largest. It is used to determine the grading or aggregates and the fineness modulus, an index to the fineness and coarseness and uniformity. Fine Aggregates should be clean, sound, tough, and durable and uniform in quality. They should also be free of soft, friable, thin or laminated fragments and deleterious substances like alkali, oil, coal, humus or other organic matter. Therefore, the quality of brick produced is very much influenced by the properties of its aggregates. Fine Aggregate grain size distribution or gradation is one among those properties and should be given due consideration.

After this taste analysis is carried out that fine aggregates are described as well graded, poorly graded, uniformly graded, gap graded, etc. Each of the above aggregate categories has close association with a range of quality of mortar produced using the fine aggregate.

Procedure for sieve analysis

To determine the fine aggregate 2 kg of a sample of sample and quarter the sample using a riffle box was weighed and from the quartered sample took 500gm. Empty sieves were recorded and placed the pan to the bottom of the sieve and shaker and put the other sieves in to the pan with increasing opening sizes of the sieves weighed.

After 500gm of sample placed on the top of sieve (having large opening size) then shake about 2 minutes in a sieve shaker then each sieve together with the aggregate retained on it was weighed and the weight retained on each sieve was calculated this is by fill the result obtained in the gradation chart and the fineness modulus (FM) was computed by diving percentage retained on each sieve by 100.

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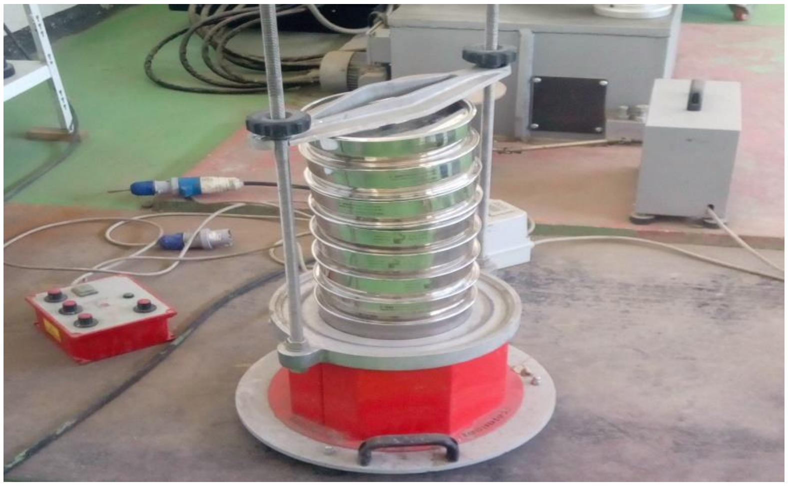

Figure 7 Fine aggregate sieve analysis taste AASTU construction laboratory

x. Specific Gravity (relative density) and absorption tests of fine aggregate (sand)

Specific gravity of fine aggregate (sand) is the ratio of the weight of given volume of aggregates to the weight of equal volume of water. Sand brought on to a building site or other works may contain an amount of moisture which will cause it, when loosely filled into a container, to occupy a larger volume than it would occupy if dry. If the sand is measured by loose volume, it is necessary in such a case to increase the measured volume of the sand, in order that the amount of sand put into the concrete or mortar may be the amount intended for the nominal mix used (based on dry sand). It was necessary to increase the volume of sand by the 'percentage' bulking. The correction to be made is only a rough approximation, because the system of measurement by loose volume is a rough method at the best, but a correction of the right order can easily be determined and should be applied in order to keep the mix uniform [25].

Preparation of test Sample

A 1kg of the fine aggregate obtained from the sample by use of a sample splitter or by quartering then the sample is dried by suitable pan at a temperature of 110±5°c to a constant weight. The sample was allowed to a comfortable temperature, that cooled and covered with water, and permitted to stand for l 5±4hrs after this the sample was spread on a flat surface that exposed to a gently moving current of warm air and stir frequently to secure uniform drying. This operation is continued until the test sample approaches a free-flowing condition. Then place a portion of the partially dried fine aggregate loosely into the mold, held firmly on a smooth non-absorbent surface with the large diameter down, and lightly tamped the surface 25 times with the tamper, and lift the

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mold vertically. If surface moisture is still present, the fine aggregate will retain the molded shape. Continue drying with constant stirring and test at frequent intervals until the tamped fine aggregate slump slightly up on removal of the mold. This indicated that it has reached a surface-dry condition.

Procedure

A 500.0g of the fine aggregate sample prepared and immediately introduced into the pycnometer that filled with water to approximately 90% of the capacity and the pycnometer was rolled, inverted and agitated that used to eliminate all air bubble in the equipment. Then the total weight of the pycnometer, sample and water determined and recorded by the equation of C =0.9976 Va + 500 + W Where; C is weight of pycnometer filled with sample plus water (gm), Va is volume of water added to pycnometer (cm^3) and W is weight of the pycnometer empty (gm).

Then fine aggregate was removed from the pycnometer, and dried at a temperature of 105±5°C, to constant weight the cooled in air at room temperature for half to 1 hrs. and weighed. Then weight of the pycnometer that filled with water at 23±I.7°C to its calibration capacity was determined by B=0.9976V+W where; B is weight of flask filled with water (gm), V is volume of flask (cm^3) and W is weight of the flask empty (gm). The calculation for bulk specific gravity found by $\frac{A}{B=50-C}$ where, A is represented weight of oven-dried sample in air (gm),B is weight of pycnometer filled with water(gm) and C is weight of pycnometer that filled with sample and water to calibration mark (gm) also percentage absorption (%) is calculated $\frac{500-A}{A} * 100$ where A is the weight dried sample in air (gm).

3.3.2 Optimization of blended mortar pasts material

To measure the produced specimen of brick in the research the blended sample are ready for the taste of mortar workability, flexural strength tastes, compressive strength of blended mortar and bricks and also water absorption taste for brick.

I. Workability of fresh blended Mortar tests

The composition of mortar can be varied in relation to its end use. Mortars of different quality like (strength, workability, etc.) can be produced by varying the proportion or types of the constituent (cementitious materials, siliceous materials and water (w/c ratio)). For instance, mortar produced from sand of circular grains results in better workability than those produced from sand of angular grains. On the other hand, sands of angular grains give better strength. This is workability or fluidity of fresh mixed mortar optimization for percentage replacement of 0%, 10%, 15%, 20% and 25% of BA.

II. Flexural strength taste optimization for blended mortar pastes

Mixing manner to blend the ingredient uniformly, well vibration the molded pastes, and also curing date at standard room temperature and closed thanks are used to optimize the flexural strength of the blended mortar pastes. Same to that of compressive strength taste for blended mortar and brick 10%, 15%, 20% and 25% of BA is replaced the OPC cement for flexural strength taste.

III. Compressive Strength of blende Mortar Taste Optimization

Percentage replacement of 0%, 10%, 15%, 20% and 25% of BA are used in the brick production. To optimize the compressive strength of mortar factors like water cement ratio (W/C), cement to sand ratio, type and grading of sand, manner of mixing and demolding specimens, curing conditions, size of specimen, and moisture content at time of test, loading conditions and curing age that influence the strength are considered.

IV. Compressive Strength of cementitious Brick Block Optimization

To optimize the compressive strength of blended cementitious brick the percentage replacement of 10%, 15%, 20%, and 25% of BA blended mortar are used. Blended Mix ratio of cement to BA, water cement ratio, mixing manner, vibration and curing date are the main consideration during production of Brick block. Requirements(tools) used for optimization of BA blended mortar is Rectangular 60mm*120mm*240mm moulds, vibrator, curing water thanks, mixer these all are play a great rule in the research to optimizing the blended cementitious bricks.

V. Water absorption tastes optimization of cementitious Brick block

Absorption of brick is its capacity to absorb water to saturation. The rate of absorption or suction of brick has an important effect on the adhesion of brick and mortar because if the brick absorbs water too quickly from the mortar, the mortar will set too soon and adhesion will be poor. Compaction(vibration) of the sample during production is the main rule in optimizing water absorption.

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3.3.4 Measure and compare the blended incinerated MSWIBA against the standard.

To measure the produced specimen of brick in the research the blended sample are ready for the taste of mortar workability, flexural strength tastes, compressive strength of blended mortar and bricks and also water absorption taste for brick.

a. Measure the Workability of fresh blended Mortar tests

To measure the workability of blended mortar for each percentage replacement of BA, the following procedure are used.

Experimental Procedure

First cement sand and water with given proportion was prepared mix for about a minute (dry mix) then add the required amount of water and mix for about two minutes. Carefully wipe the flow table top clean and dry then place the flow mold at the center of the table. Fill the mortar to the mold with three layers and tamp 25 times each layer with a tamping rod. Cut off the mortar to a plane surface, slush with the top of the mold, by drawing the straight edge of the trowel then wipe the table top, clean and dry to remove any water around the age of the flow mold. Then lift the mold away from the mortar and then drop the table 25 times with in15sec, through a height of 13mm. finally using the caliper the flow was determined by measuring the diameter of the mortar along the lines on the tabletop (take four readings)[19]. Calculation; The averages of the four readings $a + b + c + d$ divided by four; Where *a, b, c* and *d* are the four reading on the top table of the flow molds.

Figure 8 Workability taste for blended mortar paste AASTU construction laboratory

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b. Measure for Flexural strength taste for blended mortar

Place the sample in the testing machine with the two side face on the two opposite side supporting rollers and with its longitudinal axis normal to the supports. Apply the load vertically at the center of the specimens by means of the loading roller to the opposite side face of the sample and increase it smoothly until fracture. Keep the sample until fracture under the testing machine and record the failure load to calculate the flexural strength (Rf) in N/mm^2 [20]. Then the formula $1.5 * F_f * l$ that divided by b^3 was used where; R_f is the flexural strength, in newton's per square millimeter, b is the side of the square section of the prism, in millimeter, F_f is represents the load applied to the middle of the sample at fracture, in newton's and l is the distance between the supports, in millimeter.

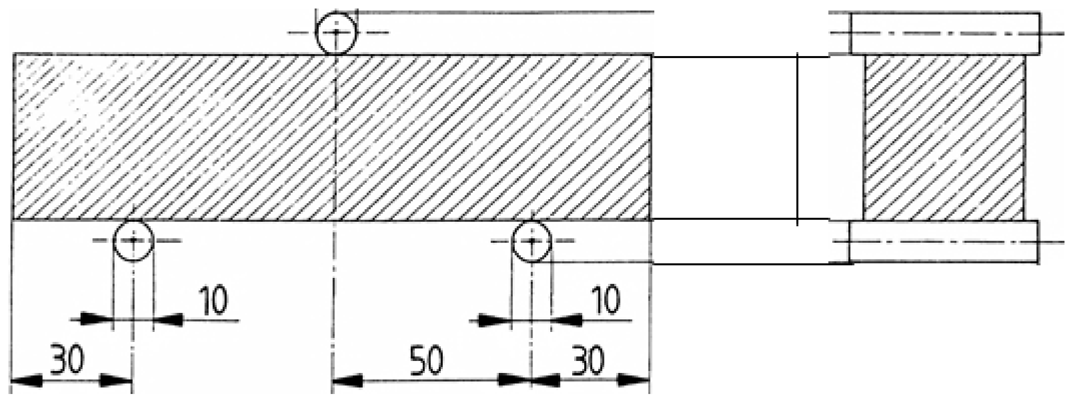

Figure 9 Figure from British standards of mortar flexural strength taste machine[25].

c. Measure for Compressive Strength taste of Mortar

Half prisms obtained in the flexural strength test which over an area of 40 mm × 40 mm are used for compressive strength taste. The compressive strength tests then are carried out by selecting one from the two halves of the prism broken during flexural by suitable means which do not subject the prism halves too harmful stressed. Some specifications for cement require tests done on neat pastes while others require that the tests be carried out on mortars. Since such tests clearly depend on the type of sand used, standard graded sand has to be used for mortar tests.

Test halves the sample in compression on the side faces by means of the equipment [20]. states that Centre the prism halves laterally to the platens of the machine within ± 0.5 mm, and longitudinally such that the end face of the prism overhangs the platens or auxiliary plates by about 10 mm. Increase the load smoothly at the rate of (2.400 ± 0.20) KN/s over the entire load application until fracture. Then calculate the compressive strength Rc in KN/mm2. Using experimental procedure stated in [19] compressive strength of the mortar is calculated by the formula of P equal to dividing the crushing load by the area of half mortar prism P equal to $\frac{F}{A}$ Where: P is applied pressure in (MPa), A is a half mortar 40mm*40mm area of specimen in contact with the load (mm^2) and F was a crushing load (N).

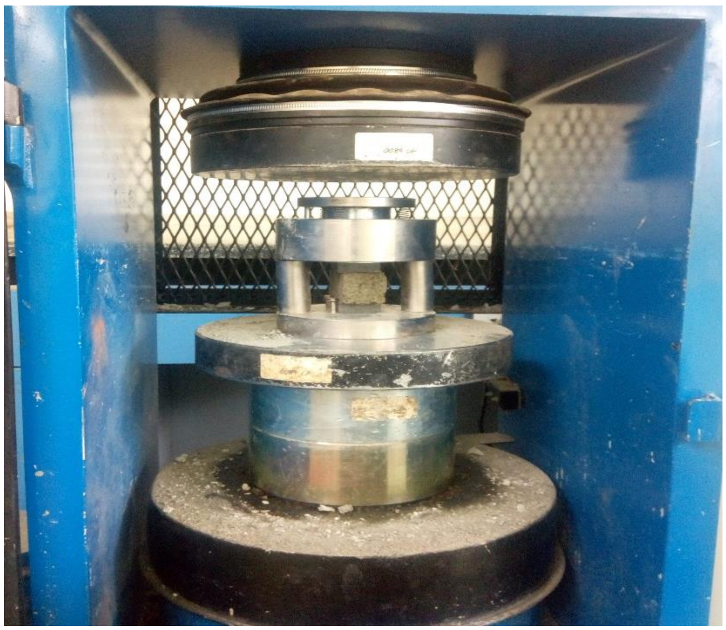

Figure 10 Compressive strength of blended mortar

d. Test for Compressive Strength of cementitious Brick block

Compressive strength of brick is determined by testing the brick under standard condition using a compression testing machine. Compressive strength of brick is determined by placing brick in compression testing machine. After placing the brick in compression testing machine apply load on it until brick breaks. Brick is a small building unit and most widely used for the construction of structural and/or non-structural walls.

Experimental Procedure

The dimensions of the brick were first measured and place each sample in a position such that the load is applied in the same direction as in service and the sample is centralized between the pressure surfaces. Then finally the compressive strength of cementitious brick block was calculated by (R_C) found by $\frac{Fc}{A}$ where; Fc is maximum load at failure and A is area of bed face.

Figure 11 Compressive strength of cementitious brick block tastes

e. Water absorption taste and measurement for cementitious Brick block

All bricks absorb water due to its pores in surface and also dryness of brick. But some permissible limits are there to suggest the quality of brick against water absorption. The absorption of water by the bricks is not over 3 % after 48 hours of immersion [26].

Test Specimens

The test specimens shall consist of half brick pieces with the length equal to the width ± l cm. A specimen may be obtained by any method that will produce, without shattering, a specimen with approximately plane and parallel ends.

24-hr Submersion Test

Dry the test specimens in a ventilated oven at 110±5°C for not less than 24hrs and until two successive weightings at intervals of 2hrs show an increment of loss not greater than 0.2% of the last previously determined weight of the specimen (w_1). The dry specimen submerged, without preliminary partial immersion, in clean water (soft, distilled, or rain water) at 15 to 30°C for 24hrs. The specimens were removed, wipe off the surface water with a damp cloth, and weigh the specimen (w_2). Then percentage water absorption calculated using $\frac{100(w2-w1)}{w1}$ where; W_1 is dry weight of the specimen W_2 is saturated weight of the specimen after 24 hours of submersion in cold water.

Figure 12 Specimen immersion for water absoption of mortar taste.

3.4 Preparations of Test Specimens

The brick that will produced by partially replacing the OPC cement by municipal solid waste incinerated bottom ash (MSWIBA) uses a mixture of different raw materials. The substituted incinerated municipal solid waste is grinding, milling and sieved below 75µm after sorting the furious material that are passed from the magnetic resonance of the plant. The sand, bottom ash and cement were firstly mixed in the mixer in dry state. Mixer was being well covered during the mixing process to avoid the volatility of bottom ash due to its light weight. Then, water will be added and mixing continued. Water content will be adjusted until the required flow ability will achieved. The mixture is considered flow able when the spread diameter coming from 200 ± 20 mm on a horizontal surface caliper. The fresh mortar mixture will then pour into brick molds of size (240 mm * 120 mm * 60 mm); after which the specimens will removed from the molds and transfer to curing condition of 95% relative humidity. The specimens are prepared in the sample for each curing date of compressive strength and flexural strength tests. The curing condition will achieve by keeping the bricks in the curing water thank and keep the water thank in an air conditioned room. Submerge the specimens either horizontally or vertically in the storage containers of water with maintain temperature of (20 ± 1) °C. During curing the spacemen apart one from each other so that the water has free access to all six sides of the specimens.

The depth of water in the container above the upper faces of the specimens is less than 5 mm or similar with the spaces between the specimens placed during curing. Out the specimens that are ready for test at each particular age from the water thank and keep not more than 15 min before the test is carried out, [20]. This is by removing any deposit on the test faces and cover the specimens with a damp cloth until tests are carried out. The specimens 'test both for compressive strength of cementetious brick block and flexural strength for mortar are take place at the curing age of different days of day3, day7 and day28 for each percentage of bottom ash replacements'; This is from the time of mixing the cement and bath in to water up to the beginning of the test.

Figure 13 Produced cementitious brick block

3.5 Experimental Design and Data Analysis

Huge amount of data was being generated using the above sample characterization, brick production and sample testing. Those data are then being analyzed in different angle with the help of scientific tools and software. Data analysis is conducted to transforming that all needed data for the research of based on the specified experimental design in the process of cementitious brick block production. The municipal solid waste incinerated bottom ash (MSWIBA) are collected from *Reppi* waste to energy incinerator and other data are collected from locally purchasers to implement the research in the production of cementitious brick block. Some ferrous material that are passed away through the resonance magnet from incinerator plant are sorted from the collected and dried up to 8% of moisture content of bottom ash and are grinded up to cement size. Well

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graded locally purchased river sand are mixed with clear and potable water based on the mix design of 1:3 mortal ratio and recommended water cement ratio. Workability or fluidity of fresh mixed mortar is conducted by using apparatus of flow table and flow mold.

The fresh mortal is fill in to the mold in three layer and tamp 25times with in a tamping rod, take four reading the flow along the line on table top using caliper. The blended cementitious mortar is poured in to the prepared triple brick molds and well vibrates. The internal parts of the molds paint oil before pouring the fresh mortar; this is to de mold simply. The sample are de molded after 24hr and immersed in to water thank. Curing is continued in the water tank up to date of strength of 3days, 7days and 28days. Finally, the samples are out from the water tank and dry the surface water by to crush under test machine for each curing days.

Table 2 Summary for compressive strength of brick and Mortar flexural strength

Percentage of MSWIBA blended	No of samples (days)			Cement (gm)	MSWIB A(gm)	Fine aggregate (sand)(gm)	Water (L)
	3	7	28				
C-BA 0%	3	3	3	9583.1	0	28948.82	4.8
C-BA 10%	3	3	3	8624.70	119.8	28948.82	4.31
C-BA 15%	3	3	3	8145.70	1437.46	28948.82	4.07
C-BA 20%	3	3	3	7670.0	1916.61	28948.82	3.84
C-BA 25%	3	3	3	7190.0	2395.76	28948.82	3.60
Total	15	15	15	41213.35	6708.13	141059.24	20.61

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CHAPTER FOUR
RESULT AND DISCUSSION

4.1 Result of chemical Composition of Municipal Solid Waste Incinerated Bottom Ash (MSWIBA)

According to Ethiopian geotechnical institute the analysis MSWIBA are determined by the method of AAS. The result of the main oxides present in the MSWIBA samples are SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, MnO, P_2O_5, TiO, H_2O and LOI. The results are given in percentage of mass in the table-3 below.

Table 3 Chemical composition of MSWIB ash

No.	Chemical composition	Weight (%) MSWIBA	OPC weight in %[13]
1.	SiO_2	40.26	17-25
2.	Al_2O_3	9.22	3-8
3.	Fe_2O_3	7.32	0.5-6
4.	CaO	18.84	60-65
5.	MgO	1.92	0.5-4
6.	Na_2O	2.22	0.5-1
7.	K_2O	3.04	0.5-1
8.	MnO	0.20	6

According to Ethiopian geological and surveying investigation the chemical composition of incinerated bottom ash is not fulfil the percentage weight range of OPC[13]. The percentage composition in weight of SiO_2 in the sample result given table-3 above has high in percentage content than OPC this cause effects in maintaining consistency and workability of the blended mortar pastes and also excess of SiO_2 cause slow in setting time of the pastes. Aluminum oxide (Al_2O_3) imparts in quick setting property of cement but the excess results in MSWIBA determine

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that weakens the strength of cement. Other chemical composition like Fe_2O_3, CaO, MgO, Na_2O, K_2O and MnO are discussed as SiO_2 that was excess in amount which cause lose in consistency, workability and slow in setting time. Aluminum oxide (Al_2O_3) in the sample resulted with 9.22% in weight are higher than the OPC cement and lower the strength of cement pastes and the higher contents of iron oxide in the sample also responsible in fusion of the ingredient during mix design. The lesser amount of CaO in sample was adversely reduce the strength of and setting time of the pastes than the OPC. MgO obtained in the sample fall in between the ranges of the OPC standards that parts in hardness of blended mortar cement pastes. The excess amount of both sodium and potassium oxide found in the sample is cause efflorescence and sample cracks than the OPC and also the highly lesser amount of oxide of manganese contents that affects the early strength of pastes adversely.

4.2 Test Result for Physical properties of materials testes

a. Result of Specific gravity (relative density) of MSWIBA

Based on the moisture contents of the sample bottom ash, specific gravity can either increase or decrease. The values of specific gravity for MSWIBA higher or lower values shows the sample grinded into fine powder during it production or the sample has more moisture contents. The weighed of emptied flask apparatus (W_1) is 105.5gm and weight of the flux with the sample (W_2) =155.4gm the flask with kerosene and MSWIBA weighed (W_3) is 329.2gm then the weight of flask is emptied and filled with kerosene (W_4) was 297.1gm which results 1.0687 of specific gravity.

Since specific gravity is determining the ratio of the volume of a sample to equal volume of water so determine whether the replaced MSWIBA material is sinking in the water or not during mix. Normally the values of any material specific gravity less than one means the material is float on the water and if the values above one then the material sink. In the calculation above the values of MSWIBA specific gravity which is 1.0687 indicates that the material is heavier and sink in the water. The value of specific gravity for MSWIBA calculated in the research is lower value than OPC that is stated[27] shows the sample grinded into fine powder during its production or the sample has less moisture contents. Since Specific gravity is the ratio of density of a material to the density of the water, these the value calculated in the research above is indicates that MSWIBA are fairly denser as Portland cement. This lower value show that the percentage replacement of MSWIBA is denser than the Portland cement that contain less void space.

b. Result of Tests for Bulk density of MSWIBA

The bulk density of the MSWIBA in the research is calculated to determine the void space present in the particle of the sample that has a significant effect during the mix of paste, the Weight of MSWIBA sample (W) was 50g and specific gravity of MSWIBA is 1.0687 the density of reference (kerosene) is 0.8gm/cm^3 and the density of MSWIBA (D_{BA}) that is calculated according to [19] is 0.85gm/cm^3. The volume of sample (V) and bulk density of MSWIBA was resulted 58.82cm^3 and 0.85gm/cm^3 respectively. Bulk density decrease with increasing moisture contents of the sample this is due to increase in void space that resulting during grinding of the MSWIBA up to cement fine that determine the fineness properties of the bottom ash. The result bulk density obtained above due to the organic contents, texture of bottom ash, the density of grinded sample (i.e. too fineness) that lead the result was low in values.

c. Result of Fineness Tests for Cement vs. Bottom Ash

The 50 gm. samples of cement and bottom ash is sieved by 150mµ sieve size and the residues on the sieve are used to determine the fineness of the samples. The results of the percentage fineness for each trial are calculated below. The fineness of cement with weight (w) of 50gm that was retained on the sieve of 150mµ as residues (Rs) of first trial is 4gm and for MSWIBA of the same weight as the OPC that was residue on the sieve for first trial (Rs) which resulted 1.8gm these the percentage fineness of OPC and MSWIBA was calculated according to[19] is recorded in the table -4 below.

Table 4 Fineness modulus test result of OPC and MSWIBA

Cement type	Trails	Cement (gm.)	Sieve size(mµ)	Residue (gm.)	%fineness
Cement (OPC)	1	50	150	4	92
	2	50	150	3.8	92.4
			Average		92.2
Bottom ash	1	50	150	1.8	96.4
	2	50	150	4.2	91.6
			Average		94

The percentage of fineness to which cement is ground during its production can have a considerable effect on the behavior of the blended cement paste during hydration. The main purpose of fineness taste determination for MSWIBA is to known the rate of hydration increases with increasing fineness of the sample in practical uses. The average percentage of fineness importance of the MSWIBA which is resulted table-4 above 94% are both higher rate of strength gains and a higher rate of heat evolution which lead fast hydration of the mortar pastes during bricks productions; that stated according to Ethiopian standards of recommended percentage fineness of cements[19]. Hydration is takes place at the surface of cement and the percentage of MSWIBA replacement particles; and further hydration is hindered by the formation of the chemical reaction of the brick products, which finer particles are more hydrated than coarser particles. So the percentage finer of the cement are 92.2% and the percentage replacement of MSWIBA 94% are mostly finer than the cement particle which are hardened faster than the OPC in the cementitious block brick production. The result of increasing fineness percentage replaced MSWIBA causes increase in hydration, high strength, and bleeding are reduced in brick block products and also require more water for workability during mixing the paste; this resulting in higher possibility on dry shrinkage.

d. Loss Mass on Ignition (LOI) of Incinerated Bottom Ash Result

The lost on ignition represents the actual material lost during refining in the furnace under specified temperature of 950^{o}c until a constant weight loss of the sample due to heating. The lost on ignition to the product of the MSWIBA indicates the extent to which the pyro processing was incomplete. This is done to determine the high water contents in the MSWIBA or carbonation as these reduce

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the quality of the percentage of replaced bottom ash in the mortar pastes and used to provide a measure of the organic fraction by comparing the difference in mass of samples before and after ignition. Wight loss during heating can be due to the evaporation or volatilization and carbonation variety of components from the sample. The emptied crucible that sample is to be placed in was weighed and labeled as W_1 is 321 gm and the bottom ash that is measured with tarred platinum crucible was weighed and labeled as W_2 is 352gm and also the W_3 that is removed from the muffle furnace (950^{o}c) after 30min length of time with crucible was 340.9gm also the percentage loss on ignition of the sample 11.10% was found.

The result of the above percentage calculation of ignition loss which are 11.10% indicates the percentage replaced sample MSWIBA is more loss in mass on ignition than the normal OPC cement according to the Ethiopian Standard of the total loss in mass on ignition that not exceed 4% for ordinary Portland cement[19]. The high loss in ignition of MSWIBA indicates pre hydration and carbonation of the actual material which may cause by improper and prolonged storage during stoke before use and smelting or refining in a furnace. The result shows that mortars containing cement with high LOI were slower strength gains than that of mortars containing cement with low LOI [15].

e. Result of Determination Soundness of blended sample taste

Soundness is done in the research to determine the ability of a hardened cement and substituted percentage of MSWIBA paste to retain its volume after setting or prevent excessive volume change after setting by using Le Chateleir apparatus. For 10% MSWIBA replacement the distance between the indicator needles boiling point in 30 minutes and continued for one hour (L_1) is 13.5mm and the distance between the needles and indicator after removed the mould from the water to cooled and 15mm was recorded as L_2 then expansion after setting was calculated as 1.5mm. Soundness was performed for each percentage replaced and the result of the other is entered in the table-5 below.

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Table 5 Soundness taste result for blended cement

Description	Percentage replaced BA				
	0%	10%	15%	20%	25%
Av. L_1(mm)	13.8	13.5	13.4	12.5	12.75
Av. L_2(mm)	16.6	15	14.6	13.5	13.5
Expansion after setting (mm)	2.8	1.5	1.2	1	0.75

Unsoundness / soundness in the blended mortar pastes results from excessive volume change after setting or hardened. According to the Ethiopian Standard, for the expansion of Portland cement after hardening stated that expansion shall not exceed 10mm [19]. These values obtained in the Table 5 above, determined that as the percentage bottom ash increase expansion is decreased because of less lime (CaO) and magnesium oxide (MgO) in the pastes, however slow cracking and failure of the mortar paste will result on the brick block products due to less expansion.

The results of this study indicate that the partial replacement of ordinary Portland cement by MSWIBA that 10%, 15%, 20%, and 20% contents while can improve stability under different curing dates. Even if the mortar paste is lower in expansion and other physical tastes are not fulfilling the standards the strength of specimens is not straightforward relationship with the expansion in some instances. It follows that because a smaller amount of organic contents is passed from the incinerator plant bottom ash exhausts that are less binding properties and cause expansion. Therefore, it is necessary to use some form of accelerated test, so that tendencies toward unsoundness can be detected as a quality control measure.

f. Consistency Tests for blended Cement and Bottom Ash

The amount of water required for normal consistence which is 0% bottom ash are expressed as a percentage by weight of blended mortar that are 30% of water is required to make the paste consistence. For this the amount of water required to penetration a depth of 10mm by using vicat apparatus having 300g of needle which released to the mould filled with pest are 150ml. The normal ranges of consistency for water cement ratio are between 26%-33% [19], these the percentage of water required for this paste is fall in the rage of standards of normal cement pastes. The amount of water required for normal consistence of 10% bottom ash are 29.5% this is also

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fall in between the range of standards and attain the normal consistence that penetrated required depth released to the mould filled with blended pest and required water of 147.5ml. The normal consistency of 15% bottom ash is 29% and amount of water required for normal penetration of 10mm by using vicat apparatus which released to the mould filled with blended pest are 145ml and for the other percentage replacement of 20% and 25% bottom ash replacement are recorded in table below. The decrease in normal consistency was due to the reduction of cementitious binder in the fresh mixture with the increase of ash content and the chemical composition of the sample the sample contained highly excess amount of silicon die oxide (SiO_2) that are cause lose in consistency of the blended pastes.

Table 6 Summary results of percentage replaced consistency and Amount of water required

Cement and MSWIBA blended paste	(0% BA)	(10% BA)	(15% BA)	(20% BA)	(25% BA)
Consistency (%)	30	29.5	29	29	27
Amount of water required to penetrate a depth of 10mm in vicat apparatus taste (ml)	150	147.5	145	145	137.5

g. Setting Time Tests for Cement vs. Bottom Ash

Setting times results showed an increase in both initial and final setting times with the increase in MSWIBA content. The variation increments in the percentages replacement of MSWIBA between 10% and 15% replacement paste Initial setting time increased by 6.76% whereas increase in final setting time is 14.6%. This is reasonable as the increase of MSWIBA replacement content reduced the cement content in the mixture and also decreased the surface area of the cement. As a result, the hydration process slowed down causing setting time to increase. The slow hydration means low rate of heat development. That is the initial setting time for cement should not less than 45min and final setting time not to exceed 10 hours 20% and 25% replacement has significant delay of setting time in comparison with the plain ordinary Portland and 10% and 15% cement paste obtained.

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It was observed that the OPC mortar pastes are show shorter initial and final setting time than the MSWIBA blended mortar pastes. This attributes that MSWIBA has low contents of cementitious material than OPC. The blended mortar is hardened slowly and MSWIBA are low amount of heat that increases the setting temperature resulting to fasten the hydration of the paste.

Table 7 Summaries of normal consistency and setting time

Cement Paste	Normal consistency	Initial setting time(min)	Final setting time(min)
0%MSWIBA	30	47.6	567
10% MSWIBA	29.5	56.5	593
15% MSWIBA	29	60.6	625
20% MSWIBA	29	68.7	732
25% MSWIBA	27	74.5	829

h. Results for Moisture Content of Fine Aggregates (sand)

A 500gm.weight of fine aggregate was prepared this amount of sample was mixed using graduated cylinder and after oven dry was measured as weight B is 499gm these the percentage moisture contents are calculated found 0.16% of moisture that is used to determine the quantity of water added to the mix design of mortar. High percentage moisture contents of sand or positive means leads to high water cement ratio. As a consequence, the result calculated above solves the porous and low strengths problem of cementitious bricks products that arise due to high percentage of moisture contents. If the percentage moisture content of the fine aggregate is very less or negative that means the aggregate is dry to some extent that suck up more water and affect the mix design of the mortar.

i. Silt Contents of Fine Aggregate (Sand) taste result

Amount of silt deposited above the sand was 1ml and the amount of clean sand at the bottom of the cylinder was 30ml from this the percentage silt contents of the sand was calculated as 3.33 %. According to the Ethiopian building code of Standard it is recommended to wash the sand or reject if the silt content exceeds a value of 6% it shall not be used for construction [19]. So, the result percentage of silt content 3.33% shows that the silt content is not exceed the permissible amount and it is recommended for the mix design. During the establishments of the mix proportion of the mortar less silt contents in the fine aggregate that not has an effect on the strength and durability of the brick product. During practical uses of the fine aggregate in mix design of any mortar pastes if the content of the silt is to high wash the sand before use; washing the sand implies too much loss of fine sands components, therefore this would result in less moisture contents and well grading of fine aggregate material.

j. Result for Specific Gravity and Absorption Tests of Fine Aggregate

The results for specific gravity of fine aggregate (sand) and percentage of water absorption are 0.387 and 2.86% respectively that are calculated from 481.1gm of weight of sand after oven dry and weight of pcynometer equipment filled with water to its capacity and also the weight of pcynometer addition to weight of sample and water which is 1788.89gm and 996.001gm respectively. The specific gravity is normally used for construction are ranges between 2.5 to 3.0 with the average value of 2.75. Very small values of specific gravity test which is less than one results, the fine aggregate have a light weight clay and organic materials that are float on the water and not recommended for practical constructions and construction material of brick block production due to less strength, refract simply, deteriorates and non-durability which are generally less quality of mortar pastes. Unlike the lesser values, higher specific gravity results high dehydration of the mortar mix paste that are results less workable, less binding properties and visible void spaces on the brick products.

Water absorption is determining the water holding capacity of fine aggregates in the mortar paste; this is to measure the strength or quality of the fine aggregate. According to the British standards of percentage water absorption for fine aggregate which are not greater than 3% [20], these the above calculated percentage water absorption result determination with the value of 2.86% is attain the standards and recommended for practical uses. The values with higher value is determine the fine aggregate is high pore space with light weight (low density) or recycled, this results low workability problem in the fresh mortar. When water is added to the fine aggregate the particle is move apart each other and the added water exerts a surface tension force on the particle this made increase in volume. High water absorption results less durability of fine aggregate due high pore

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space that are holding much water. This absorption indicates that the amount of mortar pastes binding cement is absorbing aggregate in the mix.

k. Result of Sieve analysis test for fine Aggregate

The cumulative grams retained on each sieve determined by weigh and record the weights retained on each sieve size cumulatively, increasing by successive additions to the nearest 0.1 gm. The average grams of the three trial retained on maximum sieve size of 3/8inch (9.5 mm) is 0 gm. The average weight of material for sieve size 4.75 mm for the three trails are then checked, and weight as 28 gm. and the 2.36 mm sieve size material with the weight of the size 4.75 mm sieve, is record as a cumulative these weigh 81.8gm. This is Repeat the procedure until all of the sieves are weighed and recorded cumulatively. The cumulative percentage retained on sieve size of 4.75mm was 285gm from the total weight of the sample which is 541.2gm and the calculated percentage retained was 4.7% and also the percentage passing for each sieve seize that are calculated by subtracting the percentage retained on each sieve from 100. This the cumulative percentage retained and passing is performed for each sieve size and the result of the other is entered in the table-8 below.

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Table 8 Fine aggregate sieve analysis test result

Size Sieve	Weight of Sieve (gm.)	Weight of fine Aggregate Retained (gm.)			Av. Retained (gm.)	Av. Cumulative Retained (gm.)	Cumulative retained (%)	Cumulative passing (%)	Ethiopian standard (ES C.03.201) Percentage Passing (%)
		Trial 1	Trial 2	Trial 3					
¾inch (9.5)mm	540.0	0.0	0.0	0.0	0.0	0	0	100	100
4.75mm	560.0	20.3	26.4	29.3	25.3	25.3	4.7	95.3	95-100
2.36mm	530.0	49.3	47.7	64.3	53.8	79.1	14.8	85.2	80-100
1.18mm	490.0	105.4	98.5	81.1	95.0	174.1	32.5	67.5	50-85
600µm	460.0	156.4	153.3	143.3	151.0	325.1	60.7	39.3	25-60
300 µ m	410.0	155.0	156.5	179.7	163.7	488.8	91.3	8.7	10-30
150 µ m	390.0	41.2	39.48	40.1	40.3	529.1	98.8	1.2	2-10
Pan	370.0	6.4	6.6	6.6	6.5	529.1	100		
Total					535.6		402.8	402.8	

Based on the determination of the analysis is carried out in table 8 above that fine aggregates are described as well graded for ¾inch (9.5) mm, 4.75mm, 2.36mm, 1.18mm, and 600µ m sieve size and poorly graded for 300 µ m and 150 µ m sieve size. These the grading of analysis has close association with a range of quality of mortar produced using the fine aggregate. The Cumulative percentage retained on all of the sieves are the sum of all except the (75 µm) sieve size and the Pan; this is resulted 3.0.

This fineness modulus of fine aggregate is an index which represents the mean average size of the particle in the sand that determines how courser or fines the aggregate in practical uses. The result of fineness modulus that obtained above 3.0 is fits and the average size particle in the mortar mix

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is found at 600mm sieve size. The fineness modulus is an indication of grading of the fine aggregate and also size and shape of particle size that are playing great roles on the values of fineness modulus. Higher fineness modulus value indicates that the aggregate is coarser and less binding properties which leads mortar pastes are higher volume of pore space exist, less workability of pastes, fracture of brick products is happen but it increases in compressive strength of the bricks because of courser material have higher compressive strength than fineness particles. Unlike of higher values a small value of fineness modulus indicates that the material is finer which are more workable that affect the stability of the pastes in the mold during production. These according to the British standards the normal fineness modulus of fine aggregate are ranges between 2.3 to 3.1 [28], these the fineness modulus of the above result are fall between the range.

4.3 Optimization results for blended material and its measurement against the standards

1. **Result for Workability of fresh blended Mortar tests result**

In the research the result of workability or fluidity of fresh blended mortar using the caliper determine the flow by measuring the diameter of the mortar along the lines on the table top by taking four readings. For the percentage of 0% BA replacement the four reading was 94.5mm,96.2mm,97.4mm and 98mm these the average workability of the paste is calculated and the result was 96.5mm, thus workability is performed for each percentage replaced bottom ash and the result of the other is entered in the table-9 below.

The optimization of the sample average reading results that is obtained is not fall in between the ranges that stated according to ASTM standards, that mortar is said to be workable if the sum of the four diameters is between 95 and 100[19]. The research realizes that the values of workability for blended mortar below the standard ranges describe that mortar is too dry, the bond are weak, less consistency and setting time. Workable life of fresh mortar after mixing, stiffening time of the mortar during production of the bricks and also setting time of the pastes for these all table-9 below for the determination of mortar quality, consistency is playing a great role to fix the amount of water that should be added during the mix designs and also realize the replaced percentage bottom ash is possibly works or not. According to the table below workability of blended sample is decrease with the increment of percentage replaced bottom ash this is because of chemical composition of bottom ash and also amount of organic contents that found in the sample.

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Table 9 Workability of blended mortar taste results

No of Reading	0%MSWIBA	10% MSWIBA	15% MSWIBA	20% MSWIBA	25% MSWIBA
R1	94.5	93.5	93.7	94.2	90.2
R2	96.2	91.2	92.3	90.3	91.3
R3	97.4	97.1	95.2	97.2	92.7
R4	98	96.6	96.5	94.4	91
Av. Workability (mm)	96.5	94.6	94.43	94.03	91.3

2. Result for Flexural strength test of blended mortar

The flexural strengths of blended mortar with percentage of replaced incinerated bottom ash after different curing ages of 3, 7 and 28days are tested in MPa is describe that percentage replacement of bottom ash adversely affect the flexural strength of the specimens. Table -11 below shows that the compressive strength of the specimens decreases with the increasing of bottom ash replacement relative to the reference of 0%BA replacement. According to the graph -14 bellow representation result for the flexural strength that expressed as the arithmetic mean (average) of the three specimen's increase with the increasing curing date for each percentage replacement of bottom ash.

Optimization of the mix design of the sample for each percentage replacement BA that tasted by the research is successful when compared with normal compressive strength of clay brick[19]. The calculation of flexural strength for day three (3) curing paired and 0% of MSWIBA replacement was 5.14N/mm^2 determined using 40mm square section of prism(b), average load applied to the middle of the sample at fracture (F_f) which is 2233N and the distance between the support (*l*) of 110mm. The same for day three curing paired and 10% of MSWIBA replacement the calculation of flexural strength with 40mm,2230N and 110mm of square section of prism, applied load and distance between the support respectively are 4.89N/mm^2.

The result of flexural strength for the other samples with their percentage of MSWIBA replacement and with their respective curing period are determined and showed in the graph-14 below.

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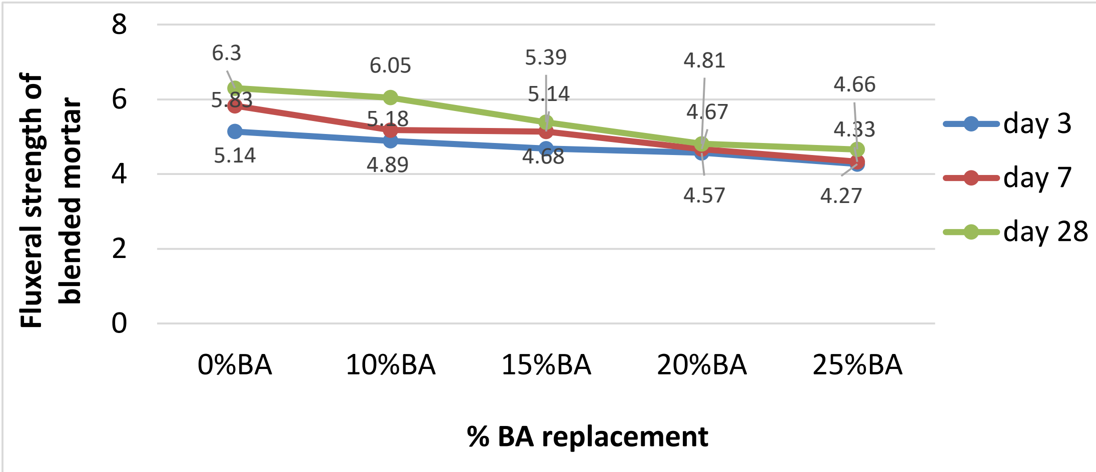

Figure 14 BA replaced flexural strength of blended mortar taste

3. Optimization and measurement result for compressive strength of mortar

The test results of compressive strength that tasted in the research as the arithmetic mean (average) of the three prisms sample of blended mortar paste when compared with the reference of 0% bottom ash is a decreasing results as the percentage replacement is increase from 10% to 25% of BA as express in the graph-20 bellow. Calculation for the measurement of compressive strength of mortar for day three curing paired and 0% of MSWIBA replacement using an area of specimen in contact with the load 40mm*40mm and average crushing load of 23210N is resulted as 14.5MPa and 13.17MPa for day three (3) curing paired and 10% of MSWIBA replacement. The overall compressive strength of blended mortar for each percentage of bottom ash replacement and curing test age is entered in table- 10 below.

Table 10 Compressive strength test of blended mortar pastes

	Av. Max Failure Load (N)					Compressive Strength (MPa)				
Test age (days)	**0%BA**	**10%BA**	**15%BA**	**20%BA**	**25%BA**	**0%BA**	**10%BA**	**15%BA**	**20%BA**	**25%BA**
3	23210	21070	17830	19110	18460	14.5	13.17	11.14	11.94	11.54
7	24400	21450	20770	20490	19470	15.25	13.41	12.98	12.8	12.17
28	25330	22800	22200	21530	21430	15.83	14.25	13.88	13.36	13.4

For the optimization of compressive strength of blended mortar for bottom ash to the cement ratio is increase as the percentage replacement decrease from 25% to 0% of bottom ash replacement. The effects of percentage replacements of bottom ash on the average compressive strength of mortar taste are decrease as the percentage replacement of bottom ash is increase. In the Figure 15 below the average compressive strength of day 3 curing period for each 10%, 15%, 20% and 25% of BA replacement are lesser than the control specimens (0%) and similar for the other curing dates of day 7, and 28. For curing period of day 3 and 15% bottom ash replacement the sample shows segregation and large void space that leads decrease in compressive strength of mortar blended pastes is by 4.5% from 20% bottom ash replacement; this is because of compaction during production and vibration.

Therefore, this research realizes that the effects of percentage replaced MSWIBA blended cement mortar paste chemical composition, organic contents and compaction results changes on compressive strength. These the properties of cementitious brick made from blended MSWIBA mortar address an effect on compressive strength. The compressive strength of blended mortar result obtained table above for each percentage replacement is beyond the range and mean values of 4.0 MPa that are stated in [29]

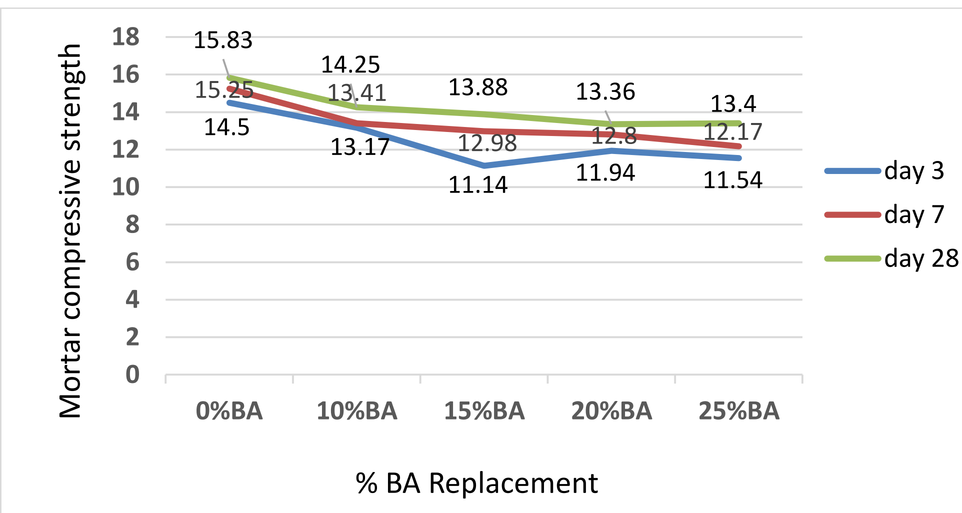

Figure 16 Replacement of bottom ash Vs mortar compressive strength

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4. **Result for Compressive Strength of cementitious Brick block**

For the optimization of cementitious brick, the blended bottom ash to the cement ratio is reach the normal clay brick that is recommended for any construction for each percentage replacement of bottom ash when compared to the construction material and laboratory manual stated [19]. The average compressive strength of brick block determined by the research for each percentage replacement is attain the normal brick strength and classified under class A brick except 20% BA replacement. Since the chemical composition of the material is varied with the Ordinary port land cement (OPC) and high organic contents but still attain the compressive strength of normal clay brick. Calculation for average compressive strength of zero percentage bottom ash replacement (0%) for day three (3) taste are 41.87MPa this is calculated from 120,604N and 28,800mm^2 of maximum failure load and area of bed face respectively. Thus the overall average compressive strength of cementitious brick block for each percentage of bottom ash replacement and curing test age are entered in table-12 below.

Table 11 Result for compressive strength of cementitious brick blocks.

Test age (days)	Av. Max Failure Load (N) of brick block					Compressive Strength (MPa)				
	0%BA	10%BA	15%BA	20%BA	25%BA	0%BA	10%BA	15%BA	20%BA	25%BA
3	1206040	862590	756450	422510	773770	41.87	29.95	26.27	14.67	23.45
7	1016520	845570	769700	567310	705440	35.30	29.36	26.73	19.70	24.49
28	1171400	898670	804700	683130	751430	40.67	31.20	27.94	13.36	24.68

According to ESC.D4001the minimum compressive strength of bricks are listed in the table-14 below and based on the result calculated in the table above are classified in different classes of A,B , C and D depend on their strength of the brick for construction uses [19].

Table 12 Minimum standards for compressive strength of bricks

Class	Standard Average of three clay bricks MPa	Standard Average of three blended cementitious bricks MPa				
		0%	10%	15%	20%	25%
A	20	A	A	A	C	A
B	15					
C	10					
D	7					

The compressive strength of cementitious brick block produced that showed in the Figure 18 below that strength of the blended brick decrease with the increment of percentage replacement from 0% to 25% of BA and increase with the decreasing percentage replacement. But unlike the percentage replacement of the BA the compressive strength of the blended brick is significantly increase with the curing date increases. For all brick sample the compressive strength is full fill the standard of all classes in the table 14 above and categorized under class A except 20% BA replacement due to improper mix, compaction and vibration during production that the sample forms segregation and large void space on the surface. This causes a significant effect on compressive strength of the products.

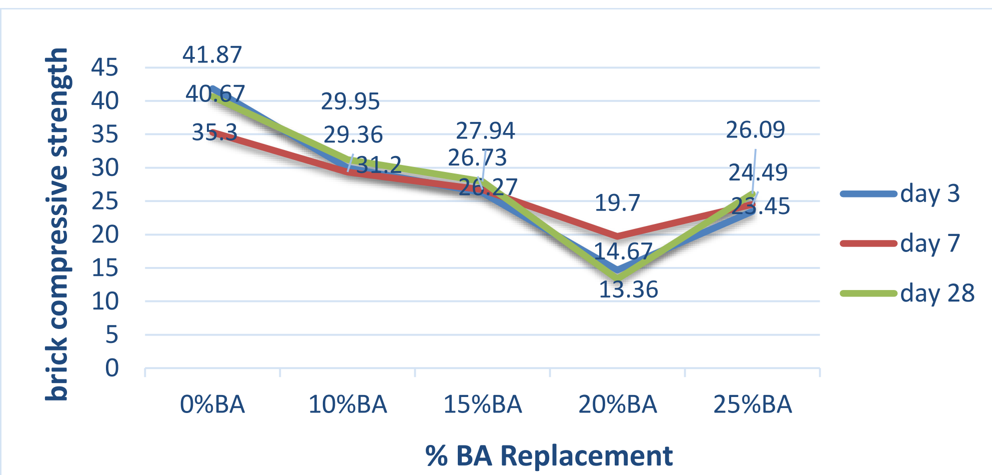

Figure 17 Replaced bottom ash brick strength with different curing date

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The average compressive sthength of three cementetious brick sample 41.88Mpa are catagorised under class A for 0% bottom ash replacement and three day curing period the same to that of 10% bottom ash replacement and day three curing period the compressive stregth of cementiotius brick are 29.95Mpa that is catagorised undur class A also fot 15% bottom ash replacement and day three curing period compressive stregth of cementiotius brick test result 26.27Mpa are catagorised under class A. unlike to the ather percentage replacement 20% of bottom ash replacement and day three curing period compressive stregth of cementiotius brick 14.67Mpa are catagorised undur class C and 25% of bottom ash replacement and day three curing period compressive stregth of cementiotius brick 23.45Mpa are catagorised undur class A.

For day seven curing period and 0% bottom ash replacement; the compressive sthength of the average of three cementetious brick block sample resulted 35.30Mpa are catagorised under class A. The compressive stregth of 10%,15%,20% and 25% bottom ash replacement that are redulted 29.36Mpa,26.73Mpa,19.70Mpa and 24.49Mpa respectively are catagorized under catagorise of class A except 20% bottom ash that is catagorised under class B. The average of three brick sample compressive sthength and day twenty eight curing period for 0% bottom ash replacement which is 40.67Mpa are catagorised under class A and the other percentage replacement of 10%, 15%,20% and 25% of bottom ash replacement compressive stregth of cementiotius brick for day twenty eight curing period are 40.67Mpa, 31.20Mpa, 27.94Mpa, 23.7Mpa and 26.09Mpa respectively that catagorised undur class A. The percentage replacements of bottom ash are an adverse effect on the compressive strength of the mortar pastes; this is due to the cementitious property that a binding capacity of percentage replaced MSWIBA pastes would be lesser than ordinary Portland cement. But the samples full fill the brick standards.

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CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

Use of blended cement for the production of cementitious brick with MSWIBA from *Reppie* waste to energy plant to become sustainable reuse of the by product is necessarily important. This help in sustainable cement for use by lowering the main resources or row material and energy consumption to grinding. Both initial and final setting time is increased when the percentage replacement of BA is increased from 10%-25% this is because of cementitious properties of replaced material is lesser than OPC and the reaction in the paste is not active due to chemical composition of BA that has significant effects on the handling, placing and giving required shape to the mortar pastes.

The average percentage of fineness importance of the MSWIBA which is resulted 94% is a relatively high fineness value than OPC this will cause greater importance of both higher rate of strength gains and a higher rate of evolution of heat which lead fast hydration of the mortar pastes during bricks productions; that stated according to Ethiopian standards of recommended percentage fineness of cements which is92.4. Since hydration take place at the surface of the brick product and further hydration is taking place after formation of chemical reaction finer particle more hydrated completely than courser particle. Also increasing fineness will decrease bleeding, but higher amount of water is required for workability this will resulting higher dry shrinkage.

The specific gravity of MSWIBA 1.0687 is more fine than 3.15 normal OPC cements due to the fineness, low moisture contents and has lesser void in the material. The specific gravity of material with the value of 3.15 above has more moisture contents or not properly minced during its production which affect the mix design and bonding between the material in the sample of brick products. Also mix design of the percentage replacements tastes like workability, compressive strength and flexural strength of mortar and compressive strength of cementitious brick block depends on the specific gravity of BA.

Compressive strength and flexural strengths of the blended mortar for the percentage replacement of MSWIBA is increase with the age of curing from 3days to 28days. But the strength is reduced gradually with the increase of percentage replacement of MSWIBA as compared of the controlled specimens (0%). This is because of less binding properties of replaced BA and high organic contents than OPC that significantly affect the strength of products.

5.2 RECOMMENDATIONS

High fineness values which cause high-volume expansion of MSWBA mixes are not recommended for practical use because cause deterioration of the sample in practical uses of construction. Addition of gypsum is recommended for proper set control of the pastes, regulate to improve strength development, reduce drying shrinkage, regulate early hydration reaction and regulate the reaction of Tricalcium aluminate (C_3A) which are available in the cement that control heat evolution [15] that completely react with water.

Addition of Gypsum in to the mix is recommended to use as stabilize agent for the blended percentage replaced mortar pastes of initial, final setting time and also workability of the blended bottom ash paste. To control the expansion of blended pastes addition of gypsum or lime and magnesium oxide is recommended. The result of compressive strength for brick block of 20% BA replacement that lesser values than the other % BA replacement this is recommended to mix sample properly and vibrate the blended mortar paste.

To make the result in the taste above acceptable and keep the standards; increasing the percentage of cement contents in weight, well compaction of blended paste, curing time, reduction of the water-cement ratio and vibration during production is recommended to gate the standards, durable and strengthen products. The total percentage replacement of the BA that is replaced for all 0%, 10%,15% and 25% except 20% is full fill the standards and the research is recommend the brick products for building construction.

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