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Adama Science and Technology University

School of Civil Engineering and Architecture

LOW –COST CONSTRUCTION THROUGH THE USE OF WOOD ASH FROM BREAD BAKERY AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

A Thesis submitted to the school of civil engineering and Architecture in partial fulfillment of the requirements for the award of degree of Master of Science in construction management technology teacher education

By	**ID. Number**
HiwotTsegay	GSR/5810/06
NigatuaMengesha	GSR/5440/06
SelomeFantahun	GSR/7565/05
TsedekeBekele	GSR/5370/06

Advisor

Tsegayekassa(Eng.)

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Adama, Ethiopia

Adama Science and Technology University

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Approval Sheet

Advisor: Name

________________________________Sig_____________Date_________

Internal Examiner

________________________________Sig_____________Date________

Department head

________________________________Sig_____________Date_________

External Examiner

________________________________Sig_____________Date________

CANDIDATE'S DECLARATION

We hereby declare that the work which is being presented in the this project ''***Low Cost Construction Through* The Use Of Wood Ash From Bread Bakery As Partial Replacement For Cement In Concrete** **"**in partial fulfillment of the requirements for the award of the degree of master of science in Construction Management is an authentic record of our own work carried out from April 2015 to June 2015 under the supervision of Tsegaye Kassa(Eng.),Department of Civil Engineering and Architecture, Adama Science and Technology University, Ethiopia.

The matter embodied in this thesis has not been submitted by us for the award of any other degree or diploma. All relevant resources of information used in this thesis have been duly acknowledged.

Name:

Hiwot Tsegay **sig** ________________ **Date** ______________

Nigatua Mengesha **sig** _________________ **Date** _______________

Selome Fanthaun **sig** _________________ **Date** _______________

Tsedeke Bekele **sig** _________________ **Date** _______________

This is to certify that the above statement made by the candidates is correct to the best of my knowledge and belief. This thesis has been submitted for examination with my approval.

Tsegaye Kassa(Eng.) __________________ _________________

Advisor Signature Date

Abstract

The purpose of this project is to minimize construction cost by replacing cement with wood ash as partial replacement for ordinary Portland cement in concrete. Provision of affordable housing especially for low-income earners, which forms the majority of the population, continues to be elusive in the nations of world. The major reason given for this is the high cost of building and construction materials. Concrete and concrete products constitute the major building construction materials. However, cement which is the main binder in concrete production has been identified as the major contributor to increasing high cost of construction. This project is present the results of investigation conducted to assess the structural suitability and adequacy, as well as affordability of using wood ash as partial replacement of cement in the production of concrete structural works for low-cost building and construction purposes. The workability and compressive strength of the concrete was determined. Wood ash was replacing 5% - 20% by weight of the cement in concrete. Concrete with no wood ash serves as the control. The mix ratio used was 1:2:4 with water to binder ratio maintain at 0.5. The Compressive strength was determined at curing ages 7 and 14, days. The compressive test conduct for 7 and 14 days curing age was determined by single sample spacemen for each mix design. The strength value was a single specimen.

Keywords: *Wood ash, Bread bakery, Pozzolan, Workability, Compressive strength*

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Acronym and Symbols

AASHTO	American Association of State Highway and Transportation Officials
ACTIV	Accelerated Corrosion Test with the Impressed Voltage
Al_2O_3	Alumina
ASTM	American Society for Testing and Material
BRWA	Wood, Rice Husk and Sugarcane Biogases Waste
BS	British Standard
CLSM	Controlled Low Strength Material
CSH	Calcium Silicate Hydrate
ECAE	Ethiopian Conformity Assessment Enterprise
ES	Ethiopian Standard
Fe_2O_3	Iron Oxide
FM	Fineness Modulus
Kwh	Kilo Watt
MPa	Mega Pascal
OPC	Ordinary Portland cement
RCC	Reinforced Cement Concrete
SEM	Scanning Electron Microscopy
Sio_2	Silica
Ton	Tone
UWM	Use of Wood Ash in Cement Based Material
W/b	Water Binder Ration
W/c	Water Cement Ration
WA	Wood Ash

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CHAPTER ONE

1. Introduction

Concrete is a versatile construction material that is widely used in virtually all structural works. It is a composite material comprising cement, aggregates, water and admixtures. Wood ash concrete is a type of concrete with wood ash as partial replacement for cement.

Fly ash is defined as a material collected from a practical combustion device after the fuel is consumed [1]. It is an industrial by- product that possesses hydraulic and pozzolanic properties. This type of material imparts technical advantages to the resulting concrete and also enables larger quantities of cement replacement to be achieved [2]. Wood ash is similar to fly ash since it is obtained from a practical combustion device – bread bakery in this case.

1.1. Background

Ethiopia is a typical example, where nearly all its rural population depends on biomass energy sources for cooking and other energy requirements. Of the different biomass energy sources, fuel wood accounts for around 78 percent of the total energy demand, while animal dung and crop residue account for 12 percent and 9 percent, respectively (WBISPP 2004).[3]

Wood ash is a by-product of combustion from bread and 'engera' bakeries, for home cooking purpose and to boil coffee one of beloved tradition in Ethiopia is done by wood coal. Nearly all of the about 80% of Ethiopians living in rural areas have no access to electricity. All rural population and some urban population depend on fuel wood energy sources for cooking and other energy requirements. [4] Approximately 100% of the wood ash a byproduct of combustion wood is being land filled. Wood ash is composed of both inorganic and organic compounds. The physical and chemical properties of wood ash vary significantly depending upon various factors such as type or species of trees/wood, method and manner of combustion and other supplementary fuel used with wood.

Use of wood ash has been better known as soil supplement, but its possible utilization in cement-based materials has not been explored. In 1995, the UWM Center for By-Products Utilization took a major initiative in investigating the use of wood ash in cement-based materials. Research was carried out to utilize wood ash in making self-compacting controlled low-strength materials (CLSM), air-entrained and non-air-entrained concretes, and bricks/blocks/paving stones. Initial test results indicated that wood ash could be successfully used in making:

(1) CLSM (with up to 90 % of total materials)

(2) air-entrained structural-grade concrete up to 28-day compressive strength of 50 MPa with wood or its blends (up to 40 %) of wood ash and coal fly ash;

(3) non-air-entrained structural-grade concrete (up to 60 MPa 28-day compressive strength) with wood ash or its blends with coal fly ash (up to 40 %) as partial replacement of cement; and

(4) Good quality bricks/blocks/paving stones with wood ash or its blends with coal fly ash (up to 35%) as partial replacement of cement. [5]

In Ethiopian history the use of wood ash is not seen usually as we know this land fill material dispose as waste material. No use for any purpose the result of this waste is causing a respiratory health problem especially who leave near by the accommodation of wood ash .and also pollute the underground source of water. For fill the gap of people abdomen to answer the request of stomach people buy ‘engera’ and bread as a major food varieties. These engera and bread bakeries all over Ethiopia use wood to bake their breads. Not only that for each and every house hear in Ethiopia to use wood and wood charcoal as a main source of energy for instant to cook, bake and to boil coffee which is done twice or three times a day .Especially in rural area they don’t have any other energy option, their source of energy relies on only wood, wood waste and dried dung. The byproduct of this small industry (wood ash) this research used in this paper to evaluate the effectiveness of its properties by using as supplementary cementious material.

The aim of this project is to produce cost effective and structurally suitable supplementary cementious material. As like fly ash wood ash don’t have many researches and investigation but this project determine the appropriate ratio of wood ash by cement weight and the effectiveness of wood ash as supplementary cementious material.

1.2. Statement of the Problem

Most construction project in this country not complete as per schedule, from enormous problem the number one is that lack of money. To encounter the problem, the cement will be partially replaced by wood ash that is a byproduct of bread bakery and home use wood to prepare food found all over the Ethiopia.

In this country the demand of cement is increasing rapidly because the boom construction industry. Constriction has been done for infrastructure, industries, housing project and for repairing works. This high demand of construction material especially cement could not satisfy by the local cement factories as well importers. The research proposes ideas are to solve this problem by partially replacing cement by wood ash that is found freely from bread bakery and home use wood to prepare food.

Portland cement concrete has a grater pore size distribution that's why it needs proper compaction. To overcome this problem studies have shown that concrete containing more than 20% fly ash by weight of cement has a much smaller pore size distribution. Wood ash is similar to fly ash since it is obtained from a practical combustion device – bread bakery in this case.

To improve a property of concrete many admixtures are added. From those retarder is one of the admixtures used widely in concrete production. It delays a setting time of concrete in such structure especially finishing work or ornamental casting, delayed hardening time and delay setting time concrete is required. Wood ash can be compensate the use of retarder admixture and improve the concrete properties as well.

To increase workability of concrete it is an option for traditionally production of concrete adding water. The more water we add the more strength we lose. Using wood ash as partial replacement of cement reduces a water required amount in concrete and it increase the workability of concrete without adding more water.

1.3. Objective

1.3.1. General Objectives

Low cost –construction through the use of wood ash as partial replacement of cement in different concrete structure works.

1.3.2. Specific Objectives

The specific objectives of this project are to:

- be cost effective (cement can be partially replaced by wood ash)
- Meet the demand of cement in the country by replacing it with locally found material.
- Minimize pore size distribution in concrete mix (concrete containing more than 20% fly ash by weight of cement has a much smaller pore size distribution)
- Improve properties of concrete by compensating wood ash for retarder
- Increase workability of concrete. And
- Reduce water requirement in concrete mix.

1.4. Scope

Scopes of the project are:-

I. constructing buildings with low cost construction material through the use of wood ash as partial replacement of cement

II. Improve concrete properties

1.5. Significance of the Study

This paper will encourage:

- Low income earners able to begin planning their house project and also generate income by producing concrete blocks, concrete tiles and concrete precast beam in the small micro enterprise by wood ash cement.
- Civil engineers and craft workers by improving properties of concrete such as it increase workability, reduce pore size distribution in concrete mix and reduce water requirement in concrete mix.

1.6. Limitation of the Project

- Sometimes wood ash contain appreciable amount of un-burnt carbon which reduces its pozzolanic activity.
- Lack of laboratories to analysis the chemical composition of wood ash nearby Adama town.
- As we are students it is difficult to spend much amount of money on the project so it limits the effectiveness of the project.

CHAPTER TWO

2. Literature Review

Materials engineers are responsible for the selection, specification, and quality control of materials to be used in a job. These materials must meet certain classes of criteria or materials properties (Ashby and Jones 2005). These classes of criteria include economic factor [6]. The fly ashes that have been widely studied are those obtained from power plants where coal is used as a fuel [7-12]. This study will see an alternative source of fly ash by investigating the properties of the wood ash obtained from bread bakery. 'Engera' and Bread are staple food in Ethiopia that is consumed regularly by a large number of people. Thus, bread and 'Engera' bakery is located in every nooks and cranny of the country to cater for the high demand for the product. The bakeries use wood as fuel for their operation thereby resulting in high volume of ash as by-product. The ash particles solidify as microscopic, glassy spheres that are collected from the bakery's exhaust before they can "fly" away, hence the product's name - fly ash [13].

Fly ash with potential for use in concrete is classified into two categories as Class C and Class F [14]. The classification is based on sum of (SiO_2 +Al_2O_3 +Fe_2O_3). Where the sum is greater than or equal to 70%, the ash is classified as Class F, while it is Class C if the sum is greater than or equal to 50% [15].

This study will examine the use of wood ash from 'Engera' and bread bakery as partial replacement for ordinary Portland cement in concrete. It needs to involve the determination of the chemical composition of the ash but as we try to explain in chapter six as limitation of the project lack of chemical determination procedures lab equipment and also chemicals. We forced to conduct our investigation by trial and error method. Because of this reason we also conduct mechanical tests which is compressive strength of the concrete as well the workability of the concrete.

2.1. Concrete

Cement concrete is a mixture of cement, sand, pebbles or crushed rock and water. When placed in the skeleton of forms and allowed to cure, becomes hard like a stone. Cement concrete is important building material because of the following reasons.

- It can be molded into any size and shape of durable structural member.
- It is possible to control the properties of cement concrete.
- It is possible to mechanize completely its preparation and placing processes.
- It possesses adequate plasticity for mechanical working.

The cement concrete has the following properties

- It has high compressive strength
- It is free from corrosion
- It hardens with age and continues for a long time after concrete has attained sufficient Strength
- It is proved to be economical than steel
- It binds rapidly with steel and it is weak in tension, steel reinforcement is placed in Cement concrete at suitable places to take up tensile concrete or simply R.C.C.
- It forms a hard surface, capable of resisting abrasion stresses. This is called reinforced cement.
- It has tendency to be porous to avoid this proper grading & consolidation of the aggregates, minimum water-cement ratio should be adopted.

Advantages and limitations

Concrete is the most widely used construction material in the world. It is used in many different structures such as dam, pavement, building frame or bridge. Also, it is the most widely used material in the world, far exceeding other materials. Its worldwide production exceeds that of steel by a factor of 10 in tonnage and by more than a factor of 30 in volume. The present consumption of concrete is over 10 billion tons a year, that is, each person on earth consumes more than 1.7 ton of concrete per year. It is more than 10 times of the consumption by weight of steel. Concrete is neither as strong nor as tough as steel, so why is concrete so popular?

Advantages:

A) **Economical:** Concrete is the most inexpensive and the most readily available material. The cost of production of concrete is low compared with other engineered construction materials.

Three major components: water, aggregate and cement. Comparing with steel, plastic and polymer, they are the most inexpensive materials and available in every corner of the world. This enables concrete to be locally produced anywhere in the world, thus avoiding the transportation costs necessary for most other materials.

b). **ambient temperature hardened material:** Because cement is a low temperature bonded inorganic material and its reaction occurs at room temperature, concrete can gain its strength at ambient temperature.

c) **Ability to be cast:** It can be formed into different desired shape and sizes right at the construction site.

d) **Energy efficiency:** Low energy consumption for production, compare with steel especially. The energy content of plain concrete is 450-750 kWh / ton and that of reinforced concrete is 800-3200 kWh/ton, compared with 8000 kWh/ton for structural steel.

e) **Excellent resistance to water.** Unlike wood and steel, concrete can harden in water and can withstand the action of water without serious deterioration. This makes concrete an ideal material for building structures to control, store, and transport water. Examples include pipelines (such as the Central Arizona Project, which provide water from Colorado River to central Arizona. The system contains 1560 pipe sections, each 6.7 m long and 7.5 m in outside diameter 6.4 m inside diameter), dams, and submarine structures. Contrary to popular belief, pure water is not deleterious to concrete, even to reinforced concrete: it is the chemicals dissolved in water, such as chlorides, sulfates, and carbon dioxide, which cause deterioration of concrete structures.

f). **High temperature resistance:** Concrete conducts heat slowly and is able to store considerable quantities of heat from the environment (can stand 6-8 hours in fire) and thus can be used as protective coating for steel structure.

g). **Ability to consume waste:** Many industrial wastes can be recycled as a substitute for cement or aggregate. Examples are fly ash, ground tire and slag.

h). **Ability to work with reinforcing steel:** Concrete and steel possess similar coefficient of thermal expansion (steel 1.2 x 10^{-5}; concrete 1.0-1.5 x 10^{-5}). Concrete also provides good protection to steel due to existing of CH (this is for normal condition). Therefore, while steel bars provide the necessary tensile strength, concrete provides a perfect environment for the steel, acting as a physical barrier to the ingress of aggressive species and preventing steel corrosion by providing a highly alkaline environment with pH about 13.5 to passivity the steel.

i) **Less maintenance required:** No coating or painting is needed as for steel structures.

Limitations:

a) **Quasi-brittle failure mode:** Concrete is a type of quasi-brittle material. (Solution: Reinforced concrete)

b) **Low tensile strength:** About 1/10 of its compressive strength. (Improvements: Fiber reinforced concrete; polymer concrete)

c) **Low toughness:** The ability to absorb energy is low. (Improvements: Fiber reinforced concrete)

d) **Low strength/BSG ratio (specific strength):** Steel (300-600)/7.8. Normal concrete (35-60)/2.3.Limited to middle-rise buildings. (Improvements: Lightweight concrete; high strength concrete)

e) **Formwork is needed:** Formwork fabrication is labor intensive and time consuming, hence costly (Improvement: Precast concrete)

f). **long curing time:** Full strength development needs a month. (Improvements: Steam curing) g). **working with cracks:** Most reinforced concrete structures have cracks under service load. (Improvements: Prestressed concrete).

2.2. Concrete Making Material

Concrete, as pointed out above, is a composite material made of Portland cement, water and aggregates. In some cases admixtures may be added to give the concrete special properties either when fresh or hardened or both. In this part, we deal with the properties of the component materials and the requirements they have to fulfill in order to produce good and sound concrete.

2.2.1. Portland Cement

It is the name given to a cement obtained by thoroughly mixing together calcareous and argillaceous, or other silica, alumina and iron oxide-bearing material, burning them at a clinkering temperature, and grinding the resulting material. No material, other than gypsum, water and grinding aids may be added after burning.

Manufacture of Portland cement

From the definition of Portland cement given above, it can be seen that it is made primarily from a combination of a calcareous material, such as limestone or chalk, and of silica and alumina found as clay or shale. The process of manufacture consists essentially of grinding the raw materials into fine powder, mixing them intimately in predetermined proportions and burning in a large rotary kiln at a temperature of about 1400 $^{\circ}C$ (2550 $^{\circ}F$) when the material sinters and partially fuses into balls known as clinker. The clinker is then cooled and ground to a fine powder, with some gypsum added, and the resulting product is the commercial Portland cement used throughout the world.

The mixing and grinding of the raw materials can be done either in water or in a dry condition; hence, the names wet and dry process. In the dry process the raw materials are crushed, dried in rotary driers, proportioned, and then ground in ball mills consisting of rotating steel cylinder containing a charge of hard steel or ceramic balls. The resulting powder is then burnt in its dry condition in the rotary kiln.

In the wet process the materials are mixed with enough water to form slurry, which is 30 to 35 percent water. In this form the materials are further proportioned, mixed, ground and pulverized and then pumped to a furnace called a kiln. Quality control of materials is critical and throughout the manufacturing process samples are continually taken for laboratory analysis.

The mixture is fed into a rotary kiln, sometimes (in the wet process) as large as 5m in diameter and 200m long. The kiln is slightly inclined. The mixture is fed at the upper end while pulverized coal (or other source of heat) is blown in by air blast at the lower end of the kiln, where the temperature may reach about 1500 ^{o}C (2750 ^{o}F). The amount of coal required to manufacture one tone of cement is between 100kg and about 350kg depending on the process used.

As the mixture of raw materials moves down the kiln, it encounters a progressively higher temperature so that various chemical changes take place along the kiln. First, any water is driven off and CO_2 is liberated from the calcium carbonate. Further on, the dry material undergoes a series of chemical reactions until, finally, in the hottest part of the kiln, some 20 to 30 percent of the material becomes liquid, and lime, silica and alumina recombine. The mass then fuses into balls 3 to 25mm in diameter, known as clinker.

Afterwards, the clinker drops into coolers, which provide means for an exchange of heat with air subsequently used for the combustion of the pulverized coal. The cool clinker, which is characteristically black, glistering, hard and porous, is then fed into ball mills where it is inter ground with a small quantity of gypsum, 2 to 3 percent by weight, in order to prevent flash setting of the cement. Once the desired degree of fineness is reached to about $1.1x10^{12}$ particles per kg, the cement is conveyed to storage silos from which it is drawn for packing in the familiar paper bags of 50kg each. At some plants it is fed directly to bulk-cement Lorries for delivery to large construction sites.

Proportioning of Raw Materials

In the manufacture of Portland cement, correct proportioning of the raw materials is of prime importance in securing clinker of proper constitution. In order to fix the proportions accurately, chemical analysis should be made on the raw materials. The results of chemical analysis are usually reported in terms of the oxide of the principal constituents (Table 2.1), and this procedure is the basis for proportioning the raw materials in the manufacture of Portland cement. The proportions may vary depending on the oxide composition of the raw materials, and indeed different types of cement are obtained by suitable proportioning of the materials.

Table 2.1. Approximate Oxide Composition Limits of Raw Materials.

oxide	Content (wt. %)
Lime (CaO)	60-67
Silica (SiO_2)	17-25
Alumina (Al_2O_3)	3-8
Iron oxide(Fe_2O_3)	0.5-6.0
Magnesia(MgO)	0.1-5.5
Sculpture trioxide(SO_3)	1-3
Alkalis-Soda(Na_2O) Potassium(K_2O)	0.5-1.3
Titanium Oxide(TiO_2)	0.1-0.4
Phosphorous Pentaoxide (P_2O_3)	0.1-0.4
Carbon dioxide(CO_2)	1-3
Manganese Oxide(Mn_2O_3)	0-0.1

Present day trend in the manufacture of Portland cement is towards higher lime content, above 65%. Cements with lower lime content are slow to harden. On the other hand, the maximum lime content should be limited in order to avoid the presence of free lime in the cement since free lime may cause volume instability (unsoundness) in the hardened cement paste.

The alumina and iron oxide act as a flux to reduce the burning temperature; this explains the limit on their lower percentage. On the other hand the upper limit of these oxides is determined by the need to control the rapidity of the setting of the cement. Iron oxide imparts the gray color to cement. In cement chemistry it is customary to represent the oxides by abbreviations (Table 2.2) [16]

Table 2.2. Abbreviations of Common Oxides

Oxide	Abbreviation
CaO	C
SiO_2	S
Al_2O_3	A
Fe_2O_3	F
H_2O	H
SO_3	$\bar{S}$
MgO	M
Na_2O	N
K_2O	K

2.2.2. Fine Aggregates:

The material, which is passed through 4.7625mm B.S. test sieve, is termed as fine aggregates. Usually natural river sand is used as fine aggregates. But places where natural sand is not available economically, finely crushed stone may be used as fine aggregates.

Sand is a natural product which is obtained as river sand and pit sand. However sea sand should not be used for the following reasons:

1. It contains salt and hence structure will remain damp. The mortar is affected by

   Efflorescence and blisters appear.

2. It contains shells and other organic matter which decomposes after some time, reducing the life of the mortar. Sand may be obtained artificially by crushing hard stones.

   Usually artificial sand is obtained as a by-product while crushing stones to get jelly (coarse aggregate).

Sand is used in mortar and concrete for the following purpose:

1. It sub-divides the paste of binding material into thin films and allows it to adhere and spread.
2. It fills up the gap between the building blocks and spreads the binding material.
3. It adds to the density of the mortar.
4. It prevents the shrinkage of the cementing material.
5. It allows carbon dioxide from the atmosphere to reach some depth and thereby improve setting power.
6. The cost of cementing material per unit volume is reduced as this low cost material increases the volume of mortar.
7. Silica of sand contributes to formation of silicates resulting into the hardened mass.

The properties of good sand are:

1. It should be chemically inert.
2. It should be free from organic or vegetable matter.
3. It should be free from salt.
4. It should contain sharp, angular and coarse grains.
5. It should be well graded.
6. It should be hard.

2.2.3. Coarse Aggregates:

Aggregates generally occupy 65 to 75% of the volume of concrete. Hence due consideration should be given in their selection and proportioning. Aggregates range from fine sands to rocks 38 mm in diameter or larger. The quality of the concrete is affected in several ways by the aggregate. The strength of the aggregate limits the strength of the concrete. The surface of the grains affects the plasticity of a concrete mix. Rounded grains will move more easily as the concrete is placed. Long and thin aggregate will weaken concrete. The aggregates used in concrete may be natural aggregates, such as sand and gravels taken directly from riverbank or gravel deposits, or they may be byproducts of an industrial process (e.g. blast-furnace slag).

In Ethiopia the great majority of aggregates used for concrete are obtained from natural sources, either in the form of rock, which is crushed to obtain the desired maximum size or gravel, which is processed by crushing or screening oversized materials. In choosing aggregate for use in a particular concrete attention should be given to three important requirements:

- Workability when fresh for which the size and gradation of the aggregate should be such that undue labor in mixing and placing will not be required.
- Strength and durability when hardened - for which the aggregate should:
    - a) Be stronger than the required concrete strength
    - b) Contain no impurities which affect strength and durability
    - c) Contain no silt which affects the adhesive strength between aggregate and cement paste (this is mainly a problem in relation to fine aggregate)
    - d) Be resistant to weathering action
- Economy of the mixture- meaning to say that the aggregate should be:
    - a) Available from local and easily accessible deposit or quarry
    - b) Well graded in order to minimize cement paste, hence cement, requirement

Classification of coarse Aggregates

Aggregates are generally classified based on their source, their chemical composition, their weight, their size or the mode of preparation. As regards the source, aggregates may be natural or artificial. Natural aggregates are obtained from riverbeds (sand, gravel) or from quarries (crushed rock), while artificial aggregates are generally obtained from industrial wastes such as the blast furnace slag. There are three main classes of aggregates differing in their chemical composition and these are derived from argillaceous (composed primarily of Al_2O_3), siliceous (composed primarily of Si_2O_3), and calcareous rock (composed primarily of $CaCO_3$).

The classification of rocks according to their mode of formation is igneous, sedimentary and metamorphic rock .Based on their weight; aggregates are divided into three groups:

1. Heavy aggregates with densities more than 4000kg/m^3 (these include steel balls, bronze and other metals used in concrete for radiation shielding)

2. **Normal weight aggregates** with densities between 2400 and 2800kg/m^3

3. **Light weight aggregates** such as pumice and scoria which used to make lightweight concrete, having solid densities in the region of 700kg/m^3

2.2.4. Water

Water fit for drinking is generally suitable for making concrete. Substances in water that, if present in large amounts, may be harmful are: salt, oil, industrial wastes, alkalis, sulphates, organic matter, silt, sewage etc. Tests by the sense of smell, sight or taste should reveal such impurities; however water of doubtful quality should be submitted for laboratory analysis and test.

Water-used in concrete mixes has two functions, the first is to react chemically with the cement which will finally set and harden, and the second function is to lubricate all other materials and make the concrete workable. The quality of cement paste is determined by the proportion of water to cement (Water cement ratio). Too much water prevents proper setting: Too little water prevents complete chemical reaction called hydration; the water and cement combine chemically to form a new compound.

A 50 kg bag of cement requires approximately 12.5 liters of water for complete chemical combination of materials. However, the use of exactly the amount of water needed for chemical combination is not practical under field condition. Usually 20 liters to 40 liters must be used for each sack of cement. The extra water serves as a lubricant to carry the cement paste into small pores of the aggregate. Excess water is also needed to wet the aggregate so that it will not absorb water needed by the cement.

The more water added to the mix, the more fluid and plastic it will be (the better the workability will be), and the weaker the concrete will be. Too much water will cause the aggregate to segregate, resulting in concrete that is uneven in strength. The excess water will float the fine, light particles of cement to the top of freshly placed concrete. This process is called bleeding.

The amount of water to be mixed with a given quantity of cement is expressed as the number of liters of water to each 50 kg bag of cement. The proportion of water to cement is referred to as the water-cement ratio. Water may be measured either by volume or by weight.

$$\text{Water cement ration} = \frac{\text{Weight or volume of water}}{\text{Weight of cement}}$$

The tanks on modern concrete mixers are equipped with water gauges or meters that assure the proper amount of water for each batch. The amount of water in the aggregate must be determined so that the total amount of water in the design mix will be correct.

It should be pointed out that the total amount of water required per unit volume of fresh concrete depends on a number of factors that are:

1. The desired consistency of the concrete, which may be expressed as will be seen, by the slump test.
2. The maximum size, particle shape and grading of the aggregate
3. Water reducing admixtures.

2.3. Supplementary Cementitious Martial

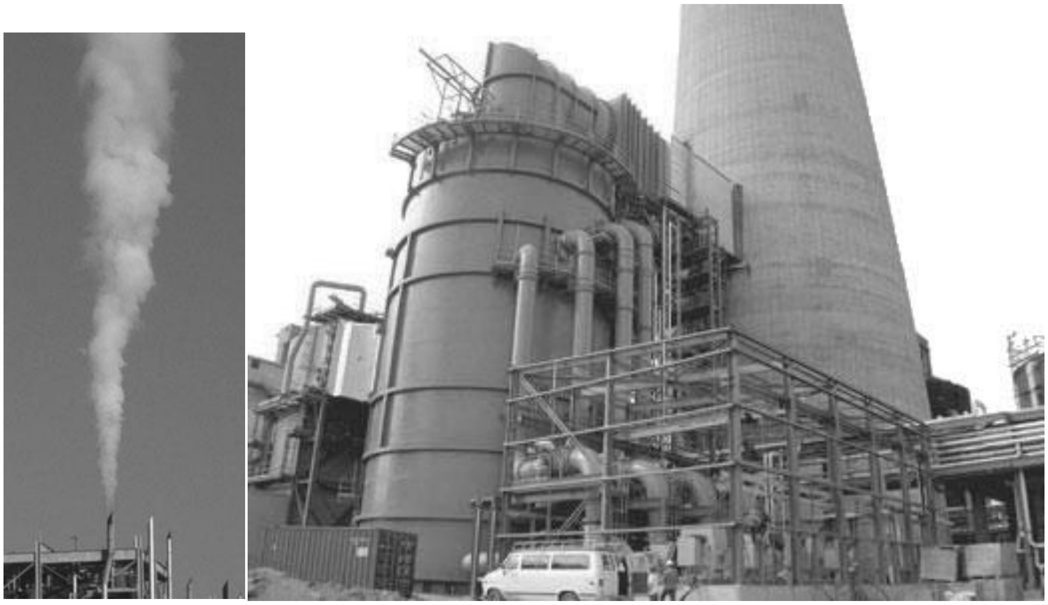
Several byproducts of other industries have been used in concrete as supplementary cementitious admixtures since the 1970s, especially in North America. These materials have been used to improve some properties of concrete and to reduce the problem of discarding them. Since these materials are cementitious, they can be used in addition to or as a partial replacement for Portland cement. In fact, two or more of these supplementary cementitious additives have been used together to enhance concrete properties. These supplementary cementitious materials include fly ash, ground granulated blast furnace slag, silica fume, and natural pozzolans.

2.3.1. Fly Ash

Fly ash is the most commonly used pozzolan in civil engineering structures. Fly ash is a by-product of the coal industry. Combusting pulverized coal in an electric power plant burns off the carbon and most volatile materials (Figure 2.1).However, depending on the source and type of coal, a significant amount of impurities passes through the combustion chamber. The carbon contents of common coals ranges from 70 to 100 percent. The non-carbon percentages are impurities (e.g., clay, feldspar, quartz, and shale), which fuse as they pass through the combustion chamber. Exhaust gas carries the fused material, fly ash, out of the combustion chamber .The fly ash cools into spheres, which may be solid, hollow (cenospheres), or hollow and filled with other spheres (plerospheres). Particle diameters range from 1µm to more than 0.1 mm, with an average of 0.015 mm to 0.020 mm, and are 70% to 90% smaller than 0.045 mm. Fly ash is primarily a silica glass composed of silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3) and lime (CaO). Fly ash is classified (ASTMC618) as follows:

Class N—Raw or calcined natural pozzolans, including diatomaceous earths, opaline cherts and shales, ruffs and volcanic ashes or pumicites, and some calcined clays and shales.

Class F—Fly ash with pozzolan properties



(a) (b)

Fig 2.1. Fly ash resulting from the combustion of ground or powdered coal

(a) Being discharged from a smelter before environmental regulations were put intoeffect and (b) collected into a bag house.

Class C—Fly ash with pozzolan and cementitious properties

Class F fly ash usually has less than 5% CaO but may contain up to 10%. ClassC fly ash has 15% to 30% CaO.

Fly ash increases the workability of the fresh concrete. In addition, fly ash extends the hydration process, allowing a greater strength development and reduced porosity. Studies have shown that concrete containing more than 20% fly ash by weight of cement has a much smaller pore size distribution than Portland cement concrete without fly ash. The lower heat of hydration reduces the early strength of the concrete. The extended reaction permits a continuous gaining of strength beyond what can be accomplished with plain Portland cement.

2.3.2. Slag Cement

Slag cement is made from iron blast furnace slag. It is non-metallic hydraulic cement consisting basically of silicates and alumina silicates of calcium, which is developed in a molten condition simultaneously with iron in a blast furnace. The molten slag is rapidly chilled by quenching in water to form a glassy, sand like granulated material. The material is then ground to less than 45 microns. The specific gravity of slag cement is in the range of 2.85 to 2.95.

The rough and angular-shaped ground slag in the presence of water and an activator, NaOH or CaOH, supplied by Portland cement, hydrates and sets in a manner similar to Portland cement. Slag cement has been used as a cementitious material in concrete since the beginning of the 1900s. Slag cement commonly constitutes between 30%and 45% of the cementing material in the mix. Some slag concretes have a slag component of 70% or more of the cementitious material. ASTM C 989(AASHTO M 302) classifies slag by its increasing level of reactivity as Grade 80,100, or 120.

2.3.3. Silica Fume

Silica fume is a byproduct of the production of silicon metal or ferro silicon alloys. One of the most beneficial uses for silica fume is as a mineral admixture in concrete. Because of its chemical and physical properties, it is a very reactive pozzolan. Concrete containing silica fume can have very high strength and can be very durable. Silica fume is available from suppliers of concrete admixture sand, when specified, is simply added during concrete production either in wet orderly forms. Placing, finishing, and curing silica fume concrete require special attention on the part of the concrete contractor.

Silicon metal and alloys are produced in electric furnaces. The raw materials are quartz, coal, and woodchips. The smoke that results from furnace operation is collected and sold as silica fume. Silica fume consists primarily of amorphous (non-crystalline) silicon dioxide (SiO_2). The individual particles are extremely small, approximately 1/100th the size of an average cement particle. Because of its fine particles, large surface area, and the high SiO_2 content, silica fume is a very reactive pozzolan when used in concrete. The quality of silica fume is specified by ASTM C 1240 and AASHTO M 307.

In addition to producing high-strength concrete, silica fume can reduce concrete corrosion induced by deicing or marine salts. Silica fume concrete with low water content is highly resistant to penetration by chloride ions. More information is available at the www.silicafume.org website.

2.3.4. Natural Pozzolans

A pozzolan is siliceous and aluminous materials which, in itself, possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, react chemically with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties (ASTM C595). Naturally occurring Pozzolans, such as fine volcanic ash, combined with burned lime, were used about 2000 years ago for building construction and pozzolan continues to be used today. Calcium hydroxide is one of the products generated by the hydration of C_3S and C_2S In fact, up to15% of the weight of Portland cement is hydrated lime. Adding a pozzolan to Portland cement generates an opportunity to convert this free lime to a cementitious material.

Tables 2.3 and 2.4 summarize the effects of supplementary cementitious admixtures on fresh and hardened concrete. These summaries are based on general trends and should be verified experimentally for specific materials and construction conditions. [7]

Table 2. 3. Effect of Supplementary Cementitious Materials on Freshly Mixed Concrete

Quality Measure	Effect
Water Requirements	Fly ash reduces water requirements. Silica fume increases water requirements.
Air Content	Fly ash and silica fume reduce air content, compensate by increasing air entrained.
Workability	Fly ash, ground slag, and inert minerals generally increase workability. Silica fume reduces workability; use super plasticizer to compensate.
Hydration	Fly ash reduces heat of hydration. Silica fume may not affect heat, but super plasticizer used with silica fume can increase heat.
Set Time	Fly ash, natural pozzolans and blast furnace slag increase set time. Can use accelerator to compensate.

Table 2.4. Effects of Supplementary Cementitious Admixtures on Hardened Concrete.

Quantity measure	Effect
Strength	Fly ash increases ultimate strength, but reduces rate of strength gain. Silica fume has less effect on rate of strength gain than pozzolans.
Drying Shrinkage and Creep	Low concentrations usually have little effect. High concentrations of ground slag or fly ash may increase shrinkage. Silica fume may reduce shrinkage.
Permeability and Absorption	Generally reduce permeability and absorption. Silica fume is especially effective.
Alkali–Aggregate Reactivity	Generally reduced reactivity. Extent of improvement depends on type of admixture.
Sulfate resistance	Improved due to reduced permeability.

2.4. Wood Ash

Wood ash is obtained from the combustion of wood. It can be related to fly ash since fly ash is obtained from coal, which is a fossilized wood [17]. Rice husk ash is also of plant origin. This implies that wood ash could be used as a pozzolana in concrete. Tarun, Rudolph and Rafat [18] reported the following elements in wood ash: carbon (5% to 30%), calcium (5% to 30%), carbon (7% to 33%), potassium (3% to 4%), magnesium (1% to 2%), phosphorus (0.3% to1.4%) and sodium (0.2% to 0.5%). The following compound composition limits were also reported: SiO_2 (4% to 60%), Al_2O_3 (5% to 20%), Fe_2O_3 (10% to 90%), CaO (2% to 37%),MgO (0.7% to 5%), TiO_2 (0% to 1.5%), K_2O (0.4% to 14%), SO_3 (0.1% to 15%), LOI (0.1%to 33%), moisture content (0.1% to 22%), and available alkalis (0.4% to 20%). The study revealed that all the major compounds present in wood ash are present in fly ash.

Fig. 2.2.a. Sample wood charcoal ash

Fig.2.2.b. Sample wood ash

A major problem arising from the widespread use of forestry biomass as fuel is related to the ash produced in significant quantities as a byproduct from the incineration of such biomasses. A major portion (approximately 70%) of the wood ash produced is land-filled as a common method of disposal (Campbell, 1990; Etiegni and Campbell, 1991; NCASI, 1993). As wood ash consists of highly fine particulate matters, which can be easily rendered airborne by winds, such a means of waste disposal may result in subsequent problems, namely, respiratory health problems to residents dwelling near the disposal site of the ash material. Moreover, contamination of ground water resources can also be expected to occur from leaching of heavy metal contents of ash or by seepage of rain water (Udoeyo et al., 2006). Hence, disposal of wood ash by means of land-filling require a properly engineered land fill which have implications in terms of the cost of disposal. Therefore, such a method of disposal is uneconomical over long term. These problems require a new and a more economical means of wood ash disposal as a solution. In addition, the current boom in the construction industry has caused a massive elevation of the demand for cement which is the main constituent material in the production of concrete.

The production of cement involves an intensive use of raw material (limestone) and energy, while at the same time, releases high quantities of carbon dioxide into the atmosphere. Research reveals that for the production of every 600 kg of cement, approximately 400 kg of carbon dioxide gas is released. The increased demand of cement implies a higher rate of environmental deterioration due to the limestone extraction activities, a higher requirement of fossil fuels and higher rate of greenhouse gas discharge. Recent research (Udoeyo and Dashibil, 2002; Elinwa and Ejeh, 2004; Udoeyo et al., 2006; Naik et al., 2003) was performed to investigate the feasibility of the use of wood ash as a partial replacement material for the energy intensive process of hydraulic cement for concrete production.

The tests showed promising results in that wood ash can suitably use as constituent material in during the production of structural grade concrete with acceptable mechanical and durability properties. These findings provide a solution for the waste management problems of wood ash and also contribute towards minimizing the consumption of energy intensive hydraulic cement production of greener concrete material supplying the ever growing demand of the construction industry. Hence, incorporation of wood ash as cement replacement material in blended cement and concrete will be beneficial not only in environmental terms for concrete material but also in production costs of the aforesaid materials.

2.4.1. Factors Influencing the Quantity and Quality of Wood Ash

There are several factors which have a significant effect on the qualitative and quantitative aspects of wood ash produced from the incineration of raw wood. This mandates the proper characterization of wood ash prior to being used as constituent material in production of concrete and blended cement paste. These factors include heat treatment temperature and the species of trees from which the wood were derived.

Combustion temperature of raw wood inside the furnace strongly governs both yield and chemical compositions of resulting wood ash. In terms of ash yield, the combustion of wood at higher temperatures generally resulted in a lower amount of wood ash produced. The reduction in wood ash yielded up to 45%with a combustion temperature increase from 538 ◦C to 1093◦C. Combustion of wood at higher temperatures beyond 1000◦C also resulted in a profound decrease in carbonate content due to the chemical decomposition of the afore-said chemical compound at such temperatures. Carbonate sand bicarbonates compound especially calcite ($CaCO_3$) are pre-dominant in wood ash produced from an incineration at temperature lower than 500◦C. However, at higher incineration temperatures greater than1000◦C which is the typical operational temperature for most wood fired boiler units, oxide compounds such as quick lime (CaO) become predominant in the chemical phase of wood ash produced.

The reduction of carbonates and bicarbonates chemical species which contribute to alkalinity of wood ash at higher combustion temperatures resulted in a corresponding decrease in alkalinity of ash. Moreover, there was a decline in composition light metallic elements such as potassium, sodium and zinc in wood ash with increasing temperature of combustion (Etiegni and Campbell,1991).

Some species of trees from which the wood were derived has shown to be a dominant factor governing the chemical properties of wood ash produced. The chemical composition of essential oxide compounds which governs the suitability of wood ash as a cement replacement material such as silica (SiO_2), alumina (Al_2O_3), iron oxide (Fe_2O_3) and quicklime (CaO) varies significantly with various species of trees.

2.4.2. Uses of Wood Ash

Currently, ash by-products from the combustion of wood are commonly used as a soil supplement to improve the alkalinity of soil for agriculture applications. Wood ash is also used as a filler material in the construction of flexible pavements for road-sand highways (Etiegni and ampbell, 1991). Recent research findings confirm the suitability of wood ash as a partial cement replacement material in the production of structural grade concrete and self-compacting concrete for applications in building construction (Elinwa and Mahmood, 2002; Elinwa et al., 2008; Abdullahi, 2006).

2.4.3. Physical Properties of Wood Ash

Wood ash is reported to consist of heterogeneous mixture of variable size particles which are generally angular in nature. These particles were unburned or partially burned wood or bark. In terms of fineness, average amount of wood fly ash passing sieve #200(75µm) and retained on sieve #325 (45µm) were 50% and 31%respectively. The bulk density of wood fly ash was determined to be relatively low at 490kg/$m^3$with a specific gravity value of 2.48.

Wood fly ash was found to have low average autoclaved expansion value of 0.2% (Naik, 1999).Naik et al. (2003) evaluated the physical properties of wood ashes from five different sources which concluded that wood ash samples have varying values of unit weight that range from 162kg/m^3 to a maximum of 1376kg/m^3. The specific gravity of wood ash samples investigated ranged between 2.26 and 2.60. The low unit weight and specific gravity of wood ashes relative to neat cement indicate a possibility of the reduction in the unit weight of concrete material produced by the partial substitution of cement using wood ash. A higher degree in the variation of wood ash fineness was observed whereby the percentage of wood ash retained on a 45µm sieve varied between 23% and 90%.

A sieve analysis results showed that the mean diameter, d50, wood incineration fly ash obtained from an open incineration of wood in a drum to be 150µm. The corresponding surface area of wood was determined to be relatively high (150m^2/g) which, is possibly due to the increased ash surface porosity. Other physical properties of wood namely specific gravity, loose bulk density and moisture content were found to be 2.29, 830kg/m3and 0.37% respectively (Elinwa and Mahmood, 2002; Elinwa and Ejeh, 2004). Abdullahi (2006) reported similar results where by the specific gravity and the bulk densities of wood ash were found to be 2.13 and 760kg/m3respectively.

The specific gravity of wood fly ash collected from a forestry biomass fired power plant was found to be 2.54. Wood fly ash from the same source consisted of fine ash particles with an average diameter below 50µm. SEM images of wood fly ash reveals that wood fly ash consists mainly of highly angular particles with a high Extent of surface porosity. Specific surface areas of wood fly ash collected from two different sources had reported values of 40.29m^2/g and 7.92m^2/respectively.

As physical properties of wood waste ash have significant effect on pozzolanic and hydraulic reactivity, high degree in variation of physical properties of wood ash obtained from different sources mandate proper characterization of wood ash prior to being incorporated as cement replacement material in production of concrete material for construction

2.4.4. Properties of Wood Ash Blended Cement

Blending of wood ash and ordinary Portland cement (OPC) at various levels of cement replacement produces a new type of blended cement with altered physical properties and heat kinetic properties in comparison to neat OPC. Wood ash/OPC blended cement exhibit significant difference in terms of the setting times, soundness and heat evolution characteristics.

A. Initial and Final Setting Time

The inclusion of wood ash as a partial cement replacement material in wood ash/OPC blended cement resulted in a delay of cement setting hence the need for longer initial and final setting times of blended cement paste. The effects of setting time delays become more significant with the increase in the level of cement substitutions with wood ash (Elinwa and Ejeh, 2004; Elinwa and Mahmood, 2002; Udoeyo and Dashibil, 2002; Abdullahi, 2006).

At the level of cement replacement with wood ash up to 30% by total binder's weight, both initial and final setting time of the blended cement paste are still in compliance to the limits prescribed in standard code of practice BS 12: 1978 (Udoeyo and Dashibil, 2002).

Delays in the initial and final setting of cement paste in the presence of wood ash is largely due to the dilution of cement content as part of the OPC was used as a substitute with wood ash (Elinwa and Ejeh, 2004).The presence of wood ash, which is less reactive than OPC in blended cement paste, resulted in the retardation rate of cement hydration which also contributes to the delay in the blended cement paste setting. A prolonged time of setting for cement pastes is a desirable attribute of blended cement which implicates longer times in which the paste is workable. A corresponding lower hydration heat of the blended cement due to the lower hydration rate as aforementioned rendered wood ash/OPC blended cement paste suitable for applications. This allowed a desired low heat development which offsets the stress induced by temperature differential such as mass concreting work.

B. Soundness

The presence of wood ash as a partial cement replacement material in blended cement paste generally resulted in a higher magnitude of cement paste soundness. Varying levels of cement replacement using wood ash from 0 to 30% causes a corresponding increase in the soundness of blended cement paste. At a replacement level of 30%, the most sound blended cement paste reported was 1.45mm which was still in good compliance with the Maximum allowable soundness of 10mm specified by BS4550-Part3 (Elinwa and Mahmood, 2002; Udoeyo and Dashibil, 2002; Elinwa and Ejeh, 2004).

2.4.5. Bulk Density and Mechanical Strength of Hardened Wood Ash/OPC Concrete and Mortar

***A*. .Bulk Density**

Generally, the utilization of wood ash as partial cement replacement material in concrete mix reduces bulk density of hardened concrete. Reduction in bulk density becomes more significant at higher levels of cement replacement using wood ash. Bulk density of grade 20 concrete mixes was observed to be reduced from 2482kg/m^3 at 0% wood ash content to 2281kg/m^3 when wood ash content was increased up to 40%. The bulk density reduction effect is attributed to a lower specific gravity wood ash in comparison to OPC (Elinwa et al., 2005).

B.. Compressive Strength

Several researchers (Elinwa and Mahmood, 2002; Udoeyo and Dashibil, 2002; Elinwa and Ejeh, 2004; Abdullahi, 2006) had common findings that show the use of wood ash as a partial cement replacement material in concrete at all level of cement replacement ranged between 5% and 30% it reduces the compressive strength of the concrete mix produced relative to neat OPC concrete for all curing times. Udoeyo et al. (2006) justified that the trend observed is most probably due to the mechanism that wood ash particles act more like filler material within the cement paste matrix than as binder material. Thus, increasing ash content as replacement of cement resulted in an increased surface area of filler material to be bonded by decreasing the amount of cement which caused a decline in strength. However, Elinwa and Mahmood (2002) observed a marginal difference of compressive strength between wood ash concrete and neat OPC control concrete mix. This tends to decrease with prolonged curing durations, especially beyond 28 days. In addition, Udoeyo and Dashibil (2002) observed a higher rate of compressive strength gain for concrete mix with wood ash content ranging between 15% and 25% total binder weights. This was true for increments of 5% at later curing ages of 56 and 90 days. Both observations are evidence of increased CSH gel formation within cement paste matrix microstructure of wood ash concrete by pozzolanic activity. This was done between an amorphous silica content of wood ash and portlandite from the hydration of cement. Elinwa and Ejeh (2004)studied the compressive strength development of mortar mixes containing wood ash as a cement replacement between 5 and 30% at stepped increments of 5% observed that mortar mix with 10% wood ash content exhibited highest compressive strength at all ages of curing up to 60days.

At a 60day curing age the mortar mix with 10% of wood ash as Partial cement replacement material exhibited similar compressive strength as equivalent mortar mix with only OPC as binder. Naik et al. (2002) investigated the compressive strength development behavior of a concrete mixture made with wood fly ash used as a partial cement substitution material for curing age up to 365 days. Wood fly ash was included in the mix at binder substitution levels of 5, 8 and 12% by total binder weight while a quantity of binder, aggregate and water/binder ratios remained constant for all mixes produced. From the compressive strength results acquired, they concluded that

Control concrete mixture (without wood ash content) achieved strength of 34MPa at 28 days and44MPa at 365 days. The strength of concrete mixtures containing wood fly ash ranged from 33MPa at 28 days and between 42and 46MPa at 365 days.

The inclusion of wood fly ash in a partial substitution of cement in concrete up to a replacement level of 12% had a significant contribution to the strength development of concrete mixtures produced. Continuous strength was gained from the wood fly ash concrete mixes upon prolonged curing durations. This indicated a presence of pozzolanic reactions between wood ash and the cement hydration product. Elinwaetal. (2005) attempted to improve compressive strength of wood ash/OPC concrete by the including trace amounts of metakaolin as an additive in the concrete mixes. The concrete mixes produced had 20MPa target strength. This mix included wood ash as a cement replacement using a 5% step increments between 0 and 40%. Metakaolin was used as an additive material at a constant dosage of 3% by total binder weight.

It was observed that the inclusion of metakaolin though at small dosage, contributed towards the enhancement of an early rate of compressive strength gain of wood ash/OPC concrete. OPC concrete with 10% wood ash total binder weight exhibited a compressive strength and modulus of rupture which was respectively 37% and 7% higher in comparison to the neat OPC concrete though both mixes had same content of metakaolin. Concrete mixes with wood ash at cement replacement levels of 5%, 10%, 15%and 20% and 3% metakaolin as additive reached target strength of20MPa after 28 days of curing period.

Further evidence of pozzolanic characteristic of wood ash was reported by Elinwa et al. (2008) that incorporation of wood ash as partial cement replacement material by 10% of total binder weight in self a compacting mortar mix resulted in improvement in compressive strength of mix relative to controls the mortar mix containing neat OPC as binder. Self-compacting mortar mixes with wood ash beyond 10% total binder weight was observed to have lower compressive strength than neat OPC mortar for curing ages up to 28 days. At a prolonged curing age up to 90 days, mortar mixes with wood ash content of 15% exhibited compressive strength similar to neat OPC mortar. Similar trends of a higher rate of compressive strength development at later curing ages beyond 28 days up to 90 days relative to neat OPC mortar were exhibited by all mortar mixes which had wood ash content of 5, 10, 15and 20% of total binder weight.

Rajamma et al. (2009) investigated the compressive strength of cement mortar mixes containing wood fly ash obtained from a wood biomass fired power plant. Wood fly ash was used as cement replacement material at replacement level of 10, 20 and 30% of total binder weight. It was observed that mortar mixes with a wood fly ash content of 10% exhibited higher 28-day compressive strength but lower flexural strength in comparison with equivalent neat OPC mortar. The use of wood fly ash as a partial cement replacement material at higher replacement level of 20 and 30% of total binder weight was observed to reduce 28 day compressive strength relative to equivalent neat OPC mortar mix.

Utilization of very finely ground ash from the co-combustion of wood, sugarcane bagasse and rice husks as partial cement replacement material in concrete was found to significantly improve the compressive strength of the concrete mix produced.

2.4.6. Durability Properties of Wood Ash/OPC Concrete

A. Resistance against Acid Attack

Udoeyo and Dashibil (2002) investigated the resistance of concrete containing wood ash against acid attack. Two batches of concrete specimens having the same mix proportions (1 binder: 2 sand: 4 gravel and w/c ratio of 0.65) were produced. One of the batches contained neat OPC as a binder while the other batch had 15% total binder weight of wood ash used in partial replacement of cement and 85% total binder weight of cement. The hardened concrete cubes produced were immersed in a 20% concentrated nitric acid solution. The cubes were immersed and their loss of mass was noted at 7, 14, 21, 28, 35, 42, 49, 56, 63 and 70 days. There was a continuous marginal increase in mass for both sets of concrete specimens upon immersion in the concentrated nitric acid solution up to 9 weeks of immersion due to the absorption of water. At the tenth week of immersion, there was observable mass decrease in both batches of specimens and it could be noted that mass decrease of the concrete specimens with 15% total binder weight of wood ash were less pronounced in comparison to control concrete specimens with neat OPC as binder. Elinwa and Ejeh (2004) studied the effects of incorporating wood ash in concrete for resistance against corrosive action.

Two types of corrosion tested were concentrated nitric acid and sulphuric acid both having a 20% concentration. A batch of concrete with wood ash used as a partial cement replacement level of 10% total binder weight and a corresponding batch of control concrete a having similar mix proportion as the former but without wood ash content. Both specimens were immersed in both types of acid solution mentioned earlier. Their loss in mass

Was noted every week for total immersion up to 5weeks.Theresistance of concrete containing 10% of wood ash by total binder weight against corrosive action of nitric acid was observed to be higher than control concrete mix because loss in mass of wood ash concrete was less pronounced relative to the control concrete. However, a 10% wood ash concrete mix was observed to have a lower resistance against the corrosive action of sulphuric acid in comparison to the control concrete containing only neat OPC as binder. This is due to higher loss in mass of 10% wood ash concrete as compared to OPC concrete when immersed in 20%.

B. Water Absorption

Elinwa and Ejeh (2004) studied the effects of the incorporation of wood ash as a partial cement replacement material in mortar mixes on its water absorption property. Two batches of mortar mixes with the same mix proportions (1 binder: 3 sand: 0.6 w/b ratio) were cast whereby one batch contained 15% wood ash as a partial replacement material while the other had no wood ash content. It was observed that inclusion of wood ash as a cement replacement material at 15% total binder weight contributed towards the reduction in water absorption of the mortar mix produced. Average water absorptions of mortar mixes with 15% of wood ash and without wood ash content were recorded to be 0.8% and 1.25% respectively whereby both are still far below maximum of 10%.

Udoeyo et al. (2006) investigated the water absorption properties of concrete with wood ash as a partial cement replacement material. Concrete mixes with wood ash content ranging between 5% and 30% at increments of 5% were produced for water absorption tests. The water absorption of concrete with wood ash as a partial cement replacement material was observed to increase gradually from 0.14 to 1.05%with the increase in level of cement replacement from 5% to 30%. At levels of cement replacement by wood ash up to 30%, concrete mix produced still has satisfactory values.

C. Chloride Permeability

Wang et al. (2008b) investigated the chloride penetration resistance of air entrained in a concrete mix with a partial replacement of cement binder using wood fly ash and wood/coal blended fly ash. Level of cement replacement by several types of fly ash was maintained at 25% total binder weight. Various types of fly ash used as a partial cement replacement material were, to name a few, combustion of wood (Wood), class C coal/wood blended fly (Wood C), class F coal/wood blended fly ash (Wood F), class C and class F coal fly ash and fly ash from co-combustion of coal and switch grass (SW1 and SW2). Wood C and Wood F blended fly ash were produced by

Blending class C and class F coal fly ash with pure wood ash at a mass ratio of 80% coal fly ash and 20% wood fly ash. All concrete mixes produced were moist cured for 56 days prior to being subjected to a rapid chloride permeability test which was performed in accordance to ASTM C1202-91. Based on the test results obtained, they observed that:

(i) The incorporation of wood ash at a cement replacement level of 25% in air entrained concrete mix did not result in a significant impairment of the chloride permeability property of concrete. (ii) The utilization of wood /class F coal blended fly ash in partial substitution of cement had significant Contribution towards lowering of chloride permeability property of concrete mix. A slight increase in chloride permeability of concrete mix with 25% wood ash used in partial substitution of cement relative to control concrete mix with pure OPC binder observed was probably attributed to coarse particle size (30–130μm) of wood ash used.

Horsakulthai et al. (2011) studied the effects of incorporating a very finely ground ash from the co-combustion of wood, rice husk and sugarcane bagasse waste (termed as BRWA) as partial cement replacement material on the chloride permeability property of concrete mix produced. The accelerated salt ponding method was used to evaluate chloride permeability of two different grades (grade 20and 35) of concrete mixes produced by the incorporation of BRWA at a cement replacement level of 0, 10, 20, and 40% total binder mass. The test results concluded that the incorporation of finely ground BRWA as partial cement substitution in concrete resulted in the enhancement of resistance against chloride penetration and lowered the chloride diffusivity coefficient. The presence of BRWA in a concrete mix at a cement substitution level of 10, 20 and 40% resulted in the reduction of the chloride diffusion coefficient by30–40%, 65–70% and 75% respectively in comparison to control concrete mixes with only OPC as binder. The gradual reduction trend of the chloride diffusion coefficient for two different grades of concrete was examined. The increasing level of cement replacement by BRWA.

D. Corrosion Current and Electrical Resistance

Horsakulthai et al. (2011) investigated the effects of partial substitution of cement with very finely ground ash from co-combustion of chop wood, rice husks and sugarcane bagasse (termed as BRWA). These substitutions were tested in two different grades of concrete on the corrosion current and electrical resistance of hardened concrete mixes. The two concrete mixes had a target strength grade of 20MPa and 35MPa respectively. For grade 20 mixes, BRWA was used as partial cement replacement material at a replacement level of 0 (control mix), 10, 20, and 40%.Meanwhile, for the grade 35MPa mix, BRWA was used at a cement replacement level of (control mix), 10 and 20%.The corrosion current and electrical resistance of mixes produced were evaluated by an accelerated corrosion test using the impressed voltage (ACTIV)method.

From the test results they observed that increased levels of cement replacement using BRWA resulted in increased electrical resistance of the mix. This is indicated by a lowered value of initial corrosion current passing the mix. For grade 20 concrete, values of initial corrosion current of the mixes with BRWA content of 0, 10,20 and 40% were recorded to be 27.4, 18.8, 7.9 and 4.0m A respectively. While for the grade 35 concrete mix, with BRWA content of0, 10 and 20%, currents reported were to be 26.1, 14.5 and 6.4mArespectively.

The enhancement in electrical resistance of the concrete mix with the use of BRWA as partial cement replacement material was largely attributed to the effect of the overall reduction of the average pore size. There was a quality improvement of the interfacial transition zone between the cement paste matrix and the aggregates formed by the additional CSH compounds from the pozzolanic reaction. This reaction, in turn occurred between the amorphous silica content of BRWA with portlandite formed during the OPC hydration stage. Test results of the accelerated corrosion test, by impressed voltage, also showed a delay in time for the formation of the first micro-crack within the concrete mixes. These were examined upon immersion in the concentrated sodium chloride solution with an increased level of cement replacement by BRWA. Furthermore, the loss in mass of the steel bar embedded in the concrete mixes upon immersion in 3% sodium chloride solution was observed to decrease with an increased level of cement replacement by BRWA.

D. Drying Shrinkage of Concrete Containing Wood Ash

Naiketal. (2002) studied the drying shrinkage properties of concrete mixtures made by the incorporation of wood ash as a partial cement replacement material. For mixes produced during the study, wood ash was used at cement substitution level of 0, 5,8 and 12%. Length changes of concrete specimens produced were monitored up to 232 days. It was reported that the shrinkage value of control concrete specimens was−0.0092 %(7days)/−0.052 %(232days). Meanwhile shrinkage values of concrete mixtures with 5, 8and 12% were recorded to be 0.012%/−0.027%, 0.014%/−0.013% and−0.0051%/−0.044%. From the results of drying shrinkage, it was observed that the inclusion of wood ash significantly contributed to the reduction in magnitude of concrete upon drying. This is a desirable attribute which may reduce formation of micro cracks within concrete mix on drying. [19]

CHAPTER THREE

3. Methodology

The methodology adopted in carrying out the study is discussed under four sub headings of literature Review, Materials, Specimen Preparation and laboratory test for the tests carried out.

3.1. Literature Review

There have been a lot of published ideas about supplementary cement materials, papers, articles, free download books from internet, note lectures, materials. Literary review on supplementary cement material was performed to better understand the problem of Portland cement concrete.

3.2 Materials

The wood ash used for this study was collected from Adama Town. The wood ash was carefully collected at the exhaust of the bakery, after the fuel had burned out, with the aid of hand scoop. It was sieved to separate the ash from any unwanted material. The wood ash was ground to fine powdery form and only those retained on a 0.425 µm sieve was used for the experiments.

The Ordinary Portland cement (Muger, Brand) used was obtained from a local retailer in Adama. Sharp sand obtained from river bed was used as fine aggregates and granite as coarse aggregates. The fine and coarse aggregates used was also obtained from Adama, Ethiopia.

3.3. Specimen Preparation

Wood ash was replacing 5% - 20% by weight of the cement in concrete. Concrete with no wood ash serves as the control. The mix ratio will be 1:2:4 (binder, sand and aggregate) with water to binder ratio maintained at 0.5. The details of the concrete mixtures use in the tests are listed in Table 3.1.

Table 3.1: proportioning of concrete

Percentage of wood ash (%)	Cement (kg)	Wood ash (kg)	Fine aggregate(kg)	Coarse aggregate(kg)
0	0.93	------	2.43	5.93
5	0.8835	0.0465	2.43	5.93
10	0.837	0.093	2.43	5.93
15	0.7905	0.1395	2.43	5.93
20	0.744	0.186	2.43	5.93

3.4. Laboratory Tests

After searching literature select the material which is possible to do the work then choose the appropriate ingredients to make quality output. To get quality output quality input should be selected and the throughput should be done in proper manner and according to Ethiopian building code standard (EBCS) to get good result, which is safe and serviceable concrete structure. Go to test the quality material accept the good material and reject the poor material.

3.4.1 Silt Clay Content of Sand

Normally sand is a product of natural and artificial distinction of rock and minerals because of this reason it does not provide pure sand. The impurities of sand decrease the quality of concrete strength, to determine the silt content of sand by using Ethiopian standard (ES).

Apparatus

-Graduated cylinder

-Clean water

-Sand

Fig. 3.1. Silt content of sand

Procedure

1. Take graduate cylinder 1000ml
2. Pour 300ml of sand to the cylinder
3. Fill approximately $^3/_4$ ofthe cylinder with water
4. Shake the cylinder for about a minute
5. Leave the cylinder for about an hour to allow the silt to settle
6. Measure the amount of fine.

Calculation

Silt content (%) $= {}^{A}/_{B}$ X100

Where A= amount of silt deposit above the sand

B= amount of sand

According to Ethiopian standard, if the silt content of the sand more than 6% it shall not be used for construction.

3.4.2. Sieve Analysis

Sieve analysis helps to determine the particle size distribution of fine and coarse aggregate by dry sieving. Significance and use this test is used to determine the grading of materials that are to be used as aggregates. It ensures that particle size distribution complies with applicable requirements and provides the data necessary to control the material of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

Apparatus

■ Balances or scales with a minimum accuracy of 0.5 g for coarse aggregate or 0.1 g for fine

Aggregate

■ Sieves

Test Procedure

1. Dry the aggregate test sample to a constant weight at a temperature of then cool to room temperature.
2. Select suitable sieve sizes to furnish the information required by the specifications covering the material.

Test specimens

Thoroughly mix the aggregate sample and reduce it to an amount suitable for testing, using a sample splitter or by quartering. The minimum sample size should be as follows.

	Minimum Mass, Kg
Fine aggregate with at least 95% passing 2.36-mm (NO,8)sieve	0.1
Fine aggregate at least 85% passing 4.75-mm (NO,4)sieve	0.5
Coarse aggregate with a nominal maximum size of 9.5 mm (NO,$^{3}/_{8}$)sieve	1
Coarse aggregate of a nominal maximum size of 12.5 mm ($^{1}/_{2}$ $in.$)	2
Coarse aggregate of a nominal maximum size of 19.0 mm($^{3}/_{4}$in.)	5
Coarse aggregate of a nominal maximum size of 25.0 mm (1, in.)	10
Coarse aggregate of a nominal maximum size of 37.5mm (1-$^{1}/_{2}$)	15

Test Procedure

1. Dry the aggregate test sample to a constant weight at a temperature of then cool to room temperature.

2. Select suitable sieve sizes to furnish the information required by the specifications covering the material to be tested. Common sieves are 37.5mm, 20mm, 14.5mm, 10mm, 4.75mm and for fine aggregate 9.5mm, 4.75mm, 2.36mm, 1.18mm, 600μm, 300μm, 150 μm

3. Nest the sieves in order of decreasing size of opening, and place the aggregate sample on the top sieve (Figure 3.3).

4. Agitate the sieves by hand or by mechanical apparatus for a sufficient period. The criterion for sieving time is that, after completion, not more than 1% of the residue on any individual sieve will pass that sieve during 1 minute of continuous hand sieving.

5. Determine the weight of each size increment

6. The total weight of the material after sieving should be compared with the original weight of the sample placed on the sieves. If the amounts differ by more than 0.3%, based on the original dry sample weight, the results should not be used for acceptance purposes.

Fig. 3.3. Sieve set

Test Analysis

ES has given the following limitations of fine aggregates and coarse aggregates to satisfy the Ethiopian Standards.

Table 3 .2.Grading Requirement for fine aggregates according to the Ethiopian Standard.

Sieve Size according to ES	Sieve size according to ASTM	Percentage passing in each sieve
9.5mm	$\frac{3}{8}$inch	100
4.75mm	NO.4	95-100
2.36mm	NO.8	82-100
1.18mm	NO.16	52-85
600 µm	NO.30	25-60
300 µm	NO.50	10-30
150µm	NO.100	2-10

Table 3.3 Grading Requirement for coarse aggregates according to the Ethiopian Standard

Sieve Size according to ES	Sieve size according to ASTM	Percentage passing in each sieve		
		40mm agg.	20mm agg.	10mm agg.
75mm	3 inch	100	100	100
63mm	2 inch	100	100	100
37.5mm	$1\frac{1}{2}$inch	95-100	100	100
19mm	$\frac{3}{4}$inch	30-70	95-100	100
13.2mm	$\frac{1}{2}$inch	-	-	90-100
9.5mm	$\frac{3}{8}$inch	10-35	25-55	40-85
4.75mm	NO 4	0-5	0-10	0-10

3.4.3. Moisture Content Test

The sand and aggregate are dried at constant temperature of 150^0 c for 24 hours .this respective mass was recorded moisture content is then calculated.

$$\text{Moisture Content} = \frac{mass\ of\ aggregate - mass\ of\ dried\ aggregate\ x100}{mass\ of\ dried\ aggregate}$$

3.4.4. Bulk Density of Sand

Sand particles are very small in size and hence very light weight. As a result they are easily held apparent by free moisture on their surface and in their intergranular physical content. The apparent increase in volume of sand due to surface moisture is technically as bulking determining the correct volume of sand use ES .

Apparatus

-graduate cylinder

-sand

-clean water

Procedures

1. Measure 400ml of wet sand and place in the cylinder (A)
2. Fill water approximately $^{3}/_{4}$ ofthe cylinder
3. Shake the cylinder
4. Measure the height of fully saturate sand(B)
5. Calculate the bulk volume

Calculation

$$\text{Bulking (\%)} = \frac{A - Bx100}{B}$$

Where A= volume of partially saturated sand =400ml

B= volume of saturated sand

3.4.5. Slump Test

The slump test is the most widely used method to check the consistency or workability of concrete by using ASTM

Fig.3.4. slump apparatus

Procedure

1. Clean the internal surface of the slump mold**.**
2. Place the mold on the plate and by the legs on the foot pieces to fix it.
3. Fill the mold with the concrete mix we made previously, in three layers (each consists one third of the mold). And we tamped each layer 25 times by the rounded end of the tamping rod.
4. The last layer is leveled then with the upper part of the mold
5. The mold was removed gently then by holding it from the handles and moving it vertically.
6. The mold was placed next to the frustum cone shaped mix, and the slump value was measured then by measuring the difference between the difference in height of the mold and the center of the concrete mix.

Test Analysis

As the name indicates, this test measure the slump in a frustum cone shaped concrete mix, the slump that occurs is classified into Four classifications: According to ASTM: C 143 and B, S: 1882 part II

- Zero slumps: If the slump is equal to zero (Very stiff mixes)
- True Slump: If the slump is between 0 to 12.5 cm.
- Shear slump: If the mix cone sheared into two parts; one half of the cone slides down and inclined plane.
- Collapse: If the slump was between 15 to 21 cm.

Getting a true slump gives a good measure for workability, and the gained value is recorded as a measure for workability with reference to this method only.

3.4.6. Batching

Batching is the process of measuring the ingredients of concrete according to their proportion. The proportion of concrete is expressed in the form of a ratio that incorporates the cement, the fine aggregates and the coarse aggregate. The ration is given as a: b: c .The first letter a represents the cement, b represents the sand and c represents the gravel. The water is expressed by water cement ratio.

In this project all ingredients of concrete was measured in weight by using weight balance as shown in (fig 3.5)

Fig 3.5 weight balance

3.4.7. Mixing

Weight all normal ingredients which are used to make concrete and also the wood ash. Wood ash to cement ratio are 5%, 10%, 15% and 20%.

Mixing of concrete: the first procedure is weight the required C20 ingredients and spread on the plate first 4 part coarse aggregate, then 2 part sand , 1part cement and wood ash. Finally spread the remaining ingredient and mix all ingredients without adding water until too have homogeneous mixture, then the particular amount of water is added and mixed thoroughly for 3 minutes. The prefect mixture is now quickly tested for slump and poured into the molds which are kept ready. Tamping the concrete sample 35 times for each three layers with tamping rod then the top surface is properly leveled before it is kept for hardening.

3.4.8. Placing

Placing is the process of pouring the concrete in the mold.

Figure 3.6 placing concrete mix

3.4.9. Compacting

Compacting is the process of vibrating or tamping the concrete so that maximum density is obtained. By compaction the aggregate will further gate coated by cement paste, and the concrete surrounds the reinforced bars. Even for a very stiff concrete, compaction compels to close all the void spaces, recessed locations, depression and corners of the form work. It helps in giving the desired shape for the concrete.

Compaction of concrete is effected in two ways.

1. **Manual compaction :**

The concrete after placing is compacted by using tamping rods or wooden strips. But this method is not effective because it does not give complete compaction, and at the same time wooden strip may absorb water from the concrete.

2. **Mechanical compaction:**

Mechanically functioning or power driven machines are used to compact the concrete. This machines are effective in providing good compaction because they vibrate the enter volume of concrete.

We compact the mix by using standard tamping rods used for slump test. To fill the 150x150x150 mm mold with three layers we blow 35times per each layer. After that put the Mold carefully without any disturbance, and place in to shade to eliminate early loss of water from concrete mix.

3.4.10. Curing

Curing is the process of applying water to the concrete for the following reasons:

- When water evaporates out, the concrete shrinks down. The shrinkage can be minimized by replacing water for the water evaporating out.
- Cement stops its strength development if it lacks water.
- When water evaporates out of the concrete, cracks will develop.

In order to offset this problem water is constantly applied to the finished concrete work until the concrete has gained its full strength.

Curing of concrete shall not start before the concrete has passed its initial setting properties. If water is applied to the concrete before it has initially set, the water washes the cement away. Therefore it shall not start before ten (10) hours of setting. Normally in Ethiopian practice, concrete is cured after one day (24hours). And it shall continue until the concrete gains its 100% strength.

There are many methods of curing concrete:

1. **Sprinkling:** sprinkling with water are excellent methods of curing when the ambient temperature is well above freezing and the humidity is low.
2. **Ponding:** is an ideal method for preventing loss of moisture from the concrete; it is also effective for maintaining a uniform temperature in the concrete.
3. **Covering:** in this method the concrete is covered by something that keep the temperature of the concrete constant and moist. Cement bags, sacks and other similar materials are usually used to cover the concrete.
4. **Steam curing:** Steam curing is advantageous where early strength gain in concrete is important or where additional heat is required to accomplishes hydration, as in cold weather.

After placing the concrete sample in to the shade then cover the concrete with cement bag for 24 hours until the sample demoulded from the mould. After dismantling from the mould the concrete sample put in to water tanker for until it gets ultimate strength.

3.4.11. Compressive Strength Test

Compressive strength measurements will be made on 150mm cube concrete specimens. The specimens was cast in three layers, each layer was tamping with 35 strokes of the tamping rod spread uniformly over the cross section of the mould. The top of each mould was smoothened and leveled and the outside surfaces cleaned. The moulds and their contents were kept in the curing room at temperature of 27 up to 50C and relative humidity not less than 90% for 24hours. All specimens are de moulded after 24hours and cure in water at 27 up to 50C. The Compressive strength was determined at curing ages 7 and 28 days; using compression machine with maximum capacity of 1500 KN The strength value was taken with one sample specimen.

Slump test was also conduct to check the effect of wood ash on the workability of fresh concrete.

Apparatus:

- Trowels
- Cubical mold (15x15x15) cm^3
- Tamping Rod
- Compressive strength Testing Machine

Fig3.7. Compressive strength Testing Machine

Procedure

1. Use the same concrete mix for which workability is determined.
2. Prepare a cubical mold ($15x15x15cm^{3)}$ and ailed them in order to facilitate easily de moulding of the concrete cubes.
3. Fill the concrete in the cubical mould and tamp with a tamping rod to remove air bubbles
4. Smooth the surface and remove the excess concrete on the cubes mould, and also register mixing date at the top of the concrete.
5. After 24 hrs. Remove the concrete from the mould and cure in water till the required date.
6. Lead the concrete spacemen to failure at7 and 14days of age by using testing machine and record the failure loads.
7. Calculate the stresses at failure by dividing the failure loads by the respective contract areas with the load(the compressive strength).

CHAPTER FOUR

4. Experimental Results and Discussion

4.1. Silt Clay Content of Sand

The test result indicates that the silt content of sand is 12% .according to ES any sand which has more than 6% silt content result it must reject.

(Improvements: The researchers washed the sand to remove the silt content from it the silt content after washing sand, the silt content was 2%)

Fig.4.1. washed sand

4.2. Particle Size

Sieve analysis of the fine and coarse aggregates are given on table 4.1 and 4.2. The grading curve of the ingredients of aggregates are shown on Fig 4.1 and Fig. 4.2

Table 4.1 sieve analysis for fine aggregate

Sieve size	Weight retained (g)	Weight passing (g)	Percentage retained (%)	Percentage pass (%)	Cumulative percentage retain (%)	Lower limit	Upper limit
9.5mm	0	500	0	100	0	100	
4.75mm	40	460	8	92	8	95	100
2.36mm	50	410	10	82	18	80	100
1.18mm	60	350	12	70	30	50	85
600 µm	120	230	24	46	54	25	60
300 µm	140	90	28	18	82	10	30
150 µm	60	30	12	6	94	2	10
<150 µm	30	0	6	0	100	-	-
Total	500	-	100	-	286		

$$\textbf{FM} = \frac{\boldsymbol{comulativepecentageretian}}{\mathbf{100}}$$

$$\frac{\mathbf{286}}{\mathbf{100}} = \mathbf{2.86 \sim 2.9}$$

Fig. 4.2. Sieve analysis for fine aggregate graph

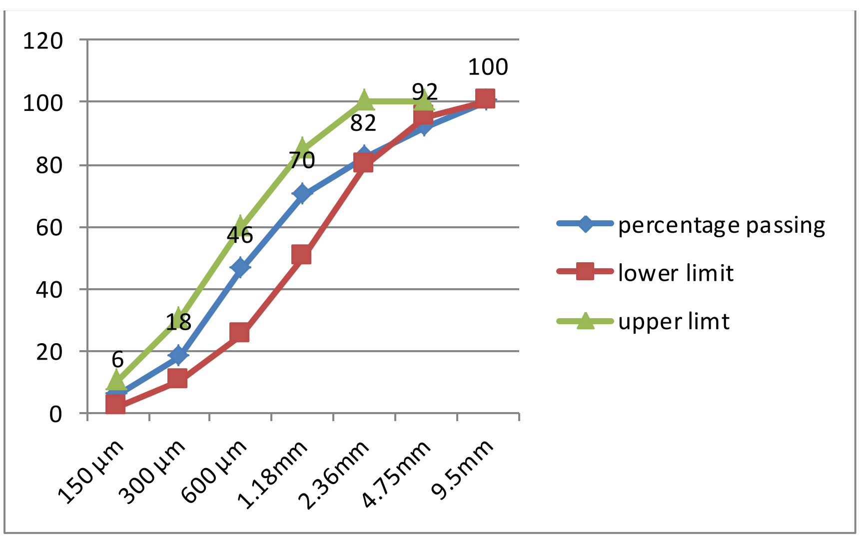


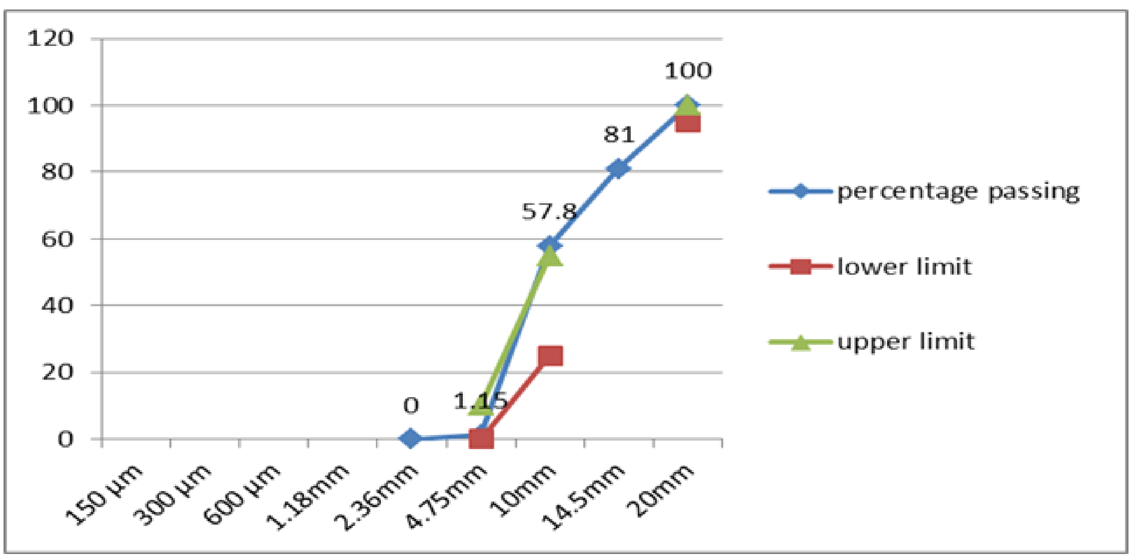
Table 4.2 sieve analysis for coarse aggregate

Sieve size	Weight retained (Kg)	Weight passing (kg)	Percentage retained (%)	Percentage pass (%)	Cumulative percentage retain (%)	Lower limit	Upper limit
20mm	0	4	0	100	0	95	100
14.5mm	0.76	3.24	19	81	19	-	-
10mm	0.928	2.312	23.2	57.8	42.2	25	55
4.5mm	2.266	0.46	56.65	1.15	98.8	0	10
2.36mm	0.046	0	1.15	0	100		
1.18mm	-	-	-	-	100		
600µm	-	-	-	-	100		
300µm	-	-	-	-	100		
150µm	-	-	-	-	100		
Total	4	-	100	-	660.05		

$$\mathbf{FM} = \frac{comulativepecentageretian}{100}$$

$$\frac{660.05}{100} = \mathbf{6.6}$$

Fig. 4.3sieve analysis graph for coarse aggregate



According to the Ethiopian standard, the FM of fine aggregates suitable for concreting works shall be in the range of 2 to 3.5 with a tolerance of ± 0.2, ant that of the coarse aggregates shall be in the range of 6-7.5.

4.3. Moisture Content Test

Table 4.3. Moisture content of the ingredients

NO	Types of ingredients	Moisture content in %
1	Sand	5.06
2	Aggregate	3.4
3	Wood ash	2.1

4.4. Bulk Density of Sand

The bulk Density of available sand used is 11.11%. Therefore, as it is recommended in ES this sand has considered for the intended mix Design.

4.5. Slump Test

Slump test results indicate that the slumps of the concrete containing wood ash have shown an increase in slump and reduce water requirement to mix the concrete.

Table 4.4 slump test result

Test No	Mix design	% of wood ash	Observed slump (cm)	Range
1	1:2:4	0	11	high
2	1:2:4	5	8.5	Medium
3	1:2:4	10	4.5	Low
4	1:2:4	15	10	Medium
5	1:2:4	20	14	High

4.6. Compressive Strength Tests

Due to shortage of time and laboratory material this research couldn't conduct 28th day compressive strength of concrete. The compressive strength of concrete cubes tested at 7and 14 days are presented in table 4.5 and table 4.6 respectively. The table indicates that compressive strength increases especially 10%WA and 15%WA while curing period increase .The control group shows decrease in strength that implies that the sample should have to be three to conduct the average compressive strength of concrete.

As we know the cubes are made from the same cement, and, gravel and water, and that they are molded, compacted and cured on the same day .in spite of all these similarities, the cubes may be differ in strengths because of:

- Speed of the cube to consume the water and hydrate is not the same.
- All the cubes may not get compacted similarly even the same procedure is done.
- The loading conditions during the test may vary.

20% shows good result in the 7 day curing period but it decrease its strength during 14 days curing. With increasing wood ash content the strength will be decrease. 15% of OPC blended with wood has favorable results. Finally as the table indicates 10-15% of wood ash has better strength than the control group. The wood ashes which have 10-15% have contributed cementitious properties to cement concrete.

Table 4.5. 7 Day Compressive Strength Result

No	Mix Design	Dimensions			Weight (gm.)	Volume Cm^3	Failure load(KN) For 7day	Compressive strength(MP) for (7) days	Unit Weight (gm./Cm^3)
		L	W	H					
1	OPC	15	15	15	7800	3375	317.3	14.10	2.31
2	OPC &WA (5%)	15	15	15	7400	3375	287.8	12.79	2.19
3	OPC&WA (10%)	15	15	15	7200	3375	202.3	8.99	2.13
4	OPC&WA (15%)	15	15	15	7500	3375	322.4	14.33	2.22
5	OPC&WA(20%)	15	15	15	7600	3375	352.3	15.66	2.25

Table 4.6. 14 Day Compressive Strength Result

No	Mix Design	Dimensions			Weight (gm.)	Volume	Failure load(KN) For 14day	Compressive strength(MPa) for (14) days	Unit Weight (gm./Cm^3)
		L	W	H					
1	OPC	15	15	15	8010	3375	257.4	11.4	2.37
2	OPC &WA (5%)	15	15	15	7900	3375	241.6	10.74	2.34
3	OPC&WA (10%)	15	15	15	7815	3375	299.9	13.33	2.32
4	OPC&WA (15%)	15	15	15	7900	3375	373.8	16.61	2.34
5	OPC&WA(20%)	15	15	15	7745	3375	262.5	11.67	2.29

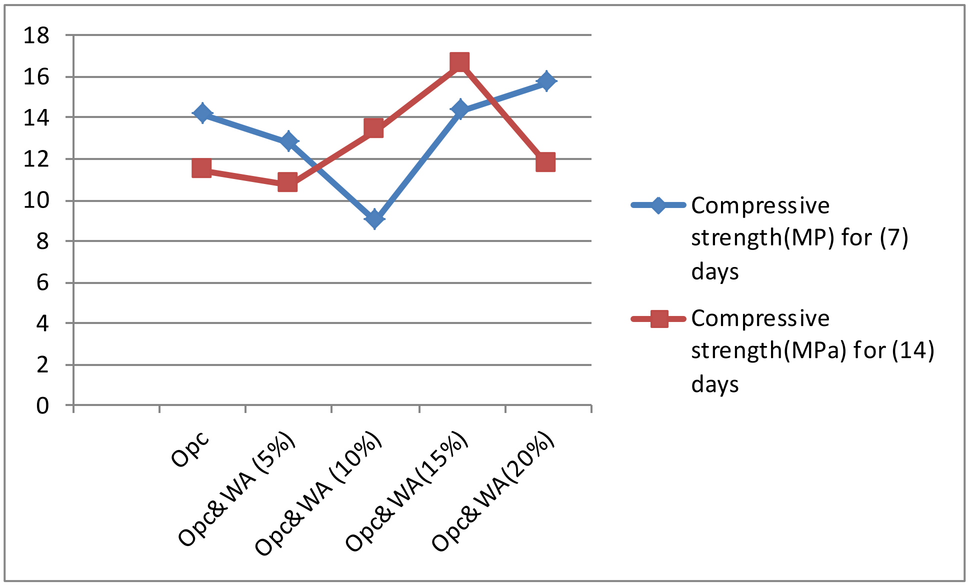


Fig.4.4. compressive strength graph

CHAPTER FIVE

5. Conclusion

From the results of the various tests performed, the following conclusions can be drawn:

Concrete becomes more workable as the wood ash content increases. This means that wood ash concrete has lowered water demand. The more water we add the more workable paste we get but the strength of concrete will be reduced. The solution for this shortcoming is that adding 10-15% of wood ash to cement concrete to get desirable consistency without adding excess water and losing strength as well.

The compressive strength generally increases with curing period and decreases with increasing wood ash content. Wood ash concrete has higher strength than the ordinary Portland cement concrete at early ages. Even if we didn't have adequate time to conduct 28days compressive strength test and more than that of concrete strength, as we see from our result as curing age increase the concrete strength increase and decrease as the wood ash content increase .

10 to 15% wood ash substitution are adequate for use in structural concrete. That means decreasing cost of 10-15% of required amount of cement in the big project. It will lead to a great economy.

For the production of every 600 kg of cement, approximately 400 kg of carbon dioxide gas is released. The increased demand of cement implies a higher rate of environmental deterioration due to the limestone extraction activities, a higher requirement of fossil fuels and higher rate of greenhouse gas discharge. This project also protect environment by reusing the bread bakery by product wood ash thus reducing the amount of cement required in the country. And also by reusing wood ash keeps the society healthy because this landfill material affects the health of society causing the respiratory disease. The other problem is that it pollutes the underground water source.

Reusing this waste material will resolve the listed problems from the society and keeps the balance of nature.

CHAPTER SIX

6. Recommendations and Limitations

It is recommended for further studies that other properties of concrete such as tensile strength, flexural strength and durability characteristics be investigated in order to provide an enlarged database on the performance characteristics of wood ash blended cement concrete.

We also recommend for further studies that concerned body for wood species and also studies should be put in standard specification about different wood type ash chemical composition , physical properties as well its pozolanic properties need further investigation from those who related in this filed especially plant scientist and chemical engineers

Limitations

- ✓ Shortage of time: the time we had after the approval of the proposal until the submission to project report is less than one month.
- ✓ Workshop machine installation: unfortunately or fortunately, the installations of machineries are good for the future project designers but for us due to time consuming operations of machine installation we lack attention as well adequate workshop space to conduct the laboratory test.
- ✓ Un calibrate workshop machine: the workshop machine in Adama since and Technology University is not calibrated for the last 7 years so then. We need to conduct the test to Addis Ababa far from Adama by about 100KM distance.
- ✓ Lack of transportation: To transport the samples to Addis Ababa there was no means of transportation from school. Lack of transportation causes a lot of problem for us because shortage of adequate transportation. It was a must for us to convey our samples by public transport not only the cost but also the loading and unloading of the sample was the major difficulty for our test samples.

- ✓ Chemical analysis: Inadequate to chemical and laboratory equipment in this university makes our project difficult to predetermine the effectiveness of our experiment. Therefore we were forced to do by trial and error

- ✓ Moulds quality: to conduct the compressive strength casting the concrete in 150 x150 x 150 mm^3 mould is must. Inadequate number of mould, inappropriate method to demould the sample and the unclean mould inner part was so difficult to clean and also to remove the sample easily.

7. Reference

[1] S. Wang, A. Miller, E. Llamazos, F. Fonseca, and L. Baxter, "*Biomass Fly Ash In Concrete: Mixture Proportioning And Mechanical Properties***,"** Fuel, vol. 87, pp. 365-371, 2008

[2] S. Wang, and L. Baxter, "*Comprehensive Study Of Biomass Fly Ash In Concrete: Strength, Microscopy, Kinetics And Durability***,"** Fuel Processing Technology, vol. 88, pp. 1165-1170, 2007

[3] European Photovoltaic Industry Association (EPIA), Solar Generation V – 2008: Solar electricity for over one billion people and two million jobs by 2020, EPIA and Greenpeace,Brussels,2008,<www.epia.org/publications/epiapublications.html>

[4]Abebe Damte, S. F. (2012, January). "*Coping with Fuelwood Scarcity***".** Environment for Development, 1-38.

[5]GOBINATH2, S. B. (October 2013). "*Evaluation Of Wood Ash As A Partial Replacement To Cement***".** International Journal of Science, Engineering and Technology Research (IJSETR), 2009-2013**.**

[6] S. Antiohos, K. Maganari, and S. Tsimas, "*Evaluation of blends of high and low calcium fly ashes for use as supplementary cementing materials***,"** Cement & Concrete Composites, vol. 27, pp. 349-356, 2005

[7] Michael S. Mamlouk, and John P. Zaniewski, "*Materials civil And Construction Engineers***",** Prentice Hall , Third Edition,2011

[8] R. Siddique, "*Performance characteristics of high-volume Class F fly ash concrete***,"** Cement and Concrete Research, vol. 34 (3), pp. 487-493, 2004

[9] C. S. Poon, X. C. Qiao, and Z. S. Lin, "*Pozzolanic properties of reject fly ash in blended cement pastes***,"** Cement and Concrete Research, vol. 33, pp. 1857-1865, 2003

[10] N. Bouzoubaa, M. H. Zhang, and V. M. Malhotra, "*Mechanical properties and durability of concrete made with high-volume fly ash blended cements using a coarse fly ash,***"** Cement and Concrete Research, vol. 31 (10), pp. 1393-1402, 2001

[11]M. N. Hague, and O. Kayali, "*Properties of High-Strength Concrete using a Fine Fly Ash***,"** Cement and Concrete Research, vol. 28 (10), pp. 1445-1452, 1998

[12] T. R. Naik, S. S. Singh, and M. Hossain, "*Enhancement in Mechanical Properties of Concrete due to Blended Ash***,"** Cement and Concrete Research, vol. 26 (1), pp. 49-54, 1996

[13] V. N. Dwivedi, N. P. Singh, S. S. Das, and N. B. Singh, "*A new pozzolanic material For cement industry: Bamboo leaf ash***,"** International Journal of Physical Science, vol. 1(3), pp. 106-111, 2006

[14] ASTM C 618-9, "*Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for use as a Mineral Admixture in Portland Cement Concrete***,"** Annual Book of ASTM Standards, Philadelphia, USA, ASTM, 1991

[15] S. Jerath, and N. Hanson, "*Effect of fly ash content and aggregate gradation on the durability of concrete pavement,***"** Journals of Material in Civil Engineering, vol. 19 (5), pp. 367-375, 2007

[16]***Sri P. Venkateswara Rao & M.Vishnukanth. (2006). "****Building Material and Construction*". (pp. 70-80). Andhra Pradesh: State Institute Of Vocational Education**.**

[17] United States Department of Transportation - Federal Highway Administration, Fly Ash Facts for Highway Engineers,<http://www.fhwa.dot.gov/pavement,> 2005.

[18] Tarun R. N., Rudolph N. K., and Rafat S., Use of Wood Ash in Cement-based Materials, A CBU Report, CBU-2003-19 (REP-513), <http://uwm.edu/Dept/CBU/report/>, 2003.

[19] Cheah CB, Ramli M. "*The implementation of wood waste ash as a partial cement replacement material in the production of structural grade concrete and mortar***":** An overview. Resour Conserv Recy (2011), doi:10.1016/j.resconrec.2011.02.002