

Feasibility of Using Bagasse as a Cement Replacement Material



'we strive for wisdom'

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GROUP MEMBERS

ID No

- | | |
|---------------------|-------------|
| 1. Abere Tura | ENGS/003/08 |
| 2. Alemeshet Atnafu | ENGS/006/08 |
| 3. Bereket Worku | ENGS/010/08 |
| 4. Bushu Siyum | ENGS/011/08 |
| 5. Daniel Asrat | ENGS/013/08 |
| 6. Melaku Tadesse | ENGS/036/08 |

ADVISORS:

1. Ins. Biruk Mulu
2. Ins. Desta Moshe

Wolkite Ethiopia

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Declaration

We honestly declare that this report is our original work and all sources of materials used in this report are duly acknowledged. The report contains actual facts and events that we are performing during the research. We are doing this report under the guidance of our adviser Inst. Biruk Mulu and Inst. Desta Mushe

Student

Signature

Advisor

1. Inst. Biruk Mulu

2. Inst. Desta Mushe

Acknowledgement

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Abstract

Sugarcane bagasse ash is a byproduct of the sugar factories found after burning sugarcane bagasse which itself is found after the extraction of all economical sugar from sugarcane. The disposal of this material is already causing environmental problems around the sugar factories. Due to the boost of the construction activity in the country, a huge shortage is created in most of the construction materials especially cement, resulting in steady increase of price. This research was therefore, conducted to examine the potential of bagasse ash as a cement replacing material. Initially, bagasse ash samples were collected from Wonji sugar factory. The bagasse ash was then ground until the particles passing the 63 μm reaches about 85%, which is similar to that of ordinary Portland cement. Ordinary Portland cement and Portland pozzolana cement were replaced by ground bagasse ash. Normal consistency and setting time of the pastes containing ordinary Portland cement and bagasse ash from 5% to 30% replacement were investigated. The compressive strength of mortars containing ordinary Portland cement and Portland pozzolana cement with bagasse ash from 5% to 30% replacements were also investigated. Six different concrete mixes with the bagasse ash replacing 0%, 5%, 10%, 15%, 25% and 30% of the ordinary Portland cement were prepared for 30MPa concrete with water to cement ratio of 0.55 and 350kg/m³ cement content. The properties of these mixes have then been assessed both at the fresh and hardened state. The results of the mortar work have shown that, up to 10% replacement of the ordinary Portland cement by bagasse ash achieved a higher compressive strength at all test ages i.e. 28 days, whereas the 15% replacement of the cement by bagasse ash in the concrete have shown a slightly lower compressive strength. It can therefore be concluded that 10% replacement of cement by bagasse ash results in a similar concrete properties and higher replacement could also be used with a slight reduction in the performance of the concrete.

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CHAPTER ONE

INTRODUCTION

1.1 General

Concrete is the most commonly used construction material in the world. It is basically composed of two components: paste and aggregate. The paste contains cement and water and sometimes other cementitious and chemical admixtures, whereas the aggregate contains sand and gravel or crushed stone. The paste binds the aggregates together. The aggregates are relatively inert filler materials which occupy 70% to 80% of the concrete and can therefore be expected to have influence on its properties [7]. The proportion of these components, the paste and the aggregate is controlled by; the strength and durability of the desired concrete, the workability of the fresh concrete and the cost of the concrete. Cement which is one of the components of concrete plays a great role, but is the most expensive and environmentally unfriendly material. Therefore, requirements for economical and more environmental-friendly cementing materials have extended interest in other cementing materials that can be used as partial replacement of the normal Portland cement. Ground granulated blast furnace slag, fly ash, silica fume, etc. have been used successfully for this purpose. Recently sugarcane bagasse ash, which is a byproduct of sugar factories found after burning sugarcane bagasse which in turn is found after the extraction of all economical sugar from sugarcane, has been tested in some parts of the world for its pozzolanic property and has been found to improve some of the properties of the paste, mortar and concrete like compressive strength and water tightness in certain replacement percentages and fineness [2]. However, nothing has been done to check the feasibility of the bagasse ash produced in Ethiopia for this purpose. The pozzolanic property of sugarcane bagasse ash came from the silicate content of the ash. This silicate under goes a pozzolanic reaction with the hydration products of the cement and results a reduction of the free lime in the concrete [3]. The silicate content in the ash may vary from ash to ash depending on the burning and other properties of the raw materials like the soil on which the sugarcane is grown. Bagasse ash as a cement replacing material. Therefore, this study attempts to make use of the bagasse ash produced in Ethiopia as a pozzolanic material to replace cement. An experimental investigation was carried out to examine the impact of adding bagasse ash to the mechanical and physical properties of pastes, mortars and concretes such as consistency, setting time, workability, compressive and flexural strength and durability.

1.2 Justification for the thesis The production of cement is one of the most environ-

mental unfriendly processes due to the release of CO₂ gases to the atmosphere. It is believed that one ton of Portland cement clinker production creates about one ton of CO₂ and other greenhouse gases [1]. This shows that the cement industry contributes to today's worldwide concern, which is global warming. This endangers the sustainability of the cement industry and that of concrete. In addition to its negative environmental impact cement is also one of the most expensive materials when compared to the other constituents of concrete. The raw materials for the cement production like lime are also being exploited in large amount which may result in running out of them, as it is predicted to happen in some places of the world [1]. The generation of energy by using bagasse as fuel also creates a great deal of waste material known as sugarcane bagasse ash which results in waste disposal problem and environmental pollution which is the case in most sugar factories. The bagasse ash is about 8-10% of the bagasse and contains unburned matter, silica and alumina [2]. Thus this thesis deals with checking the feasibility of the agricultural byproduct bagasse ash which is produced as a waste in Ethiopian sugar factories for using it as cement replacement material.

1.2 Objectives of the research

1.2.1 General objectives

The general objectives of this research work is to study the feasibility of using bagasse as a cement replacement material.

1.2.2 Specific objectives

The specific objectives of this research work can be stated briefly as follows:

- ❖ Evaluating the performance of paste, mortar and concrete
- ❖ Determine the optimum content of bagasse as replacement of cement?

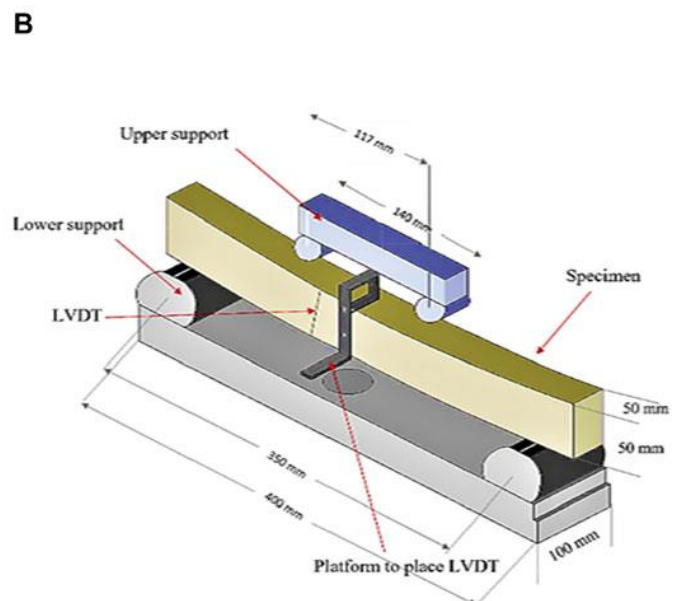
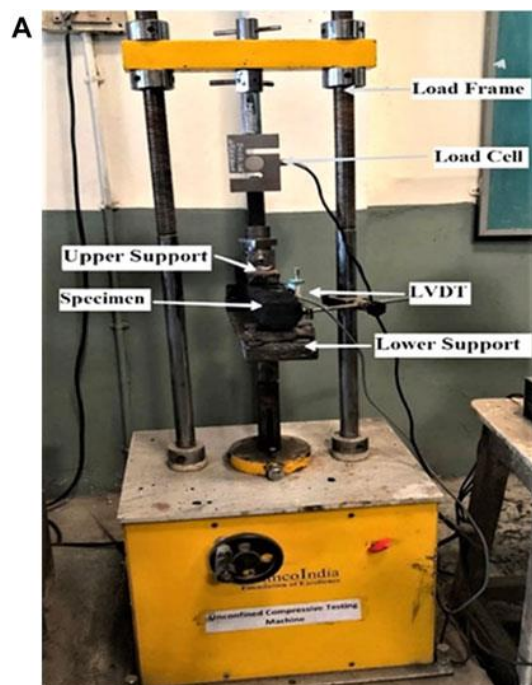
1.3 research question

1. What is the engineering performance of paste, mortar, and concrete?
2. What is the optimum content of bagasse as replacement of cement?

1.4 Research methodology

The following methodology has been employed to achieve the objectives of the research:

1. Literature survey, which includes concrete, cement replacement materials, bagasse ash as cement replacing material, the potential of Ethiopia for bagasse ash and some performance tests on the fresh and hardened concrete. The review includes text books, periodicals and academic journals, seminars, and research papers.
2. Sample preparation at different percentages of bagasse ash replacing cement.
3. Performing different tests on pastes, mortars and concretes at both fresh and hardened state, including determination of fineness for bagasse ash and cement and their blends, normal consistency and setting time, and compressive strength at 7 and 28 days for the mortar and at 7, and 28 days for the concrete including flexural tests at 7 and 28 days on the hardened concrete.
4. Analysis of the test results in which the results were presented in graphical form and interpretation and discussion were made on the research findings.
5. And finally formulation of conclusion and recommendations based on the results obtained.



CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The cement and concrete technology has shown various advancements during the past years. One of the best advancements is the use by-product materials as a cement replacement to all eviate environmental and economic impact of cement production. These cement replacing materials were reported to improve different properties of the mortar and the concrete [2, 12,13, 27].

Bagasse ash is one of these by-product materials found from sugar factories. Recently it has been studied for its feasibility as a cement replacing material in some parts of the world and has been found to improve some of the properties of mortar and concrete. The performance of mortar and concrete is assessed by different tests on both the fresh and hardened concrete. These include workability, strength and permeability. This chapter is, therefore, dedicated in discussing about cement, different performance criteria of concrete, pozzolans and bagasse ash.

2.2 Cement

Cement is a fine grey powder which when reacted with water hardens to form a rigid chemical mineral structure which holds the aggregates together acting as glue and gives concrete its strengths. The credit for its discovery is given to the Romans, who mixed lime(CaCO_3) with volcanic ash, producing a cement mortar which was used during construction of such impressive structures as the Colosseum [19]. Naik T. et al reported that in 2000, the worldwide cement clinker production was approximately 1.6 billion tons. Mixed with water and aggregates, the resulting concrete is second only to water as the most consumed substance on Earth [14]. The consumption of cement correlates to the economic development of a country as a base for new building, factories and infrastructures which are the root of development. As a result of this cement manufacturing has increased sharply in those developing countries.

2.2.1 Types of cement

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

2.2.1.1 Portland cement

Portland cement is one of the most widely used cement and is the most important hydraulic cement. It can also be used for mortar & plaster production. It is used in all types of structural concrete like walls, floors, bridges, tunnels, etc. It is further used in all types of masonry works like foundations, footings, dams, retaining walls, and pavements. When Portland cement is mixed with sand and lime, it serves as mortar for laying brick and stone; and when it is mixed with coarse aggregate and fine aggregate (sand) together with enough water, to ensure a good consistency, we get concrete. The origin of the name "Portland cement" is usually attributed to Joseph Aspdin, a brick mason in England who in 1823 took out a patent for making a powder made from mixed and ground hard limestone and finely divided clay. This forms into slurry and then is calcined in a furnace till the CO_2 was expelled. He called the resulting material Portland cement because when the mortar made with it hardened it produced a material resembling the stone which was quarried near Portland, England [8]. The method of making cement has been improved upon since that time but the basic process has remained the same. Modern Portland cement is made from materials which must contain the proper proportions of lime (CaO), silica (SiO_2), alumina (Al_2O_3), iron (Fe_2O_3) with minor amounts of magnesia and sulfur trioxide. A typical composition of general purpose Ordinary Portland cement is shown in the Table 2.1 below.

Table 2.1 Typical composition of ordinary Portland cement [10]

Chemical name	Chemical formula	Weight percentage
Tricalcium silicate	$3\text{CaO}.\text{SiO}_2$	55
Dicalcium silicate	$2\text{CaO}.\text{SiO}_2$	18
Tricalcium aluminate	$3\text{CaO}.\text{Al}_2\text{O}_3$	10
Tetracalcium Aluminoferrite	$4\text{CaO}.\text{Al}_2\text{O}_3.\text{FeO}_3$	8
Calcium sulfate dehydrate (gypsum)	$\text{CaSO}_4.2\text{H}_2\text{O}$	6

Of these compounds, C_3S and C_3A are mainly responsible for early strength of concrete. High percentages of C_3S (low C_2S) results in high early strength but also high heat generation as the concrete sets. The reverse combination, that is, low C_3S and high C_2S develops strength more slowly and generates less heat. C_3A causes undesirable heat and rapid reacting properties, which can be prevented by adding CaSO_4 to the final product. The most common classification of Portland cement is that of ASTM. It classifies Portland cement mainly into five groups (non-air entrained) differing only on the relative amount of the compounds and the degree of fineness.

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

2.2.1.2 Portland Pozzolana cement

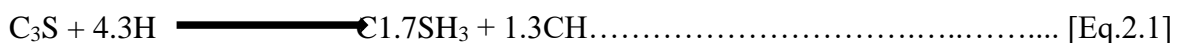
Portland pozzolana cement (PPC) is manufactured by the intergrading of OPC clinker with 15 to 35 % of pozzolanic materials [8]. Pozzolanic materials are siliceous or aluminous materials

which by themselves possess little or no cementitious properties. But in the presence of water they react with calcium hydroxide which is liberated from the hydration of cement to form a compound possessing cementitious property. The reaction of the pozzolanic materials with calcium hydroxide results in many advantages of PPC over OPC. If these pozzolanic materials were not reacted with the calcium hydroxide, free calcium hydroxide would have been present in the concrete resulting in higher permeability of the concrete and susceptibility to other attacks. The pozzolanic reaction reduces the porosity of the concrete by producing cementitious compound. It also reduces the heat of hydration since its reaction is slower than that of OPC, which implies that it has slower rate of strength than OPC, making it suitable for mass concrete construction. In addition to these cement types there are also other types of cement which are produced by either adding other materials to the clinker or by forming other compounds during burning. They are collectively called modified Portland cements. Expansive cement, calcium sulfoaluminate cement, masonry cement, oil well cement, white cement etc. can be an example for this. There are also non-Portland inorganic cements which are used to some extent.

2.2.2 Hydration of cement

When water and Portland cement are mixed, the constituent compounds of the cement and the water undergo a chemical reaction resulting in hardening of the concrete. This chemical reaction of the cement and the water is called hydration, and it results in new compounds called hydration products. Both C_3S and C_2S react with water to produce an amorphous calcium silicate hydrate known as C-S-H gel which is the main „glue“ which binds the sand and coarse aggregate particles together in concrete. Each of the compounds found in the cement react with water, but the rate at which they react is different. C_3S and C_3A are the most reactive compounds, whereas C_2S reacts much more slowly. Approximately half of the C_3S present in typical cement will be hydrated by 3 days and 80% by 28 days, in contrast, the hydration of C_2S does not normally proceed to a significant extent until approximately 14 days [9]. Gypsum is added to lower the rate of hydration of C_3A .

The hydration of C_3S and C_2S are shown in Eq.2.1 and Eq.2.2 [9]:





After a rapid initial reaction C_3S will pass through a dormant stage which has a practical significance because it allows concrete to be placed and compacted before setting and hardening.

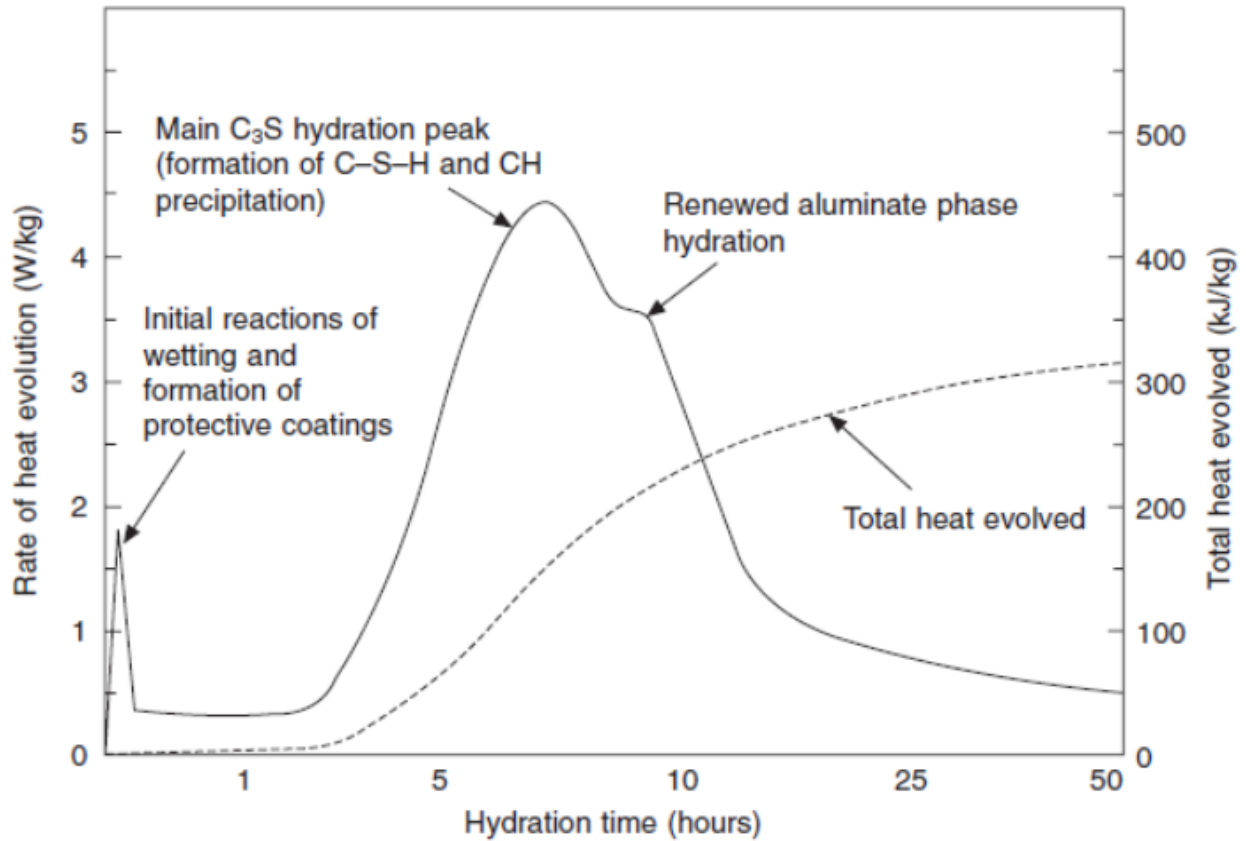


Fig. 2.1 Heat of hydration of a cement paste [7]

The rate and amount of heat of hydration are affected by various factors. Among these cement composition and fineness, water to cement ratio of the concrete, age of the paste and ambient conditions are the most common ones. Varying the cement composition affects the rate of reaction because the different compounds present in the cement have different speed of hydration.

The hydration of Portland cement as a whole is more complex than the individual compounds. This is because the different compounds have different products, reaction rate, and each of the compounds consumes water. When cement is first mixed with water some of the added calcium sulfate, dissolve rapidly. The purpose of adding calcium sulfate is in order to retard the hydration of C_3A , which without calcium sulfate results in flash set due its high rate of reaction with water.

This is because C_3A is more reactive than any of the compounds in the cement and if allowed will take much of the water. The order of reaction is $C_3A > C_3S > C_4AF > C_2S$ [7]. But the rate of hydration of these compounds differs from cement to cement depending on the fineness, the rate of cooling of the clinker and other factors like presence of impurities and other cement compounds.

2.2.3 Physical properties of cement

An understanding of the significance of some of the physical properties is helpful in interpreting results of cement tests. Tests of the physical properties of the cements should be used to evaluate the properties of the cement, rather than the concrete.

2.2.3.1 Fineness

The fineness of cement affects many of its properties. The heat released and the rates of hydration are the main properties which are affected by the fineness of cement. These properties of the cement in turn affect many other properties, like normal consistency, setting time, strength, etc.

Fineness of cement can be measured mainly by specific surface area method and particle size distribution. The specific surface area is the summation of the surface area of all of the particles in 1 gm or 1 kg of cement. Most of the time, it is a general practice to describe fineness by a single parameter, specific surface area [7]. Although it is possible to measure the particle size distribution of cement, there is still no agreement on what would contribute a best grading curve for cement. Due to this and other factors the specific surface area is preferred over the particle size distribution.

The surface area is measured by the Blaine air-permeability test (ASTM C- 204 or AASHTO T-153) that indirectly measures the surface area of the cement particle per unit mass. According to the Ethiopian standard ordinary Portland cement shall have a specific surface area of not less than 2250 cm^2/g [17], whereas the ASTM C- 150 standard recommends a minimum of 2800 cm^2/g .

2.2.3.2 Consistency of cement paste

Many of the properties of concrete are affected by its water content. The physical requirements of cement paste like setting and soundness depends on the water content of the neat cement paste. Therefore, it is necessary to define and study the water content at which to do these tests. This is defined in terms of the normal consistency of the paste which is measured according to ASTM C- 187. The amount of water required to achieve a normal consistency as defined by a penetration of 10 ± 1 mm of the Vicat plunger (ASTM C- 187) is expressed as a percentage by weight of the dry cement, the usual range being about 26% to 33% [17]. The test is very sensitive to the conditions under which it is being carried out, particularly the temperature and the way the cement is compacted into the mold. The test does not correlate to the quality of the cement; it only measures the plasticity of cement paste.

2.2.3.3 Setting time

Setting is a process in which cementitious mixtures of plastic consistency is converted into a set material which has lost its deformability and crumbles under the effect of sufficiently great external force [19]. It is preceded by a stiffening of the paste in which the apparent viscosity of the material increases without losing its plastic character. There are two types of setting time i.e. initial and final setting times. The initial setting time indicates the time at which the paste begins to stiffen considerably and can no longer be molded; while the final setting time indicates the time at which the paste has hardened to the point at which it can sustain some load. Like normal consistency these tests are also used for quality control. Ethiopian standard recommends that the initial setting time for cement not to be less than 45 minutes and the final setting time not to exceed 10 hours [17].

2.2.4 Cement production in Ethiopia

In Ethiopia, the first cement factory was established by Italians in 1936 during the five-year fascist occupation of the Country. This was the Dire dawa cement factory. The cement production has been growing since then and in 2008 there were four cement plants with a combined production capacity of about 2.85 million metric tons per year as reported by Ethiopian investment agency. However, the per capita production as of 2009 as calculated from Table 2.2 is about 33 kilograms which is among the lowest in the world and well below the levels found in china, which is about 800 kilograms and India about 125 kilograms per capita [24].

Table 2.2 Cement production in Ethiopia in 2022 [23]

Cement companies	Production capacity/year	Cement companies	Production capacity
Lemi National cement	54,000,000	Pioneer cement plc	450,000
Dangote cement plc.	2,500,000	Capital milling and packing plc.	300,000
Derba medroc cement plc.	2,300,000	Inchini bedrock cement plc.	300,000
Mugher cement	2,260,000	Ture dire dawa cement plc.	300,000
Messebo cement factory plc.	2,260,000	Zhongeshan cement plc.	250,000
Habesha cement S.C	1,400,000	Dashen cement plc.	90,000
Ethio cement plc.	850,000	Mengistab industrial \$ commercial plc	650,000
Ethio cement plc.	750,000	Feng huang cement plc	435,000

Due to this low supply and rising demand in the country, cement price has been increasing for quite some time. For this research Dangote OPC was purchased for Birr 1850 per 100kg. This high cost of cement makes its affordability under question mark in the country. There is a huge difference between the Ex-factory selling price and the retail selling price. While the Ex-factory selling price for PPC has risen from near Birr 80 in early 2006 to Birr 155 in early 2009, the retail price at selected points in Addis Ababa has risen from around Birr 225 in late 2008 to Birr 350 as of May 20, 2009 [24]. This shows that there is high profit margin on the selling price of cement which is caused by the demand supply gap. The increase in cement price calls for some form of cement replacing materials with a lower price.

2.3 Concrete

Concrete is the most commonly used modern construction materials. It forms the basis of the modern construction system. Many of our activities directly or indirectly are affected by concrete structures; the buildings we live and work in, the roads we drive on, the dams from which we get water and energy, etc. can be an example. The ability of concrete to be cast into any desired shapes and configurations is the reason for its versatility.

The word concrete comes from a Latin word *concretus* which means to grow together [7], which implies that it is a composite of different materials. It is composed of coarse granular material called aggregate or filler which is embedded in a hard matrix of material (cement or binder with water) binding the aggregates together and filling the space formed between them. When the constituents are mixed with water the concrete solidifies and hardens due to a chemical reaction between the water and the cement called hydration, which finally forms a stone like material by binding the aggregates together. Concrete is mainly composed of cement, aggregate and water. Cementitious materials, pozzolanic materials, filler materials, chemical admixtures, and some other additives may also be the constituents of concrete depending on the need and their availability. All the constituents have their own purpose in the concrete. Cement with water acts as a binding medium in which the aggregates which accounts 70% to 80% of the concrete are bound together to form the concrete. Economy, dimensional stability and wear resistance are the main reasons behind using aggregates. Different types of admixtures are used to modify the properties of ordinary concrete so as to make it suitable for any situation. If a concrete is to be suitable for a particular purpose, it is necessary to select the constituent materials and combine them in such a manner as to develop the special qualities required as economical as possible. Therefore, the selection of constituents of concrete depends on the quality and economy of the particular concrete required.

2.3.1 Strength of concrete

Strength of concrete is commonly considered its most valuable property, although in many practical cases other characteristics, such as durability and permeability, may in fact be more important. Nevertheless, strength usually gives an overall picture of the quality of concrete because it is directly related to the structure of the hardened cement paste [10].

The strength of concrete is dependent on many things. The hydration reaction, water to Cement ratio, aggregate type, amount and size, water content, cement content, curing condition, cement type, compaction method used etc. have an effect on the strength of concrete. Strength at any W/C ratio depends on the degree of hydration of the cement and its physical and chemical properties. The decrease in the water content of the concrete results in a higher strength of the concrete. The water required for the hydration reaction is less than that of the mixing water; the extra water provided is used to make the concrete more workable. The compaction of the fresh concrete reduces the amount of entrapped air and therefore increases the strength of the concrete. It is found that for each 1 % of air entrapped there will be a 5 to 6 % loss on strength [17]. Curing temperature affects the hydration of cement and hence the duration of strength gains. Cubes kept at about 10oC will have their 7-day strength reduced by 30% and their 28-day strength by 15% [17]. Different pozzolanic materials have different effect on strength. But most of them including bagasse ash have been found to improve the strength of concrete especially at latter days due to the secondary reaction.

2.3.2 Workability of concrete

Workability is the measure of how easy or difficult it is to place, consolidate and finish concrete. It contains in it different aspects like consistency, flow ability, mobility, compatibility, finishability, and harshness [7]. It can also be defined in terms of the amount of mechanical work, or energy required to produce full compaction of the concrete without segregation. This property of concrete is affected by a number of factors like: water content of the mix, mix proportions, aggregate properties, time, temperature, characteristics of the cement and admixtures. Water content is the most important factor affecting the workability of concrete. Increasing the amount of water will increase the workability of the concrete. However, the increase in water content of the mix will decrease the strength and also result in segregation and bleeding. When considering the effect of aggregate the amount of aggregate, the proportion of coarse and fine aggregate and the

shape and texture of the aggregate particles affect the workability of concrete. Keeping the water content and cement content constant increasing the amount of aggregate reduces the workability of concrete. Spherical and smooth aggregate result in a Bagasse ash as a cement replacing material more workable mix, whereas flat, elongated and rough aggregate particles will result in reduction of workability. The increase in the ambient temperature will reduce the workability of the concrete, due to increase of evaporation and rate of hydration caused by the higher temperature.

The cement content and cement replacing materials also affect the workability. Higher cement content reduces workability. The effect of cement replacing materials depends on their nature. Finer materials result in reduction of workability while spherical materials increase it.

2.3.3 Permeability of concrete

The movement of fluid through a porous medium due to a pressure head difference is called permeability. Thus ability of the concrete to transmit fluids through it caused by pressure head difference is called permeability of concrete. This term applies to both gases and liquids. This property of concrete plays a great role in the durability of the concrete because it controls the entry of moistures which may contain aggressive chemicals and the movement of water during heating and freezing. Durability of concrete refers to the ability of concrete to resist weathering actions, chemical attacks, abrasions or any processes of deteriorations. The w/c (or w/cm) ratio of concrete has major influence on the permeability of concrete. As the w/c ratio decreases the porosity of the paste decrease and the concrete becomes more impermeable. This variation of permeability with w/c ratio is largely due to large capillary porosity rather than gel pores. Most pozzolanic materials were found to decrease the permeability of concrete due to the pozzolanic reaction and their higher fineness. The pozzolanic reaction consumes the free lime in the concrete and the higher fineness of the pozzolan fills pores in the concrete both resulting in a lower permeability. Tests to measure permeability usually fall into three categories [7]. Two of them involve the movement of water through concrete, while the third one involves the movement of electric charge. Here the gas and water permeability are discussed.

2.3.3.1 Water permeability

Among the fluids penetrating concrete water is the most important one. This property of concrete is not a simple function of its porosity, but depends also on the size, distribution, shape and continuity of the pores. According to Neville, although the cement gel has a porosity of 28 percent, its permeability is only about 7×10^{-16} m/s. The reason as explained in Neville is due to the extremely fine texture of hardened cement paste: the pores and the solid particles are very small and numerous, whereas, in rocks, the pores, though fewer in number, are much larger and lead to a higher permeability. Due to this fact the water permeability of granite is about the same as that of mature cement paste with a water/cement ratio of 0.7, i.e. not of high quality [10]. The progress of hydration affects the permeability of concrete. In a fresh paste the size, shape and concentration of the un-hydrated cement particles controls the permeability. As hydration proceeds the permeability decreases rapidly because the gross volume of gel is approximately 2.1 times the volume of un hydrated cement, so that the gel gradually fills some of the original water-filled space [10]. The water/cement ratio of the concrete greatly affects the permeability of concrete. The reduction in the coefficient of permeability is faster the lower the water/cement ratio of the paste. For cement pastes hydrated to the same degree, the permeability is lower the higher the cement content of the paste. Moreover, increasing the wet curing duration of concrete with a very high water/cement ratio from 1 day to 7 days reduces its water permeability by a factor of 5 [10].

In addition to these the permeability of concrete is affected by the properties of the cement used. Coarser cements tend to produce a higher permeability than finer cements. The compound composition of the cement affects the permeability of concrete because it affects the hydration of the cement paste. Two types of water permeability methods are used to measure the penetration of water into concrete. These are the steady state water permeability and the non-steady state water permeability. In the case of steady state, water is allowed to move across the specimen until steady state flow is attained. The penetrated water is recorded when the flow of water becomes steady. The Darcy's law is used to find the coefficient of permeability. Whereas, in the case of non-steady state, the depth of water penetration is measured without the water flow necessarily reaching a constant value.

A succession of water is applied across the specimen as follows [(ISO/DIS/7031), 20]:

- 0.3MPa (3Bar) for the first 24 hours,
- 0.5MPa (5Bar) for the next 24 hours, and
- 0.7MPa (7Bar) for the last 24 hours.

At the end of the 72 hours' period, the specimens will be removed from the rig and split at the center as shown in Figure 2.3. Just after splitting, the maximum and average depths of penetration are visually observed and measured at a desired spacing [21, 20].

2.4 Pozzolans

The modern concrete technology uses different types of admixtures in order to enhance the properties of the fresh and hardened concrete. Mineral admixtures are one of these admixtures used in concrete for a variety of purposes. They may be found naturally or artificially. These admixtures can be divided into three main categories, which are pozzolanic, cementitious and non-reactive materials. The first two categories are added at the mixer as supplementary cementing materials. These admixtures interact chemically with the hydrating

Portland cement and form a modified paste microstructure. The non-reactive admixtures are on the other hand finely divided materials such as lime-stone, silica flour, hydrated lime, etc, which may sometimes react weakly with the cement. They are blended with Portland cement to form masonry cements which have improved workability. In this research we are concerned with pozzolanic admixtures, which are described below.

2.4.1 Pozzolanic materials

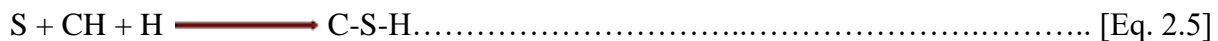
Pozzolanic materials are siliceous or siliceous and aluminous materials which alone possess little or no cementitious value but will, in finely divided form and in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [6]. Their recognition dates back long ago to the ancient Greeks and Romans. The Greeks used volcanic ash and the Romans adopted and extended the Greeks technology using ash from varieties of sources from around their empire. Pozzolanic materials can be divided into two groups: natural pozzolana and artificial pozzolana. Clay and shales, opalinchert, diatomaceous earth, and volcanic ash are an example of natural pozzolans while fly ash, blast

furnace slag, silica fume, rice husk ash, and metakaoline are example of artificial pozzolans. Most of the pozzolans in use today are mainly byproduct materials that are widely available. Because of the diversity of pozzolans their chemical composition also varies. Therefore, classifying pozzolans only depending on their chemical composition would be difficult. The reason behind using pozzolans is the improvement found on both the fresh and hard concrete. Lowering of the heat of hydration and thermal shrinkage, increase in water tightness, reduction in the alkali aggregate reaction, resistance to sulfate attack, better workability, and cost efficiency are some of the improvements achieved by using pozzolans blended with Portland cement.

2.4.2 Pozzolanic reaction

The hydration of tri-calcium silicate and di-calcium silicate with water gives calcium silicate hydrate and calcium hydroxide. The first compound has very low solubility in water while the later one is very much soluble in water and has no cementitious value and is found as a free lime in the concrete, resulting in porosity of the concrete, which in turn results in durability problems. The siliceous and aluminous compounds found in the pozzolan in a finely divided form react with the calcium hydroxide to form highly stable cementitious substances of complex composition involving water, calcium and silica. Finely divided pozzolans and amorphous silicates result a better pozzolanic reaction. The principal reaction taking place is as shown in Eq. 2.5 [7]:

Pozzolan + Calcium Hydroxide + water \longrightarrow Calcium Silicate Hydrate (gel)



This reaction is called pozzolanic reaction. It results in the consumption of the calcium hydroxide produced by the hydration of the cement and as a result lowers its amount in the concrete. The C-S-H formed in this reaction is not very different from that formed in the regular reaction, except the slightly lower ratio of C/S, which is the case for most of the pozzolans. The normal C/S ratio is believed to be around 2 [10].The pozzolanic reaction in Eq. 2.5 and its kinetics are more similar to the slow rate of hydration of C₂S [7]. Thus the addition of pozzolans has similar effect with increasing the amount of C₂S. This results in the reduction of the rate of strength development and the heat of hydration, which makes it advantageous in mass concrete structures.

The progress of hydration of cement can be measured by measuring the amount of Calcium hydroxide in the paste. In a similar manner the extent of pozzolanic reaction can be followed by monitoring the decrease in calcium hydroxide over time. Figure 2.4 shows the relative amount of calcium hydroxide as the hydration time proceeds for different pozzolanic materials.

2.5 Bagasse ash

The use of different cement replacing materials has become a common practice in the construction industry. Most of these cement replacement materials are byproducts of different industries and agricultural wastes. Blast furnace slag, silica fume, fly ash and rice husk can be cited as an example. Sugarcane bagasse ash has also been found to have such pozzolanic property. Bagasse is a cellulose fiber remaining after the extraction of the sugar-bearing juice from sugarcane. Bagasse ash is one of the biomass sources and valuable byproducts in sugar milling that often uses bagasse as a primary fuel source to supply all the needs of energy to move the plants [4]. The bagasse ash is about 8-10% of the bagasse and contains unburned matter, silica and alumina [2]. Bagasse ash has been a problem to the environment due to its disposal. The most significant pollutant emitted from the boilers being a particulate matter, caused by the turbulent movement of combustion gases with respect to the burning bagasse and resulting ash. Sometimes some auxiliary fuels typically fuel or natural gas may be used during startup of the boiler or when the moisture content of the bagasse is too high to support combustion, in such cases the emissions of SO_2 and NO_2 will increase.



Raw Material to Produce Bagasse Ash and Test

2.5.1 Pozzolanic property of bagasse ash

As described in previous sections pozzolans are siliceous or siliceous and aluminous materials which alone possess little or no cementitious value but which will, in finely divided form in the presence of moisture, react chemically with calcium hydroxide at ordinary temperature to form compounds possessing cementitious properties [6]. Bagasse ash was also tested to have such property. It acts as a pozzolanic material when added to cement because of its silica (SiO_2) content which reacts with free lime released during the hydration of the cement and forms additional calcium silicate hydrate (CSH) as a new hydration product [3]. This additional CSH improves the mechanical strength of the cement mortar and concrete.

The silica content of the ash depends on the type of soil and harvesting. It is also found that it depends on the burning temperature of the bagasse. High temperature helps eliminate impurities in bagasse ash as well. In addition to this it was found that the holding time in the furnace has also some effect on the content of the silica. A research conducted on the burning of sugarcane bagasse at 400, 500, 600, 700, and 800°C for 3, 5, 6 and 8 hours respectively, identified the suitable burning and residence time to be 600°C for 5 hours [2]. The higher temperatures will give higher amount of silica content, but the resulting silica is in crystalline form which is not in active state.

2.5.2. Bagasse ash as cement replacing material

These days' sustainability plays the major role in every aspect of human activities. Many technologies came to an end because they were not in harmony with the idea of sustainable development. Sustainability is concerned about the world we will be leaving behind for future generations, that is, to our children and their children. It focuses on the social, environmental and economic issues of human activities. Concrete being one of the most widely used materials worldwide next to water, is not free from some negative environmental impacts. Its popularity carries with it a great cost in terms of environmental aspects. Environmental problems associated with concrete can have varied origins [11]. Worldwide, over ten billion tons of concrete are being produced each year. Such volumes require vast amounts of natural resources for aggregate and cement production. In addition to this it is estimated that one ton of Portland cement production releases about one ton of. Each of the constituents of concrete release a certain amount of CO_2 as shown in the Figure 2.5. Fig.2.5 Carbon dioxide emissions by process step in a cubic yard of

concrete for mixtures with the lowest (20 MPa [3,000 psi] ready mixed concrete) and highest (50 MPa [7,500 psi] precast concrete) levels of embodied energy [12]. 2. The production of Portland cement is also energy intensive.

Aggregate prod's Transport Concrete Plant Percentage (%) Process CO₂ emission by process step in cubic yard of concrete 20MPa[3,000psi] 50MPa[7,500psi]. The demolition and disposal of concrete structures, pavements, etc., constitutes another environmental burden. Construction debris contributes a large fraction of solid waste disposal problem. 4. Finally, the water requirements are enormous and particularly burdensome in those regions of the earth that are not blessed with an abundance of fresh water. The concrete industry uses over 1 trillion gallons of water each year worldwide, and this does not even include wash water and curing water. These points show that concrete industry has become the victim of its own success. However most of the environmental problems associated with concrete come from the cement in it. This means that the final product i.e. concrete is environmental friendly material by itself [1, 11].

This guides us to play on the concrete constituents which cause the problem. One of the constituent which causes the largest environmental impact is Portland cement. Therefore, if we are able to minimize the amount of Portland cement in the concrete we will be able to minimize the environmental impact of the concrete industry as a whole. Many ways were suggested to increase the compliance of the industry to the demand of sustainable development. Increased use of supplementary cementitious materials, increased reliance on recycled materials, improved sustainability and mechanical property and reuse of wash water are some of the methods. The reduction of Portland cement in concrete can be achieved by replacing it with different supplementary cementitious materials which are a byproduct of another industry. Fly ash, silica fume, ground granulated blast furnace slag, and etc have been used for this purpose successfully. Sugarcane bagasse ash as described before contains silica which is the most important component of cement replacing materials. It is also found in large amount as a byproduct in sugar factories. Despite this abundance and silica content, relatively little has been done to examine the potential of this material for concrete production [13]. Even though little, the conducted researches confirm the suitability of this material for concrete production by replacing cement in some percentage. When bagasse ash is used as cement replacing material, it results in some improvement on the properties of concrete. At 90 days, mortar containing ground bagasse ash at 40% replacement

showed compressive strength higher than the control mortar, whereas, those that are ground i.e. the mortar with original ash showed a lower compressive strength than the control mortar [13]. This shows that fineness of bagasse ash is important factor affecting the compressive strength of mortar. Mortar containing finer ash has a higher compressive strength than ash with a higher particle size ash. This same research concludes that mortar containing the original ash had a higher water requirement than mortar containing ground ash, which is due to the large particle size and high porosity of the original ash. Fig. 2.7 Compressive strength of mortar for different percentage of bagasse ash (by mass replacement) [13] Another research [2] conducted indicated that addition of sugarcane bagasse ash retarded the setting time of the mortar. But this retardation, according to the research, was negligible and was within limits specified in ASTM C- 150-03 [2]. The suggested reasons were the adsorption of water at the surface of the ash, the development of film of silica gel around the cement grains, and a mutual coagulation of components with the paste. The strength activity index of the blended mortars was higher than the minimum 75% which is required by ASTM C- 618-03. This same research [2] finds that the filler effect was predominant only up to 15% ash substitution. At the 91 days the 10% and 15% replacement showed a compressive strength of 104% and 102% respectively, while at 20% and 25% replacement 92% and 84% of the control mortar. Fig. 2.8 Compressive strength of blended mortar in comparison with the control mortar (by mass replacement) [2] From the above research outputs we can see that sugarcane bagasse ash can be used as a cement replacing material. When used in proper replacement percentage as given by research for the locally available bagasse ash, it can improve various properties of the mortar or the concrete.

2.5.3 Availability of Bagasse ash in Ethiopia

In order to assess the potential of bagasse ash production in Ethiopia, it is imperative to evaluate the sugarcane crop yield in the country. There were three state owned sugar factories functioning in the country in 2010. Their annual production capacity is about 300,000 tons [15], the sugarcane covering about 10,000 hectares of land. This annual production is not sufficient to satisfy the local sugar demand forcing the government to annually import 1.5 million quintals from abroad [15]. To avoid this shortage of sugar in the country the government plans to establish eight new sugar factories in the coming five years with a total estimated capacity of 2.250 million tons at the start of their production according to the strategic plan and covering about

225,000 hectares [15]. Beside this the government is undertaking expansion projects on the existing factories to increase their production capacity. At the end of this expansion projects on Finchaa, Methara and Wonji and Shoa sugar factories the additional (not including the current production) total aggregate production capacity is expected to be around 365,000 tons of sugar annually [15]. In detail, Finchaa found in the western part of the country planned to increase its production to 270,000 tons; Wonji and Shoa found 100 km east of Addis Ababa plans to increase their production to 350,000 tons; Methara Sugar Factory found 250 kms east of Addis Ababa, is also expected to increase its annual production to 190,000 tons according to the sugar development Study paper. Tendaho sugar factory which will be established with the help of the Indian government is expected to have an annual production capacity of 600,000 tons is expected to be completed at the end of 2011. As can be seen from the above discussion the sugar production in the country is being boosted at a high rate, even planning to hold 2.5 percent of the world sugar market in the coming five years according to the strategic plan. Boosting sugar production will also result in high amount of bagasse and bagasse ash. Table 2.5 below summarizes the expected future sugar production of the country and the respective bagasse ash potential.

Table 2.5 Estimated bagasse ash potential of Ethiopia

Factory	Estimated bagasse (ton/year)	Estimated bagasse ash per year
Wonjii	1,050,000	84,000
Metehara	570,000	45,600
Finchaa	810,000	64,800
Tendaho	1,800,000	144,000
New-8	7,500,000	600,000

The above estimation is based on the targeted annual future sugar production in the country. Sugarcane consists of about 30% bagasse whereas sugar recovered is about 10% of the sugarcane, the bagasse leaves about 8-10% (8% taken for the calculation) bagasse ash as waste [2, 3, 26, and 27]. As can be seen from Table 2.5 about 0.94 million tons of bagasse ash is going to be generated annually when the five-year strategic plan comes into reality. Currently with sugar production of about 300,000 tons annually, the bagasse ash potential is about 72,000 tons' annual.

CHAPTER THREE

MATERIALS USED FOR THE RESEARCH

3.1 Introduction

In this chapter, the materials used for the research are described with respect to their source and relevant physical and chemical properties. All the laboratory investigations on the aggregates, fineness of cement and bagasse ash, pastes, mortars and concretes are carried out in wokite University, civil Engineering department, material laboratory; whereas the chemical properties of the bagasse ash are conducted in Geological survey center of Ethiopia.

3.2 Bagasse ash

The bagasse ash used for this research was taken from Wonji Sugar factory which is located in Oromiya Regional State - North Eastern Ethiopia. The bagasse ash in this factory is collected at each 8-hour interval from the furnace and dumped around the factory very close to the residence of the factory workers. It was not possible to measure the temperature in the furnace while taking the bagasse ash, because the measuring instrument was not long enough to go through the furnace. Even though it was not possible to measure the temperature, most furnaces have a temperature above that is required for complete combustion which is around 800°C [2]. But it was suggested that at a temperature around 650°C the crystallization of minerals occurs [2]. This reduces the pozzolanic activity of the bagasse ash. For this research, fresh bagasse ash taken from the furnace was used. It was cooled in air by applying a small quantity of water, packed in sacks and transported to Addis Ababa.

The ash is then taken to the Geological Survey center of Ethiopia for the complete silicate analysis and other related tests the result of which are given below in Table 3.3. The grinding of the ash was done in Addis Ababa University Geology laboratory using a small mill having a capacity of carrying about 100gm of bagasse ash at a time. By so doing the bagasse ash fineness was reduced to fineness similar to that of Portland cement. The grain size distribution is as shown in the Table 3.1 below:

Table 3.1 Grain size distribution for bagasse ash and OPC cement

Sieve size	% passing (bagasse ash)	% passing (cement)
150µm	100	100
125µm	99.01	100
75µm	89.32	93.0
63µm	86.35	80.2
32µm	39.21	31.2

Table 3.2 Physical properties of cement and bagasse ash

Material	Density (kg/c=m ³)	Average size (µm)
Bagasse	120kg/m ³	40.123
Cement	1970.37kg/m ³	38.745

3.3 Cement

Dangote cements are available at markets. The cements of this factory were purchased from the shops available in Addis Ababa. This cement complies with the requirements of Ethiopian Standards, ES C. D5- 201 and ES C.- 202 [16]. The chemical and physical property of the cement is as shown in Table 3.3 [16]. In addition to Dangote OPC, Dangote PPC cement is used for the mortar work.

3.4 Aggregates

The relevant tests were made to identify the properties of the aggregates which are used for this research. After that, corrective measures were taken in advance before proceeding to the mix proportioning, like blending the aggregates in order to meet the grading requirement, washing the aggregates in order to meet the standard for the silt content. In general, aggregates should be hard and strong, free of undesirable impurities, and chemically stable. Soft, porous rock can limit strength and wear resistance; it may also break down during mixing and adversely affect workability by increasing the amount of fines. Aggregates should also be free from impurities: silt, clay, dirt or organic matter.

3.4.1 Properties of fine aggregate

The fine aggregate used in the concrete productions is natural sand. In order to investigate its properties for the required application different tests were carried out which include: sieve analysis and fineness modules, specific gravity and absorption capacity, moisture content, silt content and unit weight.

3.4.1.1 Silt content

The material in fine aggregates which is finer than $75\mu\text{m}$ is generally regarded as silt. This silt in the sand for the concrete has a severe effect on the quality of the concrete. It mainly affects the workability of the concrete, and also results in the reduction of strength. From the silt content test performed on the sand, it was found that the original silt content was 13%. The Ethiopian standard restricts the silt content to a maximum of 6%. If it exceeds this maximum value, the standard recommends washing or rejecting the sand. Therefore, the sand was washed and its final silt content becomes 5.26%. 3.4.1.2 Sieve Analysis and fineness modules This is a procedure for the determination of the particle size distribution of the aggregate. It is also used to determine the fineness modulus, an index to the fineness, coarseness and uniformity of aggregates. These properties of the aggregate greatly affect the property of the concrete. The original sand sample was too coarse to meet the grading requirement and therefore it was blended with finer sand in a proportion of 70%: 30%. The grading requirement for fine aggregate according to ES C. D3.201 [17] and the grain size distribution of the fine aggregate (both the original and blended) is as shown in Table 3.4 and Figure 3.3.

Table 3.4 Sieve analysis results and standard for fine aggregate

Sieve size	% passing	% passing standard(ES C D3.201	Remark
9.5	100	100	√
4.75	99.9	95-100	√
2.36	86.2	80-100	√
1.18	54.3	50-85	√
600 μm	26.9	25-60	√
300 μm	6.8	10-30	√
150 μm	0.5	2-10	√

3.4.1.3 Specific gravity and absorption capacity

Specific gravity is an expression of the density of an aggregate. It is the ratio between the weight of the substance and that of the same volume of water. Aggregates contain pores in their structure, therefore the specific gravity depends on whether the pores are included in the measurement or not. Apparent specific gravity of an aggregate refers to the solid materials excluding the pores and bulk specific gravity refers to total volume i.e. including pores of the aggregate. The following results are found for the fine aggregate: Bulk specific gravity = 2.309 Bulk specific gravity (SSD basis) = 2.431 Apparent specific gravity = 2.566 Absorption capacity = 4.50%

3.4.1.4 Moisture content

The water to cement ratio of a concrete affects the strength and the workability of the concrete. The increase of the water to cement ratio results in a decrease of the strength of the concrete and an increase of workability. The aggregates in concrete are assumed to be inert materials. But most of the aggregates don't meet this assumption by either absorbing water (dry aggregates) or by releasing it (wet aggregates) to the mix. As a result of this property of aggregates the design water to cement ratio of the mix changes. Therefore, it is important to determine both the absorption capacity and the moisture content of the aggregate. The moisture content of fine aggregates was determined by oven drying a sample of fine aggregate (500gm) in an oven at a temperature of 110 °C for 24 hrs. and dividing the weight difference by the oven dry weight. The moisture content of fine and coarse aggregate is 3.39 % and 1.70% respectively.

3.4.1.5 Unit weight

Unit weight can be defined as the weight of a given volume of graded aggregate. It is thus a density measurement and is also known as bulk density. But this alternative term is similar to bulk specific gravity, which is quite a different quantity, and perhaps is not a good choice. The unit weight effectively measures the volume that the graded aggregate will occupy in concrete and includes both the solid aggregate particles and the voids between them. The unit weight is simply measured by filling a container of known volume and weighing it.

Clearly, however, the degree of compaction will change the amount of void space, and hence the value of the unit weight. Since the weight of the aggregate is dependent on the moisture content of the aggregate, constant moisture content is required. The unit weight of the fine and coarse aggregate sample used was found to be 1.429 g/cm^3 and 1.325 g/cm^3 respectively. The above test results are summarized in Table 3.5 below:

Properties of the coarse aggregate The coarse aggregates used for this research were crushed rock. Because the aggregates have been stored in the laboratory for a while, visual examination reveals that there is a dust film on their surface and therefore, the aggregates were washed thoroughly and dried in open air outside the laboratory. A maximum aggregate size of 19 mm was used in all the concrete work. After washing and drying, the coarse aggregates were sieved and stored. This has minimized segregation and thus variation in gradation from mix to mix.

3.5 Water

In this research, tap water supplied by Addis Ababa Water and Sewerage Authority found in the laboratory was used in all mixes.

CHAPTER FOUR

TEST RESULTS AND DISCUSSION

4.1 Introduction

In this section discussion and analysis of laboratory test results of bagasse ash for its suitability as cement replacing material are presented and analyzed. The different properties of the bagasse ash investigated are: the fineness in terms of specific surface area for different replacement of cement with bagasse ash, the consistency and setting time of the blended pastes at different replacement contents, strength of mortars containing bagasse ash which replaced ordinary Portland cement and Portland pozzolana cement, the workability, strength (both compressive and flexural) and permeability of concrete containing bagasse ash at different replacements

4.2 Test results and discussions on Experiment- I

In this part the test results on the different properties of bagasse ash and the blended pastes are discussed and analyzed.

4.2.1 Physical of Bagasse Ash

As shown in Table 3.5 bagasse has low density (2.16g/cm^3) as compared to OPC. Particle size analysis of ash samples indicated that average size of the ash particles was $40.5\mu\text{m}$ and 90% of the particles were of size less than $76\mu\text{m}$, whereas cement have an average fineness of $43.4\mu\text{m}$ which is greater than the ash and 90% of the particles were less than $72\mu\text{m}$ which is less than the ash. This shows that the bagasse ash is coarser than the cement for higher sieve sizes and the opposite for lower sieve sizes. This is also shown in the grain size distribution of the bagasse and the cement in Figure 3.2. This figure shows that the bagasse is finer than the cement for sieve size less than $63.2\mu\text{m}$ (where the two graphs meet) and the cement is finer for sieve sizes greater than this size, showing that the bagasse contains some particle coarser than cement but on average it is finer than cement.

Table 5.1 Fineness of bagasse ash and cement

Sieve size	% passing (bagasse)	% passing (cement)
0.015mm	100	100
0.125mm	98.5	100
75µm	89.7	92
63µm	84.5	80.5
32µm	36.23	33

From the results it can be seen that the blain air of the bagasse ash is higher than that of cement, and all the blended powders show a higher fineness than cement which is due to the lower density of the bagasse ash. Ajay Goyal et al [2] has reported that large surface area favors the pozzolanic reactivity of amorphous silica and other minerals.

4.2.3 Setting time of blended pastes

The Ethiopian standard limits the initial setting time of cement not to be less than 45 minutes and the final setting time not to exceed 10hrs. The results for the setting time in Table 5.3 indicated that addition of bagasse ash retarded the setting; however, this retardation was within limits as specified by the Ethiopian standard. As the bagasse ash content increases the setting time has also showed a trend of increment, even though there are some exceptions. Other researchers had also conformed to the increase in setting time of OPC-BA blended pastes. According to (2) the probable reason for the increase in setting time could be the adsorption of water on the bagasse ash surface [2]. The higher the proportion of the bagasse ash, the higher was the adsorption of water increasing the normal consistency which in turn retarded the setting time.

PRODUCT FROM BAGASSE ASH, used for partition wall very well



Table 4.3 Setting time of pastes containing bagasse ash

<i>%age</i>	<i>Setting time (initial)</i>	<i>Setting time (final)</i>
0	137 minute	263 minute
5	181 minute	291 minute
10	199 minute	309 minute
15	200 minute	321 minute
20	205 minute	324 minute
25	215 minute	325 minute
30	236 minute	328 minute

4.2.4 Compressive strength of OPC-BA and PPC-BA mortars

The compressive strength of mortar for both Dangote OPC and Dangote PPC were tested and analyzed. The average results for both OPC-BA and PPC-BA mortars are as shown in Table 5.5 and Table 5.3 respectively: Table 5.4 Compressive strength of OPC-BA mortar.

Table 4.4 Compressive strength of PPC-BA mortar

%age	7day		28day	
	Load (KN)	Strength (N/mm ²)	Load (KN)	Strength (N/mm ²)
0	83.00	31.293	126.12	51.87
5	85.15	34.00	133.58	54.85
10	86.10	34.96	127.77	56.33
15	84.21	34.51	125.90	54.57
20	63.00	29.86	123.59	52.57
25	63.91	28.92	117.32	49.49
30	64.02	26.71	113.13	46.71

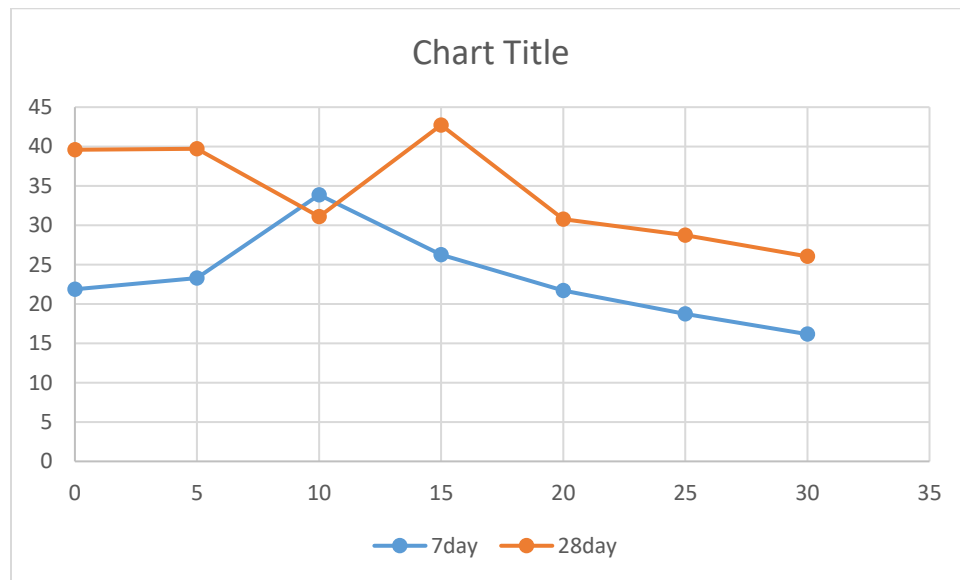
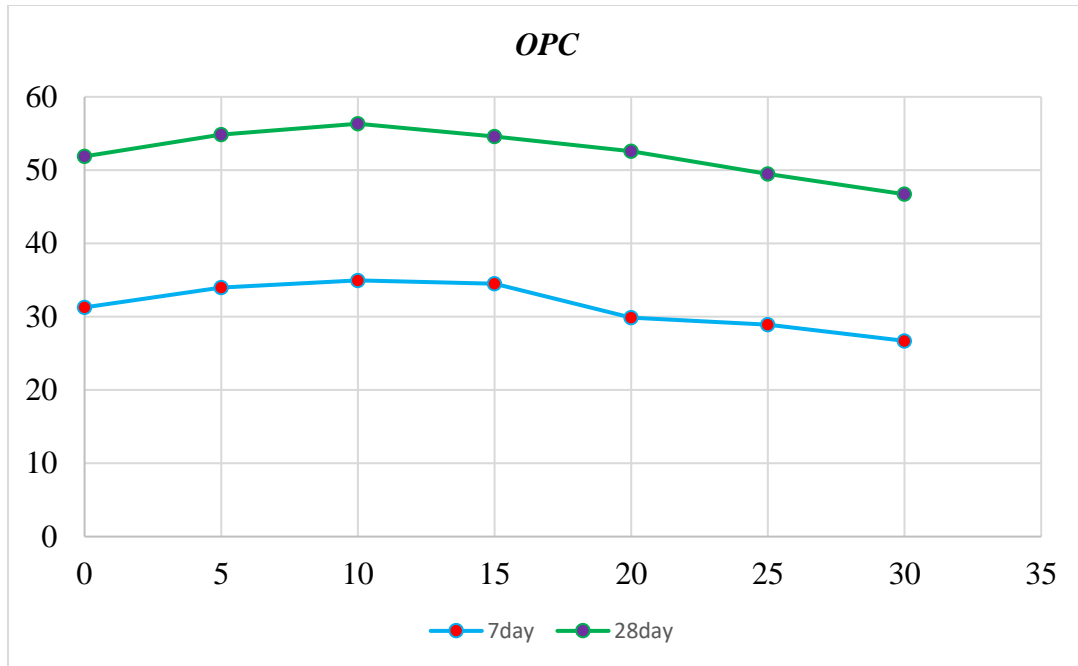
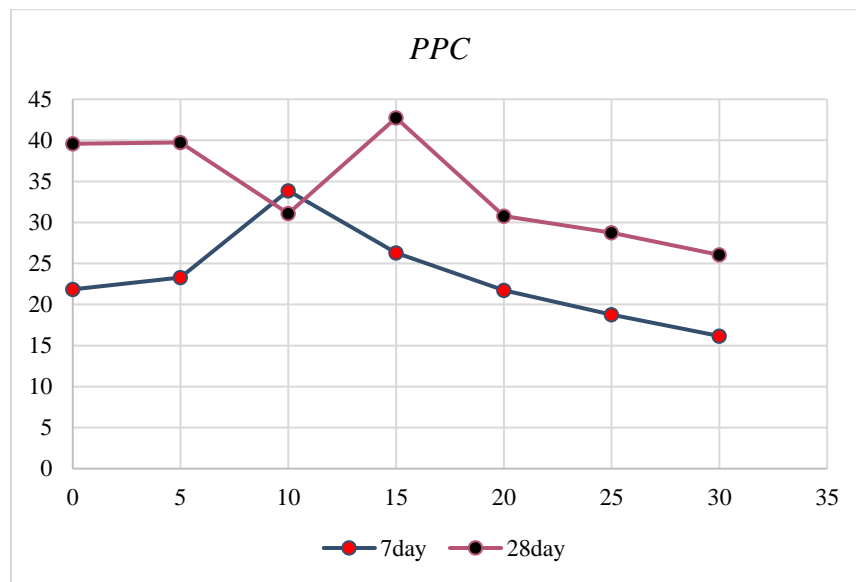


Fig.5.1 Compressive strength of OPC-BA mortar

Table 4.5 Compressive strength of PPC-BA mortar

%age	7day		28day	
	Load (KN)	Strength (N/mm ²)	Load (KN)	Strength (N/mm ²)
0	61.28	21.85	101.00	39.57
5	64.71	23.29	99.89	39.73
10	55.89	33.86	97.41	31.09
15	56.23	26.27	97.96	42.73
20	45.91	21.71	94.21	30.76
25	43.80	18.75	92.97	28.73
30	39.76	16.16	91.70	26.04



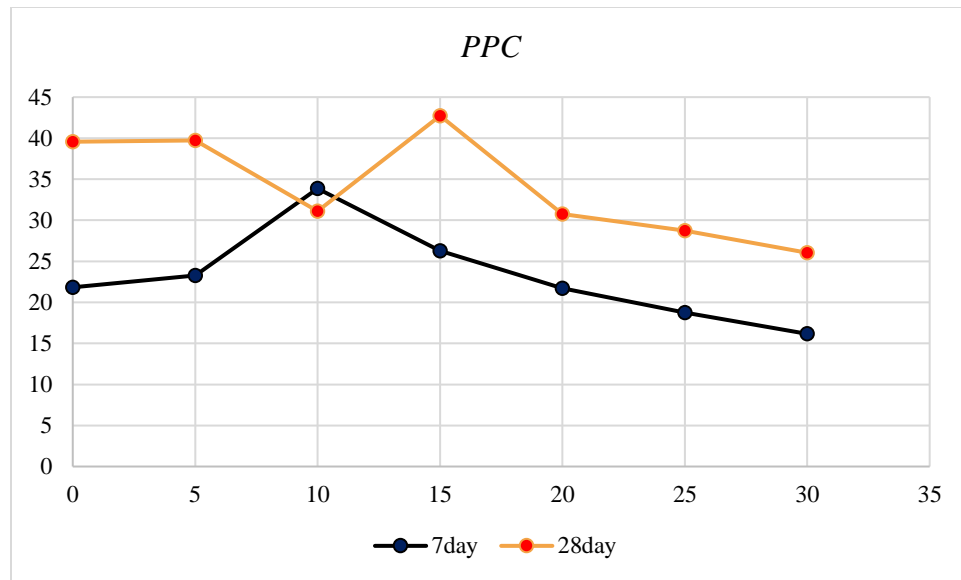


Fig. 4.2 Compressive strength of PPC-BA mortar

As shown in the tables above mortar specimens were prepared for both OPC and PPC blended with BA. This is done in order to investigate how the bagasse ash acts in the two cement types. As shown in Table 4.2, the bagasse ash at 10% replacement with OPC and PPC have shown a higher compressive strength value than the control throughout the tests period i.e. 7 and 28 days. Table 4.3 shows that the mortar work with the bagasse ash at 10% replacement with have PPC higher compressive strength than the control. However, the compressive strength of the mortar with bagasse ash and PPC had shown a reduction when we apply greater replacement of 10%.

4.2.5 Slump test

In order to assess the workability of the fresh concrete the slump test was conducted. A concrete mix should be workable enough in order to be placed, compacted and finished. The ingredients in concrete should be in such a proportion as to allow a good workability of the concrete and sufficient strength to support the required load after hardening. The trial mix for the 10% replacement with bagasse concrete gave a slump of 33mm, which is between the targeted slump i.e. 30-60mm, which is in the required range. Table 5.5 below gives the slump for all OPC BA concrete mixes:

Table 4.6 Slump test results

%	Observed slump (mm)
0	36
5	35
10	33
15	31



As can be seen from Table 4.6 the slumps of the concrete containing bagasse ash have shown a slight reduction as the bagasse ash content increases. In order to get a certain slump, OPC-BA blended concretes needs a higher water content than a concrete with no bagasse ash. The probable reason for this may be the higher specific surface area of the bagasse ash and its lower density giving it a higher porosity, resulting in higher water demand. To get similar slump for the control and OPC-BA concrete, the water content can be increased as the bagasse ash content increases.

4.2.6 Unit weight

The weights and the dimension of the concrete cubes for this research are measured just before testing them for the compressive strength. These tests were conducted at 7 and 28.

The results for the weight and dimension are given in the appendix. In this section the unit weights of the concrete are calculated by using the 28 days' weight and dimension and the results are as shown in Table 4.7.

Table 4.7 Unit weights of control and blended concretes

<i>%</i>	<i>Unit weight</i>
0	2353 Kg/m ³
5	2339 Kg/m ³
10	2331 Kg/m ³
15	2329 Kg/m ³
20	2319 Kg/m ³

Even though it is small, the concretes with the bagasse ash have shown a reduction in unit weight. A low density concrete is beneficial in many ways over a high density concrete. Using a lighter concrete, reduces the size of structural members and also reduces the pressure on form-works.

4.2.5.1 Results and discussions on compressive

The compressive strength test of concrete is the most common test type for the hardened concrete. The reasons for these are; many codes and design manuals are based on this property, many other properties of concrete depend on the compressive strength and when compared to

other tests this is an easy one. The compressive strength of each of the concrete is determined by testing the cubes in a compression machine. For each of the mixes the average value of three samples is taken as their compressive strength. At 10% replacement of bagasse on OPC cement, the compressive strength has greater value at 7 and 28 days which is 34.96 and 56.33N/mm². And the compressive strength of 10% replacement on PPC has also higher value of compressive strength at 7 days which is 33.86N/mm², but the compressive strength of the mix with 15% replacement on PPC after 28day has greater value which is 42.73N mm².

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

The Conclusions and Recommendations that could be drawn from the results of this research and experiments are summarized as follows:

5.1 Conclusions

The use of bagasse ash as a cement replacing material in concrete production was studied and after the research work is done, the following conclusions were made: Higher replacements of cement by bagasse ash resulted in higher normal consistency (implying higher water demand for certain workability) and longer setting time. The workability of mortar and concrete containing bagasse ash decreases slightly as the bagasse ash content increases which is due to the higher water demand of bagasse ash. The investigation of this research has revealed that replacement of ordinary Portland cement by bagasse ash from up to 10% results in a better compressive strength than that of the control mortar with 100% ordinary Portland cement. And the compressive strength decreases as the bagasse ash replacement increases over 10%. The compressive strength results of the concrete have revealed that the concrete with 5% cement replacement by bagasse ash have shown a 5% compressive strength improvement at 28 days over the control concrete with 100% ordinary Portland cement. The 15% and 25% replacements have shown 3.4% and 12.6% reduction at 28 days of the control concrete. Therefore, up to 10% we can say that there is no strength reduction, which is also shown in the mortar work. Since bagasse ash is a by-product material, its use as a cement replacing material reduces the levels of CO₂ emission by the cement industry and also saves a great deal of virgin materials. In addition, its use resolves the disposal problems associated with it in the sugar industries. Finally, the results of this research work have revealed that cement could advantageously be replaced with bagasse ash up to 10%. This replacement results in similar concrete properties to that of the control concrete. Higher replacement percentages can also be used with a slight reduction in the performance of the concrete. In Ethiopia, even though the construction industry is booming these days, it is still in its infant stage and needs much more effort to be made on the different construction materials. The awareness about the different cement replacing materials and their advantages is negligible, implying more work to be done on the area.

5.2 RECOMMENDATION

Therefore, based on the findings of this research, the following recommendations are forwarded: Sugarcane bagasse ash as investigated in this research work can be used as a cement replacing material with economical, technical and environmental benefits. Therefore, concerned bodies like sugar industries, cement industries and government entities should be made aware about this potential cement replacing material and promote its standardized production and usage. The sugar and cement factories in collaboration with higher education organizations in the country should work together and establish a research team to further study the use of bagasse ash as a cement replacing material.