AN EXPERIMENTAL STUDY OF CONCRETE PROPERTIES BY USING BY PRODUCT OF REPI WASTE TO ENERGY PLANT AS SUPPLEMENTARY CEMENTING MATERIAL

MSc. THESIS

HIWOT ASEGID MULUGETA

HAWASSA UNIVERSITY, HAWASSA, ETHIOPIA

March 2020

AN EXPERIMENTAL STUDY OF CONCRETE PROPERTIES BY USING BYPRODUCT OF REPI WASTE TO ENERGY PLANT AS SUPPLEMENTARY CEMENTING MATERIAL

HIWOT ASEGID

A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING FOR THE PARTIAL FULFILLMENT OF THE REQUIREMENTS ON THE DEGREE OF MASTER OF SCIENCE IN STRUCTURAL ENGINEERING

SCHOOL OF GRADUATE STUDIES

HAWASSA UNIVERSITY

HAWASSA, ETHIOPIA

REQUIREMENTS FOR THE

DEGREE OF

MASTER OF SCIENCE IN STRUCTURAL ENGINEERING

March 2020

HAWASSA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CIVIL ENGINEERING

DECLARATION SHEET

I hereby declare that this MSc Thesis “An experimental study of concrete properties by using byproduct of Repi waste to energy plant as supplementary cementing material” is my original work and has not been presented for a degree in any other university, and all sources of material used for this work are clearly acknowledged.

Name: Hiwot Asegid

Signature: ___________________

Place: Hawassa University

Date of submission: ____________________

HAWASSA UNIVERSITY

SCHOOLS OF GRADUATE STUDIES

ADVISORS' APPROVAL SHEET

THIS IS TO CERTIFY THAT THE THESIS ENTITLED "An experimental study of concrete properties by using byproduct of Repi waste to energy plant as supplementary cementing material" submitted in Partial Fulfillment of the Requirements for the Degree of **Master's of Science** with specialization In **Structural Engineering**, the Graduate Program of the **Department of Civil Engineering,** has been carried out by Menale Alaye ID. No PGSTRU /008/10, under our supervision. Therefore, we recommend that the student has fulfilled the requirements and hereby can submit the thesis to the department.

TEMESEGEN WONDIMU (PHD)	____________	____________
Name of major advisor	Signature	Date
____________	____________	____________
Name of co-advisor	Signature	Date

HAWASSA UNIVERSITY

SCHOOLS OF GRADUATE STUDIES

EXAMINERS' APPROVAL SHEET

As members of the Board of examiners of the final Master's degree open defense, we certify that we have read and evaluated the thesis prepared by Hiwot Asegid under the title "An experimental study of concrete properties by using byproduct of Repi waste to energy plant as supplementary cementing material" and examined the candidate. This is therefore, to certify that the thesis has been accepted in partial fulfillment of the requirement for the degree of **Masters of Science in Structural Engineering.**

________________	______________	____________
Name of Chair Person	Signature	Date
________________	______________	____________
Name of Major Advisor	Signature	Date
________________	______________	____________
Name of Internal Examiner	Signature	Date
________________	Binaya Patnaik	____________
Name of External Examiner	Signature	Date
________________	______________	____________
Name of Co-Advisor	Signature	Date
________________	______________	____________
SGC Approval	Signature	Date

Final approval and acceptance of the thesis is contingent upon the submission of the final copy of the thesis to the school of Graduate Studies (SGS) through the Department/School Graduate Committee (DGC/SGC) of the candidate's department.

Stamp of SGS

Date: ___________________

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to my advisor Dr. Temesgen Wondimu for his guidance and constructive comments.

Further, I would like to thank National cement share company Dire dawa branch, Mafcon engineering,, AASTU laboratory staff members for their support throughout the thesis work.

Finally my deep and respectful thanks go to my lovely family and friends for their unlimited support.

CONTENTS

LIST OF ABBREVIATIONS

ACI	American concrete Institute
ASTM	American Society for Testing and Materials International
FA	fly Ash
HSC	high strength concrete
NSC	normal strength concrete
OPC	Ordinary Portland cement
W/C	Water to Cement Ratio

LIST OF TABLES

LIST OF FIGURES

LIST OF TABLES IN APPENDICES

LIST OF FIGURES IN APPENDICES

ABSTRACT

Repi waste to energy plant, is power plant that consumes 80% of Addis Ababa's city's waste producing, 28 tones fly ash per day. However the disposal of the fly ash is becoming another challenge. To this end its use in concrete is proposed. Concrete containing this fly ash in construction is vital task due mainly to structural and economic advantages that fly ash concrete offers over conventional concrete.

This thesis presents the results of an extensive experimental test which was carried out to study the influence of Repi waste to energy plants fly ash on the compressive strength, flexural strength tensile strength, shrinkage of concrete, Sulphuric acid attack and water absorption of the concrete. Parameters involved were 0%, 10%, 20% and 30% of fly ash replacement level with high strength and normal strength concretes.

Test results indicate that for normal strength concrete 15% and for high strength concrete 10% cement replacement by fly ash has good compressive strength, flexural strength tensile strength. As fly ash percentage increases shrinkage of concrete decreases for both normal strength and high strength concretes. Water absorption decreases as fly ash percentage increases for normal strength and for high strength concrete water absorption decreases up to 20% fly ash. Acid resistance tested by weight loss and compressive strength, decreases as fly ash percentage increases.

Key words; concrete, supplementary cementing materials, Repi waste to energy plant, concrete properties, Shrinkage of concrete

CHAPTER 1: INTRODUCTION

1.1- Back ground

Concrete is the most widely used construction material worldwide. With a yearly consumption of more than 25 billion tons, is the most used construction material in the world. In the past decades, great efforts have been made to develop a new generation of concrete to improve its performance and competitiveness as a construction material. Consequently, concrete with high performance and high durability has been developed and is used much frequently to construct civil infrastructures and contributing to the popularity of concrete as construction material is the ready availability of its most basic constituents, namely, Portland cement, aggregate, water and admixtures. (Oliveira et al., 2014)

Concrete as the most common building material of our time is responsible for about 6% of total anthropogenic because the Ordinary Portland Cement (OPC) is one of the main ingredients used for the production of concrete and has no alternative in the civil construction industry. Unfortunately, production of cement involves emission of large amounts of carbon-dioxide gas into the atmosphere, a major contributor for greenhouse effect and the global warming, hence it is inevitable either to search for another material or partly replace it by some other material. The search for any such material, and one of the materials which can be used as an alternative or as a supplementary for cement should lead to global sustainable development and lowest possible environmental impact. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement is fly ash. (Rezvani et al., 2014)

Repi waste to energy plant, is power plant that consumes 80% Addis Ababa's city's waste, covering a third of household electricity consumption in Addis Ababa, according to information released during its inauguration and it is the first of its kind in the Africa, has been completed and had inaugurated on August 18, 2018.

Fly ash from power plants consists of a very fine material which mixes with flue gases and escapes the combustion chamber. And it consists of heterogeneous combinations of amorphous (glassy) and crystalline phases. (Sennour et al., 1989)

This paper presents: effect of cement replacement by fly ash from Repi waste to energy plant by 10%, 20% and 30% on mechanical properties of concrete, shrinkage, durability of concrete water absorption and acid attack tests conducted on normal strength concrete and high strength concrete produced by using.

1.2- Statement of problem

Urbanization in Africa leads to more waste and greater demand for electricity. In Ethiopia's capital, Addis Ababa, a waste-to-energy plant is set to tackle both problems at the same time, by helping to dispose of three-quarters of the city's rubbish while generating enough electricity to power one third of the city. However the disposal of the fly ash is becoming another challenge.

Thus to use this by product in concrete is the vital task but its proportion as supplementary cementing material is not known.

One of main problems in concrete is due to drying & chemical shrinkage, cracking& external deflection happens before the concrete subjected to loading. In which the cracks let in water and different chemicals leading to the corrosion of reinforcing steel and deterioration of the concrete.

1.3- Objective

1.3.1- General objective

- The purpose of this research is to produce concrete by using cement, sand, coarse aggregate and by product of Repi waste power plant, to demonstrate how this material is advantageous studying effect of Repi waste to power fly ash effect on the strength, resistivity, crack by studying effect on shrinkage and the rate of corrosion by experimental test on acid attack and water absorption.
- According to literatures adding CaO itself is giving the improvement of strength compared to basic cement without any additives at all but other chemicals with in the fly ash gives different properties and this study aimed to know different properties of concretes made of cement replaced by Repi waste power plant's fly ash volume in different percent which will have structural effect.
- All human activity results in some degree of environmental degradation .Repi waste to energy plant works to minimize this degradation by using waste for energy but here the problem again is fly ash from this plant dumping to the city. This research provide important role for disposal of fly ash from Repi waste to energy plant.
- The data collected from this study is not only to show the significant advantages of these materials provide, but also to compare their characteristics in the development of the concrete.

1.3.2- Specific objective

- Assessment on by what percent this byproduct of Repi waste power plant can be used replacing cement in normal strength and high strength concretes.

- To study effect of using byproduct of Repi waste power plant as supplementary cementing material on compression strength of concrete for normal strength and high strength concretes.
- To study structural effect on shrinkage properties, water absorption, acid attack and mechanical properties of concrete (i.e., compressive strength, flexural strength and tensile strength) of concrete by using byproduct of Repi waste power plant as supplementary cementing material.
- To draw conclusions and give recommendations based on the research findings and give solution for problem related with disposal of fly ash of Repi waste to energy plant.

CHAPTER 2: LITERATURE REVIEW

This research aims to study the structural effects of Repi waste to energy plant fly ash on plain concrete by partial replacement of cement with 0%, 10%, 20% and 30% of fly ash. Various research works have already been conducted to study the effect of fly ash on various properties of concrete at different ages and for different grades of concrete. Here some research works were reviewed and are presented in this paper.

2.1- Concrete

Concrete is the most widely used construction material worldwide. With a yearly consumption of more than 25 billion tons, is the most used construction material in the world. In the past decades, great efforts have been made to develop a new generation of concrete to improve its performance and competitiveness as a construction material. Consequently, concrete with high performance and high durability has been developed and is used much frequently to construct civil infrastructures and contributing to the popularity of concrete as construction material is the ready availability of its most basic constituents, namely, Portland cement, aggregate, water and admixtures. (Oliveira et al., 2014)

The most expensive and which is responsible for 5 to 7% of total carbon dioxide (CO_2) emission raw material component of concrete is Cement, which is a hydraulic binder produced by grinding a mixture of natural limestone with clay after treatment at high temperature. Concrete as the most common building material of our time is responsible for about 6% of total anthropogenic CO_2 emission since cement industry is major contributor in emission of CO_2. Hence there is need to reduce carbon emission by lowering the amount of Portland cement used. (Rezvani et al., 2014) Different types of concrete are produced based on the constituent material, mix design, the method of construction, area of application, and form of hydration reaction.

Normal Strength Concrete the concrete that is obtained by mixing the basic ingredients cement, water and aggregate will give us normal strength concrete. The strength of this type of concrete will vary from 10 MPa to 40MPa. The normal strength concrete has an initial setting time of 30 to 90 minutes that is dependent on the cement properties and the weather conditions of the construction site. (Murali, 2019)

High-Strength Concrete the concretes that have compressive strength greater than 40MPa of up to 100 MPa as against conventional concrete which has compressive strength of less than 50 MPa and The ingredients of high strength concrete are the same as those used in conventional concrete may with the addition of one or two admixtures. This increased strength is achieved by decreasing the water-cement ratio even lower than 0.35. (Murali, 2019)

The plain concrete will have no reinforcement in it. The main constituents are the cement, aggregates, and water. These types of concrete are mainly used in the construction of the pavements and the buildings, especially in areas where there is less demand of high tensile strength. The durability given by this type of concrete is satisfactory to high extent.(Murali, 2019)

2.2- Pozzolanic supplementary cementinious material

Fly ash is a byproduct of the coal burning process in power generating plants. It consists of a very fine material which mixes with flue gases and escapes the combustion chamber. The fly ash particles are fly ashes exhibit pozzolanic activity. And it consists of heterogeneous combinations of amorphous (glassy) and crystalline phases. The largest fraction of fly ash consists of glassy spheres of two types: solid and hollow (cenospheres). These glassy spheres usually consist of 60 to 90% of the total mass of fly ash, with the remaining fraction of fly ash made up of a variety of crystalline phases. These two fractions are not completely independent of one another. Rather, the crystalline phases can be present within a glassy matrix or attached to the surface of the glassy spheres. This union of phases makes fly ash a complex material to classify and characterize in specific terms.(Sennour et al., 1989)

For the civil engineering community, the concept of sustainable development involves the use of high-performance materials produced at a reasonable cost and with the lowest possible environmental impact. The ways to reduce environmental impact include a reduction in the production of waste, and the emission of harmful greenhouse gases, a more efficient use of mineral and metal resources, and an increased use of recycled materials such as aggregates, gypsum, and plastics. To considerably increase the utilization of fly ash that otherwise is being wasted, and to have a significant impact on the production of cement, it is necessary to advocate a use of concrete that will incorporate large amounts of fly ash as a replacement for cement. (Rathi & Modhera, 2007)

As (Folliard, 2009), study fly ash materials have also shown success in the ability of fly ash materials to extend the propagation phase of corrosion due to the high resistivity they impart to the concrete, substantially lowering chloride ingress, thus extending the initiation phase of corrosion and optimize the strengths characteristics of a wide range of high-performance concrete mixtures by implement of supplemental cementinious materials, at their most advantageous levels.

A pozzolan is a siliceous or alumina siliceous material that, in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by the hydration of Portland cement to form calcium silicate hydrate and other cementinious compounds. Natural pozzolans, fly ash and slags has pozzolanic character and categorized as supplementary Cementinious materials or mineral admixtures. (Thomas et al., 2016)

Supplementary cementinious materials are added to concrete as part of the total cementinious system. They may be used in addition to or as a partial replacement of Portland cement or blended cement in concrete, Fly ash blended cements in concrete perform better than pure cement in providing better concrete properties. Current specifications limit the use of fly ash in concrete to 30%, although an increase of this amount can be very beneficial in concrete structures, economically and environmentally. Depending on the properties of the materials and the desired effect on concrete Supplementary cementinious materials are used to improve a particular concrete property, such as: durability qualities, concrete mixes with fly ash content that is higher than the specification limit can result in concrete with acceptable good durability qualities, and with age, the durability qualities are improved due to pozzolanic reactions. Substituting high volumes of cement with fly ash in concrete can provide high quality concrete and a relief in the environment without compromising the quality of concrete. (Zulu S et.al, 2017) Presence of fly ash in concrete significantly decreases the depth of penetration to approximately which is significant increases in the resistance to chloride-ion penetration for fly ash concrete. (Thomas et al., 2016) Resistance to alkali-aggregate reactivity the optimum amount to use should be established by testing to determine (1) whether the material is indeed improving the property, and (2) the correct dosage rate, as an overdose or under dose can be harmful or not achieve the desired effect. Supplementary cementinious materials also react differently with different cements (Design and Control of Concrete Mixtures, 2003).

Fly ash is commonly used in replacement ranging from 0 to 30 percent by mass of total cementinious material. However research has shown that using a 50percent or greater replacement of fly ash can have a wide range of benefits. Fly ash is by product and therefore less expensive than Portland cement; it is also known to improve workability as a result of the "ball bearing" action of spherical fly ash particles and reduce internal temperatures. Fly ash also improves the grading in the mixture by smoothing out the fine particle size distribution and has been shown to reduce amount of water required. Fly ash from modern power plants used in large volumes can reduce the water content by 15 to 20 percent. While high volume of fly ash has a wide range of benefits, possibly the most attractive property of all is durability which results from the reduction of calcium hydroxide, which is the most soluble of the hydration products, and from changes in the pore structure. Research has shown that high volume fly ash concrete is more crack resistant than conventional concretes, due to the decreased shrinkage. This is a result of the decreased mixing water, decreased water to cementinious materials (w/cm) ratio, and also a decrease in the total volume of cement paste that is required in high volume fly ash. Also, the decreased heat of hydration at early ages reduces potential for thermal shrinkage and cracking. (Carette et al., 1993) The fly ash replacement level as 15 - 25% is recommended for high strength concrete (ACI Committee 211 2008), while it can be used as more than 50% of total binder for normal strength concrete.

2.3- Properties of pozzolanic supplementary cementinious materials

2.3.1- Chemical properties

The bulk chemical composition has been used by ASTM C618 to classify fly ash into two types: Classes C and F. The chemical composition data used to determine compliance with ASTM C618 do not address the nature or reactivity of the particles. This analysis is used as a quality-control or quality-assurance tool. Minor variations in the chemical composition of a particular fly ash do not relate directly to the long-term performance of concrete containing that fly ash. Although the constituents of fly ash are not normally present as oxides, the chemical composition of fly ash is so reported. The crystalline and glassy constituents that remain after the combustion of the pulverized coal are a result of materials with high melting points and incombustibility. The amounts of the four principal constituents—SiO_2 (35 to 60%), Al_2O_3 (10 to 30%), Fe_2O_3 (4 to 20%), and CaO (1 to 35%)—vary widely. The sum of the first three constituents (SiO_2, Al_2O_3, and Fe_2O_3) must exceed 70% to be classified as an ASTM C618 Class F fly ash; whereas their sum must only exceed 50% to be classified as an ASTM C618 Class C fly ash. Class C fly ashes generally contain more than 20% of material reported as CaO; therefore, the sum of the SiO_2, Al_2O_3, and Fe_2O_3 may be significantly less than the 70% Class F minimum limit. (ACI Committee 211 2008)

The chemical properties of fly ashes influence the performance of hardened concrete; mainly its strength and durability. The pozzolanic activity of fly ash contributes to the long term compressive strength of the concrete. It is described as the reaction of the total oxides, the sum of silica, alumina, and iron oxide, with hydrated lime released during the hydration of cement to form a secondary gel rich in calcium silicate hydrate. The SO_3 in fly ash is a result of pyrite (FeS_2) and gypsum ($CaSO_4 \cdot 2H_2O$) in the coal. The sulfur is released as sulfur dioxide gas and precipitated onto the fly ash or "scrubbed" from the flue gases, through a reaction with lime and alkali particles. High sulfur trioxide (SO_3) can invite sulfate reaction and also increases the risks of delayed setting time due to any excess of SO_3; thus it is suggested to limit the SO_3 content to a maximum of five percent. (Halstead, n.d.) The SiO_2 content of fly ash results mainly from the clay minerals and quartz in the coal. Anthracite and bituminous (higher ranked) coals often contain a higher percentage of clay minerals in their incombustible fraction than do subbituminous and lignite coals; therefore, the fly ash from the high-rank coals is richer in silica. The siliceous glass from the fly ash is the primary contributor to the pozzolanic reaction in concrete because it is the amorphous silica that combines with lime and water to form calcium silicate hydrate (C-S-H), the binder in concrete. (Vissers, 1997) SiO_2 is usually a gray colored powder somewhat similar to Portland or some fly ashes silica fume is generally categorized as a supplementary cementinious material. Silica fume or micro silica was initially vied as cement replacement material and in some area it is usually used as replaced by much smaller quantity of silica fume micro silica may be used as pozzolanic admixtures and (Luo et al., 2019) found that usage of micro silica with concrete enhance the compressive strength and reducing in the environment pollution also decrease the porosity of concrete, reduces capillary and absorption because fine particles of micro silica reacts with lime present in cement . There were found that using up to 12% replacement of cement with micro silica an increasing in the compressive strength of concrete with increasing dose of micro silica would be recognized and then decreased slightly, while the absorption and workability decreased. Sio_2 is usually a gray colored powder somewhat similar to Portland or some fly ashes silica fume is generally categorized as a supplementary cementinious material. Silica fume or micro silica was initially vied as cement replacement material and in some area it is usually used as replaced by much smaller quantity of silica fume micro silica may be used as pozzolanic admixtures. Admixture is defined as a material other than cement water and aggregate that is used as ingredient of concrete and is added to the batch immediately before or during mixing.

The magnesium oxide (MgO) can form magnesium hydroxide which can expand causing cracking in the concrete. The magnesium oxide content in the concrete is therefore recommended to be restricted. The alkali content in the fly ash is recommended to be limited to 1.5 percent because an excess can cause undesirable expansion in the concrete due to the alkali-aggregate reaction; however if the aggregate is not sensitive to the alkalis this restriction can be ignored.(Ash & Co, 1982) It has been found that a proper replacement of cement with certain fly ashes can reduce the degree of alkali- aggregate reaction. (Dote et al., 1986)

Calcium oxide is the main ingredient of cement and its function is makes cement sound and provides strength to cement. The addition of CaO itself is giving the improvement of strength compared to basic cement without any additives at all. The addition of burnt pure CaO and MgO would increase the shear bond strength and the compressive strength on specific condition up to 200^{o}C temperature. And its concentration has been suggested as another means of classifying coal fly ash. (Thomas et al., 2016) describe and discuss a recent revision of CSA A3000 to distinguish between fly ashes that have different effects on properties of fresh and hardened concrete. They concluded that calcium oxide could be used as a reasonable measure of the general chemical composition of fly ash and its influence on concrete properties.

The alkalis in fly ash come from the clay minerals and other sodium and potassium-containing constituents in the coal. Alkali sulfates in northern lignite fly ash result from the combination of sodium and potassium with oxidized pyrite, organic sulfur, and gypsum in the coal. (McCarthy et al., 1988) reported that Na_2O is found in greater amounts than K_2O in lignite and sub-bituminous fly ash, but the reverse is true of bituminous fly ash. Expressed as Na_2O equivalent (percent Na_2O + 0.658 ´ percent K_2O) alkali contents are typically less than 5%, but may be as high as 10% in some high-calcium fly ashes.

According to ASTM C618, Fly ash and natural pozzolans shall conform to the requirements as to chemical composition prescribed in Table 2.1. This standard classifies those materials in three different classes; Class N—Raw or calcined natural pozzolans that includes some diatomaceous earths; opaline cherts and shales; tuffs and volcanic ashes or pumice, calcined or uncalcined. Class F—Fly ash normally produced from burning anthracite or bituminous coal that meets the applicable requirements for this class as given herein. This class fly ash has pozzolanic properties. Class C—Fly ash normally produced from lignite or subbituminous coal that meets the applicable requirements for this class as given herein. This class of fly ash, in addition to having pozzolanic properties, also has some cementinious properties.

Table 2.1: Mineral admixture chemical properties

Chemicals Composition	Mineral Admixture Class		
	N	F	C
Silicon dioxide (SiO_2) plus Aluminum oxide (Al_2O_3) plus Iron oxide (Fe_2O_3), min %	70	70	50
Sulphur trioxide (SO_3), max, %	4	5	5
Moisture content, max, %	3	3	3
Loss on ignition, max, %	10	6	6

This specification covers coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete where cementitious or pozzolanic action, or both, is desired, or where other properties normally attributed to finely divided mineral admixtures may be desired, or where both objectives are to be achieved.

2.3.2- Physical properties

The physical properties of fly ash influence greatly the properties of fresh concrete. The size and shape of the fly ash particles, the fineness of fly ash and density of fly ash are the major physical properties. The size and shape of fly ash particles depend on the burning efficiency of the plant and the type of the collection. Using electrostatic preceptors, rather than mechanical collection means, results in the collection of a greater percentage of fine fly ash particles. It is agreed that finer ashes have higher pozzolanic activity than coarser fly ashes. (Hadchiti & Carrasquillo, 1988) The fineness affects the pozzolanic activity

The density of fly ash depends on the composition of the ash. Higher density ashes are rich in iron whereas low density ashes have high alumina, silica and carbon contents. Ashes with high carbon content are usually grey or black while ashes with high iron content are tan-colored. And according to the content of calcium oxide (CaO), FA is classified into low-calcium FA (Class F, CaO < 10% by mass) and high-calcium FA (Class C, CaO > 10% by mass).

According to ASTM C618, Fly ash and natural pozzolans shall conform to the physical requirements prescribed in Table 2.2.

Table 2.2 : Mineral Admixture Physical Requirements

Physical Properties	Mineral Admixture Class		
	N	F	C
Fineness : amount retained when wet-sieved on 45 µm (No. 325) sieve, max, %	34	34	34
Strength activity index: With portland cement, at 7 days, min, percent of control	75	75	75

Strength activity index: With portland cement, at 28 days, min, percent of control	75	75	75
Water requirement, max, percent of control	115	105	105
Soundness: Autoclave expansion or contraction, max, %	0.8	0.8	0.8
Uniformity requirements: The density and fineness of individual samples shall not vary from the average established by the ten preceding tests, or by all preceding tests if the number is less than ten, by more than: Density, max variation from average, %	5	5	5
Percent retained on 45-µm (No. 325), max variation, percentage points from average	5	5	5

Fly ash, the most widely used supplementary cementitious material in concrete, is a byproduct of the combustion of pulverized coal in electric power generating plants. Upon ignition in the furnace, most of the volatile matter and carbon in the coal are burned off. During combustion, the coal’s mineral impurities (such as clay, feldspar, quartz, and shale) fuse in suspension and are carried away from the combustion chamber by the exhaust gases. In the process, the fused material cools and solidifies into spherical glassy particles called fly ash. (Dote et al., 1986)

2.4- Fly ash effect on shrinkage

Shrinkage refers to the reduction of the volume of a concrete associated with the evaporation of the water contained in the concrete. It is composed of two simultaneous effects, drying shrinkage and carbonation shrinkage. (Sennour et al., 1989) Drying shrinkage occurs after the concrete has already attained its final set and a good portion of the chemical hydration process in the cement gel has been accomplished and the factors affecting it are cement factor, stiffness of aggregates, water content, and type of cement, curing and storage conditions and the size of concrete member. Drying shrinkage of high strength concrete, although perhaps potentially larger due to higher paste volumes, do not, in fact appear to be appreciably large than normal strength concrete. This is probably due to the increase in stiffness of stronger mixes. Using a large amount of cement in concrete production may produce negative effects, such as an increase in hydration temperature or shrinkage. Drying shrinkage produces internal stress, mass loss and consequently volume reduction of the concrete. (Gambhir et al., 1988)

Parameters influencing the drying shrinkage of concrete include fractional volume of paste, water content, cement content and type, and type of aggregate. Where the addition of fly ash increases the paste volume, drying shrinkage may be increased slightly if the water content remains constant. If there is a water-content reduction, shrinkage should be about the same as concrete without fly ash. (Davis et al., 1937) studied different fly ash cement mixtures and found no apparent differences in drying shrinkage between concrete with up to 20% fly ash content and non-fly ash concrete. (Dunstan, 1984) and Symons and Fleming (1980) found that increased fly ash content resulted in slightly less drying shrinkage.

Using a large amount of cement in concrete production may produce negative effects, such as an increase in hydration temperature or shrinkage except for concrete with a higher water/cement ratio, the use of pulverized fuel ash, ground granulated blast furnace slag, super plasticizer and shrinkage reducing admixture has no effect on strength. However, they affect creep and shrinkage of concrete. (Thomson Gale., 2007)

There are several sources of cracking in concrete. One of them is due to development of tensile stress in the restrained shrinkage condition and this type of cracking can propagate continuously on the condition that concrete still shows shrinkage and the concrete shrinkage leads to cracking which weakens the serviceability, strength, and durability of materials. (Thomson Gale., 2007)

Shrinkage cracking can be mitigated either by reducing shrinkage or by increasing the strain capacity of the concrete. (Beaudoin JJ et al., 1995)

According to (Bilodeau & Mohan Malhotra, 2000) researches the drying shrinkage strains of high-volume fly ash concrete were comparable to, or lower than, that of conventional Portland cement concrete, and it was with measured values of approximately 500×10^{-6} after 64 weeks of air drying.

Shrinkage of concrete tested by the method covers the determination of the length changes that are produced by causes other than externally applied forces and temperature changes in hardened concrete specimens made in the laboratory and exposed to controlled conditions of temperature and moisture.(Concrete et al., 2009)

Shrinkage determination length change measured as per ASTM C157 manual. Calculate the length change of any specimen at any age after the initial comparator reading as follows:

$\Delta L_x = \frac{\text{CRD} - \text{initial CRD}}{\text{G}} * 100$………….. Equation 2. 1

where:

ΔL_x = length change of specimen at any age, %,

CRD = difference between the comparator reading of the specimen and the reference bar at any age, and

G = the gage length

- The air in the room maintained at a temperature of 73 6 3 °F [23 ±2°C]

Length change measured in accordance with ASTM C157:500microstrain (0.05%) at 28 days of drying. The specified limit of length change can be 400microstrain (0.04) or lower. Drying shrinkage limits are typically specified when shrinkage or associated cracking can impair intended functionality or reduce service of life. Shrinkage requirements are often specified for floor slabs, bridges members, structural members that require dimensional stability, and for environmental engineering structures.

2.5- Fly ash effect on compressive strength and density

(Marthong & Agrawal, 2012) studied the effect of fly ash additive on concrete properties and found that the normal consistency increases with increase in the grade of cement and fly ash content. It was also concluded that the use of fly ash improves the workability of concrete. Moreover, it was also observed that the compressive strength of concrete increases with the grade of cement. As the fly ash content increases in all grades of OPC there is reduction in the strength of concrete. The reduction is more at earlier ages as compared to later ages. Fly ash concrete was also found to be more durable as compared to normal OPC concrete. Studied the effects of fly ash on compressive strength of M20 mix design concrete and found that till the addition of fly ash up to 10%, there is negligible change in the strength of concrete. It was also observed that at the replacement till 30%, fly ash blocks have shown very low compressive strength in comparison to concrete containing no fly ash. Blocks containing fly ash were lighter in weight than the concrete block contains no fly ash.

(Wankhede & Fulari, 2014) studied the effect of fly ash on properties on concrete and found that slump loss of concrete increases with increase in w/c ratio of concrete and increase in quantity of fly ash. It was also concluded that concrete with 10% and 20% replacement of cement with fly ash shows good compressive strength for 28 days than normal concrete, but in case of 30% replacement of cement with fly ash ultimate compressive strength of concrete decreases.

(Bansal et al., 2015) studied the effect on compressive strength with partial replacement of fly ash and found that by 10% replacement of cement by fly ash, 20% and 50% decrease in compressive strength was observed at the age of 7 and 28 days respectively. At 20% replacement, 7% and 11% increase in compressive strength was observed at the age of 7 and 28 days respectively. In 30% replacement, 23% and 25% increase in compressive strength was observed at the age of 7 and 28 days respectively. It was also observed that with the increase in age the compressive strength also increased for fly ash replaced concrete.

It has been found that increasing CaO and MgO contents in the slag positively affects strength, whereas SiO_2 has a negative impact ((Halstead, n.d.) .The content of Al_2O_3, however, is controversial, as some say an increase results in increased strength due to increased reactivity (Ash & Co, 1982).

Research done by (Kearsley & Wainwright, 2001) showed that compressive strength is a function of dry density and decreases sharply with a decrease in density and examined the relation between air content, compressive strength and density, and revealed that density decreases without a substantial loss in compressive strength due to increasing the air content. Increasing the air content does not increase the size of the void but increases the number of voids per unit volume. And this experiment works proposed that further increasing the air above the optimum value leads merging of air bubbles and increase the size of void, which in turn reduces the strength. For densities higher than 1000 kg/m^3, as the air voids are far apart to have an influence on the compressive strength, the composition of the paste determines the compressive strength (Visagie M et al., 2002).

The strength gain of concrete containing Type A fly ash is The compressive strength is lower at early ages but higher at later age. (Halstead, n.d.) For Type B fly ash, the strength at early ages is comparable, if not higher than, conventional concrete. This behavior of concrete containing Type B fly ash is due to its contribution to the strength through its cementitious and pozzolanic reactions. Type A fly ash on the other hand contributes only through its pozzolanic activity. ((Fly et al., 1983) Le and Ludwig conducted a series of tests on concrete containing various industrial and agricultural wastes as cement replacements. A 6.8% increase in compressive strength was found in concretes produced with a cement substitution combination of 20% FA.

2.6- Effect on durability

The durability of concrete is a major consideration in its application in aggressive environments for a long service life. Concrete mixes with fly ash content that is higher than the specification limit can result in concrete with acceptable good durability qualities, and with age, the durability qualities are improved due to pozzolanic reactions. Substituting high volumes of cement with fly ash in concrete can provide high quality concrete and a relief in the environment without compromising the quality of concrete.(Zulu S et al.,)

The durability properties like permeability, resistance to sulphate and acid attack, carbonation, alkali silica reaction, fire, abrasion, chloride ion penetration, etc. of pozzolanic concrete with addition of mineral admixtures such as fly ash, silica fume, metakaolin and rice husk ash were reviewed Historically, the durability of fly ashes has been judged based on their classification, Class F or Class C. Use of Class C ashes can increase long-term expansion due to sulfate attack whereas Class F ashes normally mitigate those problems.

CaO content has been shown to be the primary indicator of both durabilities and recently, the ASTM subcommittee chooses 18% CaO content as the division between Class F and Class C. January 5, 2018 ASTM C09.24 ballot reclassify fly ashes as Class F or Class C based on a CaO percentage of 18%. Those fly ashes with CaO contents greater than 18% are Class C and those with CaO less than 18% are Class F.

2.6.1- Fly ash effect on acid attack and durability of hardened concrete

The sites near industries are more susceptible to sulphate attack, since soil near these areas does have more sulphate contents. Similar locations also experience water contents which tend to be slightly acidic. In this context it is pertinent that utility of fly ash concrete under such environment is studied extensively. (Balakrishnan & Awal, 2014) research aims at exploring the durability of fly ash concrete in corrosive environment. And usually consider loss in compressive strength, ion permeability and weight loss, freezing and thawing resistance. In concrete specimens as durability measurement indices after subjecting the specimens to different periods in alkali or acidic or saline environments these parameters are measured to indicate measure of durability. The durability of fly ash concrete considering chloride ion penetration, compressive strength and weight loss as durability indicators have been investigated, High fly ash concrete was observed to be more durable in Salt, acidic and sulphate prone environment.

Much emphasis has been placed on the initiation phase of corrosion (the time it takes for chlorides to reach the steel) through lowering permeability and reducing cracking. Microorganisms that produce sulfuric acid accelerate the deterioration of concrete sewer pipes in a process termed Microbial induced Concrete Corrosion (Kawai et al., 2005) (Murthy NRD et al., 2007) study done the acid resistivity of three different grades of fly ash concrete immersed in 5 percent H_2SO_4 solution for 7 and 28 days have been measured in terms of compressive strength loss and weight loss. They reported that, at 7 days the weight loss observed was very less and with 40percent fly ash replacement concrete has given better performance.

(Kawai et al., 2005) have proposed a prediction method for the deterioration of concrete due to sulfuric acid. Concrete cylinder specimens were immersed in various concentrations of sulfuric acid. Also, sulfuric acid was circulated over the surface of concrete. It was found that the rate of concrete deterioration caused by sulfuric acid depended on pH value of acid solutions. Also, time of exposure of concrete to acid plays a crucial role in rate of deterioration Paper also monitors depth of erosion.(Beulah et al., 2012)the authors carried out an experimental investigation to study the effect of replacement of cement by 20% Met kaolin on high performance concrete with hydrochloric acid attack. Concrete cubes and concrete cylinders were immersed in various concentrations of Hydrochloric acid. The compressive strength of cubes and cylinders decreases with increase in concentration of acid. Also, the study revealed that acidic curing environment has a negative effect on the compressive strength and density of the concrete. Immersion of cubes leads to drastic reduction in compressive strength as compared to sprinkling for any type of acid. The reduction in compressive strength due to complete immersion is almost double than that for sprinkling of any particular acid (Hydrochloric or Sulphuric or Nitric acid) for particular exposure period (30 days or 60 days). As the exposure period increases, the effect on strength and reduction in mass of the cubes also increases. This is applicable for both the methods of attacks – complete immersion and sprinkling, also for all the types of acids.

As a general rule, Class F fly ash can improve the sulfate resistance of concrete mixtures. The increase in sulfate resistance is believed to be due in part to the continued reaction of fly ash with calcium hydroxides in concrete to continue to form additional C-S-H, which fills in capillary pores in the cement paste, reducing permeability and the ingress of sulfate solutions. The situation with Class C fly ash is somewhat less clear. Evidence suggests that some Class C fly ashes may reduce sulfate resistance when used in normal proportions. The sulfate resistance of fly ash concrete is influenced by the same factors that affect concrete without fly ash: curing conditions, exposure, and water cement ratio. The effect of fly ash on sulfate resistance will be dependent on the class, amounts, and the individual chemical and physical characteristics of the fly ash and cement used.(Kawai et al., 2005)

In experimental investigations to detect the acid resistance of ternary (cement, fly ash, silica fume) blended concrete to compare with the binary (cement, fly ash) blended concrete and control concrete the researchers have used the Sulphuric acid and hydrochloric acid as acidic medium. They have considered mass loss and strength deterioration as durability measures. They concluded that ternary blended concrete having 20percent fly ash and 8percent silica fume gives the highest resistance to acid. (Murthi P et al., 2008)

(Sahoo et al., 2015) studied sulphate resistance of fly ash concrete comparing the compressive strength of fly ash concrete (0-20%) cured in water and H_2SO_4 for a period of 28, 60, 90. In acidic environment, the strength decreases with age of concrete and increase percent of fly ash replacement. Optimum strength of concrete was observed at 10 percent fly ash replacement. With varying percentage of fly ash replacement in different grade of concrete, the compressive strength was observed to be decreasing rapidly in case of normal concrete than fly ash concrete when exposed to sulphate solution for 28 days. Regardless of the fly ash type, the addition of the fly ash in concrete enhances the durability properties.

(Aydin, 2009) found that several Class C fly ashes used at 30% replacement of several cements made the system less sulfate resistant. And also resulted pozzolans of high fineness, high silca content. (Attiogbe & Rizkalla, 1989) in their paper the response of four different concrete mixes to sulfuric acid attack was evaluated in an accelerated laboratory test program. Small test specimens cut from standard concrete cylinders and a 1 percent sulfuric acid solution with a pH of 5 were used in the test program. Changes in weight and thickness of the test specimens were used as physical indicators. The degree of deterioration, while increase in sulfur content of the test specimens was used as a chemical indicator of the degree of deterioration the study shows that all three indicators of deterioration are effective measures on concrete response to the acid attack. The study is aimed at evaluating the response of different concrete mixes to sulfuric acid attack, using both physical and chemical indicators of the degree of deterioration. An accelerated laboratory test program was conducted. The program involved alternate acid immersion and drying of test specimens, as well as continuous acid immersion of other test specimens. Changes in weight and thickness of the test specimens were used to evaluate the physical degree of deterioration of the concrete, while the increase in sulfur content of the test specimens, as measured with a scanning electron microscope (SEM) equipped with an energy dispersive x-ray analyzer, was used to evaluate the chemical change in the concrete. Photomicrographs of the test specimens were used to study the extent of the acid attack. And their study resulted on the increase in sulfur content of test specimens, as measured with an SEM equipped with an energy-dispersive x-ray analyzer, is a good indicator of the extent of damage in concrete due to exposure to sulfuric acid, Photomicrographs, as well as the variation in sulfur concentration with distance from the acid-exposed surface of test specimens, clearly show that deterioration of concrete due to sulfuric acid attack starts at the surface and progresses inwards, the relationship between degree of concrete deterioration and depth of penetration of sulfuric acid could be represented by the variation in sulfur concentration with the depth of acid penetration, the increase in volume and the decrease in density of concrete due to sulfuric acid- cement paste reaction would be larger the higher the acidity of the acid solution.

Chemical resistance of geopolymer concrete and control concrete against acid, salt and sulphate solution for 30, 60 and 90 days of exposure were investigated. (Mustafa et al., 2013) reported that the loss in weight was observed in all specimens and the acid and sulphate resistance of geopolymer concrete is significantly better than that of control concrete. Geopolymer concrete specimens were immersed in 10 percent Sulphuric acid and tested the samples for acid resistance at 7, 28, 56 days of immersion. The study confirmed that geopolymer concrete is highly resistant to Sulphuric acid in terms of very low mass loss less than 3 percent. The corrosion current and cracking behavior of geopolymer concrete was investigated and it was observed that geo-polymer concrete immersed partially in sea water for 21 days after 28 days water curing, shows excellent resistance to chloride attack and longer time to corrosion cracking compared to control concrete.

At early age of water curing, control concrete shows good strength related behavior is well established. Since the pozzolanic reactions of fly ash are slow the behavior of fly ash concrete in strength and durability aspects vastly improves with longer water curing age. The superior resistance of the concrete mix against sulphate attack can be brought in by the pore refinement process and densification of transition zone occurring due to conversion of lime forming from the hydration of cement in to additional binding material through pozzolanic activity. Strength loss in concrete may be attributed to three reasons. Free lime of cement in control concrete reacts with sulphate to form gypsum. The volume of gypsum being higher it causes expansion internally and results in crack propagation there by reducing the strength of concrete. The sulphate also react with the aluminate of concrete forming ettringite which also helps in crack formation and propagation because of similar reason.(Othman, n.d.) studied result for all the concrete the rate of strength loss is very high in acid solution; however in the longer water curing period, rate of strength loss comes down and For 28 days of water curing control concrete has the highest resistance only up to 30 day chemical exposure, then after up to 120 days of chemical exposure low fly ash concrete has the highest resistance than that of high fly ash concrete and normal concrete.

2.7- Effect on tensile strength

The data of tensile properties are necessary to enable prediction of the cracking behavior of restrained shrinkage in concrete. Tensile strength may be used as a key parameter to determine the limit of stress at which concrete is considered to crack. Tensile strength is affected by the method of test application. (Torrent RJ., 1983)

This test method consists of applying a diametric compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load. Tensile failure occurs rather than compressive failure because the areas of load application are in a state of triaxial compression, thereby allowing them to withstand much higher compressive stresses than would be indicated by a uniaxial compressive strength test result. (A.p.aroumugame et al., 2016)

Splitting tensile strength is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture). And it will calculate according to ASTM C 496 as

Follows:

$$T = \frac{2P}{\pi\, l\, d} \text{ ………….. Equation 2. 2}$$

where:

T = splitting tensile strength, psi (kPa),

P = maximum applied load indicated by the testing machine, lbf (kN),

l= length, in. (m), and

d = diameter, in. (m).

Whether cracking is likely to occur or not depends on the magnitude of development of tensile stress in comparison with the tensile capacity of concrete. (Jiang X., 1997)

2.8- Effect on flexural strength

Based on experimental investigation on the flexural strength of concrete made of cement partially replaced by fly ash, flexural strength increases up to 11.08% when 20% replacement of cement by fly ash. (Pitroda, 2013)The flexural tensile strength at failure is called modulus of rupture. The determination of flexural tensile strength is essential to estimate the load at which the concrete members may crack. As it is difficult to determine the tensile strength of concrete by conducting a direct tension test, it is computed by flexure testing. Knowing the value of modulus of rupture is useful in the design of pavement slabs, airfield runways, finding deflections and crack widths as flexural tension is critical in these cases.

(Collepardi et al., 1997) studied the effect of replacing a portion of the fine sand and ground silica by naturally graded aggregate with a maximum aggregate size of 8 mm (0.31 in.). The results showed reduced flexural strength as the size of the aggregate increased. (Wille et al., 2012) studied the effect of optimizing the cementitious packing.

Flexural Strength test is carried out according to ASTM C293- 02. Duplicate beam specimens were tested and the average results were considered. The flexural strength determined by using equation.

- when the fracture occurs in the tension surface outside of the middle third of the span length by not more than 5 % of the span length

$$R= \frac{3\,Pa}{2bd^2} \quad \text{................. Equation 2. 3}$$

- when the fracture initiates in the tension surface within the middle third of the span length

$$R=\frac{PL}{bd^2} \quad \text{........................ Equation 2. 4}$$

Where

R= flexural strength, (MPa).

P = maximum app.lied load, (N).

l = span length, (mm).

d = depth of the specimens, (mm).

b = width of the specimens, (mm).

a = average distance between line of fracture and the nearest support measured on the tension surface of the beam, in., (or mm)

CHAPTER 3: MATERIALS AND METHODS

3.1- General

The major objective of this research is to study the structural properties influence of concrete produced by fly ash from Repi waste to energy plant located at Addis Ababa as supplementary cementing material.

Different mix proportions targeting for different compressive strength of C25/30 and high strength C50/60 also made. The influence of fly ash from Repi waste to energy plant as supplementary cementing material on the compressive strength, drying shrinkage, water absorption, acid attack, tensile strength and flexural capacity was studied.

Physical tests of materials, compressive strength, water absorption, acid attack, tensile strength and flexural capacity tests were carried out in Addis Ababa science and Technology University(A A S T U), chemical analysis for materials were done in National cement share company in Dire Dawa whereas drying shrinkage test were carried out in Mafcon engineering.

3.2- Material

3.2.1- Cement

Locally produced ordinary portland cement type I (OPC from Mesebo cement factory) was used for preparation of the mix. It was bought from one of the Addis Ababa’s building material shops.

3.2.2- Fly ash

Fly ash from Repi waste to energy plant has collected to use as supplementary cementing material chemical analysis done by National cement Share Company

3.2.3- Aggregates

3.2.3.1- Fine aggregates

Local river sand, with a fineness modulus of 2.54 was used as a fine aggregate. Specific gravity and water absorption tests were conducted according ASTM C128. The fine aggregate had specific gravities of 2.74, and water absorptions of 1.1%. Fine aggregate passing sieve size 4.75mm used in this experimental study.

3.2.3.2- Coarse aggregate

Coarse aggregate used for this research was crushed stone which was bought from one of Addis Ababa building material shop. In order to design and make a concrete mix, the aggregates properties had to be assessed and a number of tests were carried out on the above materials. The performed test includes: sieve analysis, bulk and dry density, moisture content, absorption capacity, unit weight, etc. All of the aggregates tests were done in accordance with the Ethiopian standards and conforms to the ASTM requirements. And it with maximum passing sieve size of 28mm and 10mm for concrete strengths C25/30 and C60/70 respectively. Relative density (specific gravity) and water absorption tests were conducted according ASTM C127 by taking the ratio of mass of an aggregate to the mass of a volume of water equal to the volume of the aggregate particles – also referred to as the absolute volume of the aggregate. And the coarse aggregate has specific gravities of 2.72 with water absorptions of 1.54% and specific gravities of 2.73 with water absorptions of 1.99%. In coarse aggregates there were lots of dusty material and pieces of leaves in it and the material was washed and kept in the laboratory.

3.2.4-Water

A tap water, which is supplied from the Addis Ababa water supply and sewerage Authority, is used for all concrete mix.

3.3- Experimental methods

To understand different properties of concrete composed of fly ash and what is required to produce such type of concrete will be made possible by referring different literature written on properties of concrete specifically on concrete produced by cement replaced by fly ash.

Steps followed on conducting experimental methods:

Specify properties of materials which are necessary for making normal strength and high strength concretes.

- Collecting and purchasing necessary materials: coarse and fine aggregates, fly ash from Repi waste to energy plant, cement.
- Preparing materials as per ACI standards.
- Conducting characterizing tests on materials: physical tests and chemical analysis tests.
- Preparing concrete mix design as per ACI manual for both high strength and normal strength concretes.
- Conducting tests on both high strength and normal strength concretes by changing percentage of fly ash replacement and analysis of test results: compressive test, water absorption test, shrinkage test, acid attack test, tensile strength test and flexural strength tests.
- Analyze and compare it with ASTM standard.

Both review of written literature and laboratory experimental studies guide to study effect of fly ash content on the properties like durability, strength, and shrinkage and water absorption of concrete. Based on literature review different percentages of fly ash from 0%

to 40% used and above tests conducted to verify up to what percent is Repi waste to energy plant's fly ashes applicability as construction material.

3.4- Mix proportion

In order to study the influence of fly ash from Repi waste to energy plant different mixes for characteristic strength of normal strength and high strength were prepared according to The ACI Standard 211.1 method of proportioning concrete mixes.

Table 3.1: Normal strength concrete mix proportions

Mix	Mix Proportion In Kg/m^3				
	Cement	Sand	Coarse Aggregate	Water	FA
NSC 0%	359	732	1164	176	0
NSC 10%	323.1	732	1164	176	35.9
NSC 20%	287.2	732	1164	176	71.8
NSC 30%	251.3	732	1164	176	107.7

Table 3.2: High strength concrete mix proportions

Mix	Mix Proportion In Kg/m^3				
	Cement	Sand	Coarse Aggregate	Water	FA
HSC 0%	1467.5	467	1072	175	0
HSC 10%	1320.75	467	1072	175	146.75
HSC 20%	1174	467	1072	175	293.5
HSC 30%	1027.25	467	1072	175	440.25

3.5- Laboratory tests

3.5.1- Compressive strength

The most common tests carried out on concrete specimens are compressive strength test due to the fact that:

- Structural design codes are based mainly on compressive strength of concrete;
- It is assumed that most of the important properties of concrete are directly related to compressive strength, and
- The test is easy and relatively inexpensive to carry out

The results of this test used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures; and similar uses.

To investigate the compressive strength of concrete by using byproduct of Repi power plant, 12 specimens having size of 150x150x150mm cube specimens were casted. And after 28 days by applying a compressive axial load to molded blocks at a rate which is within a prescribed range until failure occurs. The compressive strength of the specimen was obtained automatically from compressive strength testing machine.

Table 3.3: Specimen preparation for compressive strength test

Concrete grades	Number of Control specimens	Specimens with varying percentage of byproduct of Repi power pant		
		10%	20%	30%
C25/30	3	3	3	3
C50/60	3	3	3	3

3.5.2-Tensile splitting test

This test is carried out on concrete specimens since splitting tensile strength is simpler to determine than direct tensile strength and splitting tensile strength is used to evaluate the shear resistance provided by concrete in reinforced concrete members.

By using ASTM C496-96 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens This test method consists of applying a diametric compressive force along the length of a cylindrical concrete specimen at a rate that is within 11KN/s range until failure occurs. This loading induces tensile stresses on the plane containing the applied load and relatively high compressive stresses in the area immediately around the applied load.

To investigate the tensile splitting test of concrete by using byproduct of Repi power plant, 12 specimens having size of 150x300mm cylindrical specimens were casted. And after 28 days Thin, plywood bearing strips are used so that the load is applied uniformly along the length of the cylinder and then applying a diametric compressive force along the length of a cylindrical concrete specimen axial load to molded blocks at a rate which is within a prescribed range until failure occurs. The tensile strength of the specimen was obtained automatically from compressive strength testing machine.

Table 3.4: Specimen preparation for tensile splitting test

Concrete grades	Number of Control specimens	Specimens with varying percentage of byproduct of Repi power pant		
		10%	20%	30%
C25/30	3	3	3	3
C50/60	3	3	3	3

3.5.3-Acid attack test

Chemical attack results in loss of weight, cracking of concrete and the consequent deterioration of concrete and it is one of durability test to asses concrete's original form, quality and serviceability when exposed to environment chemical attack test.

Acid attack test was performed as per ASTM C267-97 for a period of for total 90 days. Sulphuric acid of 3% concentration was taken as a medium for acid resistance test which is intended to evaluate the chemical resistance and which provide for determination of change in weight loss, appearance and compressive strength of the specimen the durability studies, the test specimens are subjected to Acid attack. The concrete cubes of size 150mm*150mm*150mm were casted and cured for a period of 28 days. After 28 days curing of specimens, cube surfaces were cleaned and weighed. The identified specimens were immersed in acid solution. After the 28, 56 and 90 days of immersion, the specimens were removed from the solution. Using weight loss method, percentage weight loss was determined and the compressive strength after immersion in acidic solution was determined.

To study the effect of Sulphuric acid attack, the test specimens were casted with and without byproduct of Repi power plant. For the first 28 days, the specimens were cured in potable water. Then after 28 days curing, cube surfaces cleaned and weighed. The identified specimens then immersed in 3% H_2SO_4 (Sulphuric acid) solution for 90 days. Then after percentage weight loss of the samples, compressive strength after immersion in acidic solution was determined.

Table 3.5: Specimen preparation for Sulphuric acid attack test

Concrete grades	Number of Control specimens	Specimens with varying percentage of byproduct of Repi power pant		
		10%	20%	30%
C25/30	3	3	3	3
C50/60	3	3	3	3

3.5.4-Shrinkage tests

ASTM C157 Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete used to determine measurement of length change permits assessment of the potential for volumetric expansion or contraction of concrete due to various causes other than applied force or temperature change. This test method is particularly useful for comparative evaluation of this potential in different hydraulic cement mortar or concrete mixtures.

To assess the reduction of shrinkage of concrete by using byproduct of Repi power plant, 12 specimens having size of 100x100 x300 mm was casted and then after it was removed from the molds at an age of $23\frac{1}{2}$ hour after the addition of water to the cement during the mixing operation.as per ASTM C157 the specimens cured in water for 7 days and followed by 28 days of air storage.

Table 3.6: Specimen preparation for shrinkage test

Concrete grades	Number of Control specimens	Specimens with varying percentage of byproduct of Repi power pant		
		10%	20%	30%
C25/30	3	3	3	3
C50/60	3	3	3	3

3.5.5 Flexural strength test

The flexural test on concrete was conducted according ASTM C78 using three point load test to test tensile strength indirectly. Flexural tests of moist-cured specimens were made as soon as after removal from moist storage since surface drying of the specimen results in a reduction in the measured flexural strength.

To investigate the flexural strength test of concrete with Repi waste to energy plant fly ash replace with 10%, 20%, 30% by volume of ordinary Portland cement and all mix has the same quantity of water content, fine aggregate and coarse aggregate as control group or 0% replace of cement 12 specimens having size of 100x100x 500mm prism specimens were casted during molding the specimens were vibrated by table vibrator after molding the concrete was remolded and subjected to curing in water for 28days. And after 28 days the specimen was tested for flexural strength using a flexural testing machine of 100 kN capacities. Flexural strength is in N/mm^2 is reported.

Table 3.7: Specimen preparation for flexural strength test

Concrete grades	Number of Control specimens	Specimens with varying percentage of byproduct of Repi power pant		
		10%	20%	30%
C25/30	3	3	3	3
C50/60	3	3	3	3

3.5.6 Water absorption test

It is now recognized that the strength of concrete alone is not sufficient, but also the degree of harshness of the environmental condition to which concrete is exposed over its entire life is equally important. In order to obtain the durability of concrete with Repi waste to energy plant fly ash replace with 10%, 20%, 30% by volume of ordinary Portland cement the water absorption test was conducted and test results are reported and discussed.

Water absorption test was done as per ASTM C642-81. 12 specimens having size of 150x150x150mm cubic specimens were casted during molding the specimens were vibrated by table vibrator after molding the concrete was remolded and subjected to curing in water for 28days . After 28 days of curing the specimens had taken out from curing tank and dried in an oven at a temperature of 105°C for 24 hours, then cooled to ambient temperature and weighting it accurately (dry weight). Dried specimens then immersed in water. Weights of specimens at predetermined intervals of 12 hours taken after wiping the surface with a dry cloth. This process continued for 48 hours till a constant weight obtained in two consecutive observations. Percentage of water absorption then determined by equation:

Absorption after immersion, % = $[\frac{B-A}{A}] * 100$…………Equation 3

Where:

A = mass of oven-dried sample in air, g

B = mass of surface-dry sample in air after immersion, g

Table 3.8: Specimen preparation for saturated water absorption test

Concrete grades	Number of Control specimens	Specimens with varying percentage of byproduct of Repi power pant		
		10%	20%	30%
C 25/30	3	3	3	3
C 50/60	3	3	3	3

CHAPTER 4: TEST RESULT AND DISCUSSIONS

4.1- Fly ash chemical analysis

Chemical analysis on fly ash from Repi waste to energy plant was done in National cement Share Company in Dire Dawa test result is shown in Table 4.1.

Table 4.1: Chemical property of fly ash from Repi waste to energy plant

Investigated chemicals	Chemical composition in %
SiO_2	34.08
Al_2O_3	11.54
Fe_2O_3	10.27
SO_3	1.47
MgO	3.13
Na_2O	3.22
K_2O	0.64
CaO	25.65

According to (ACI Committee 211 2008) fly ash to be classified as an ASTM C618 Class C fly ash the sum of the three principal constituents (i.e.,SiO_2, Al_2O_3, and Fe_2O_3) must only exceed 50% and Class C fly ashes generally contain more than 20% of material reported as CaO . From result shown the result the summation of SiO_2, Al_2O_3 and Fe_2O_3 is 65.89 and It has been seen that this fly ash is rich in lime (CaO) which is 25.65. It implies that according to ASTM C618 it is Class C, since CaO > 10% by mass.

4.2- Compressive strength

The compressive strength test of concrete was determined by using 150x150x150 mm concrete cubes were cast using mix proportions in section 3.4 with Repi waste to energy plant fly ash replace with 10%, 20%, 30% by volume of ordinary Portland cement and all mix has the same quantity of water content, fine aggregate and coarse aggregate as control group or 0% replace of cement. During molding the cubes were vibrated by table vibrator after molding the concrete blocks were demoded and subjected to curing in water for 28days. The specimen was tested for compressive strength using a compression testing machine of 2000 kN capacities. Compressive strength is in N/mm^2.

Table 4.2: 28 Days data of compressive strength

No.	Description	C25/30			C50/60		
		Sample1	Sample2	Sample3	Sample1	Sample2	Sample3
1	Identification mark	C25/30 28day	C25/30 28day	C25/30 28day	C50/60 28day	C50/60 28day	C50/60 28day
2	Date of casting	24-Jun-2019			25- Jun -2019		
3	Date of testing	14-Jul-2019			15-Jul-2019		
4	Age of Specimen	28 days	28days	28 days	28 days	28days	28 days
5	Curing condition	Immersion in water pond			Immersion in water pond		
6	Dimensions of specimen(mm)	150x150	150x150	150x150	150x150	150x150	150x150

Table 4.3: 28 days compressive strength test results

C25/30				
FA in %	0%	10%	20%	30%
Load(KN)	742.459	745.559	713.159	729.126
Strength(Mpa)	33.0623	34.188	32.4803	32.4577
density (Kg/m3)	2518.52	2458.77	2458.77	2411.85
C50/60				
FA in %	0%	10%	20%	30%
Load(KN)	1454.97	1464.2	1440.47	1351.77
Strength(Mpa)	64.665	65.7427	63.6727	60.0663
density (Kg/m3)	2516.54	2513.09	2450.86	2411.85

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on compressive strength of C25/30 concrete mix

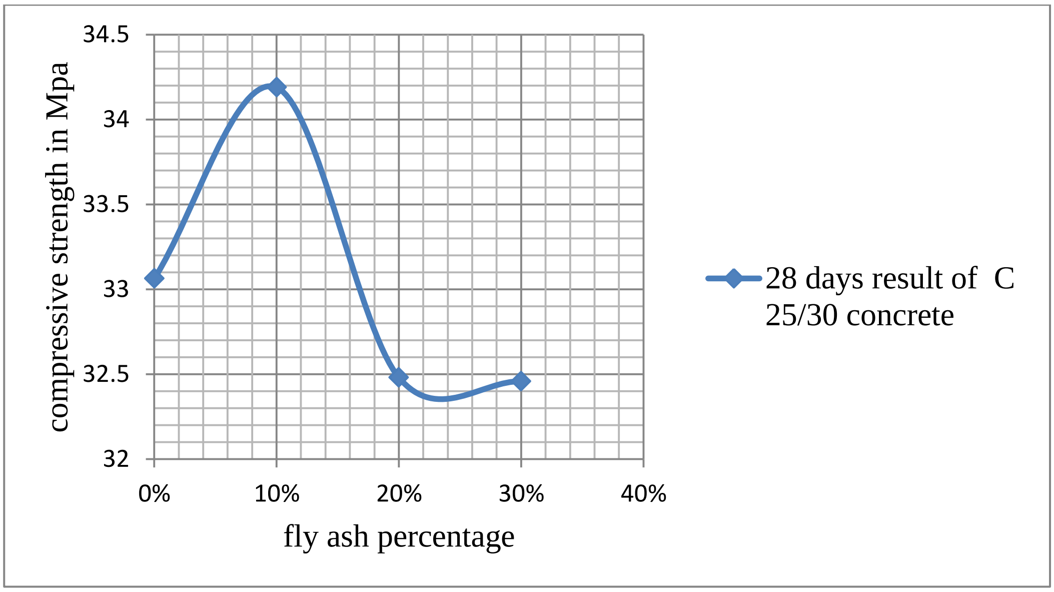

Fig 4. 1 Compressive strength test result of C25/30

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on compressive strength of C50/60 concrete mix

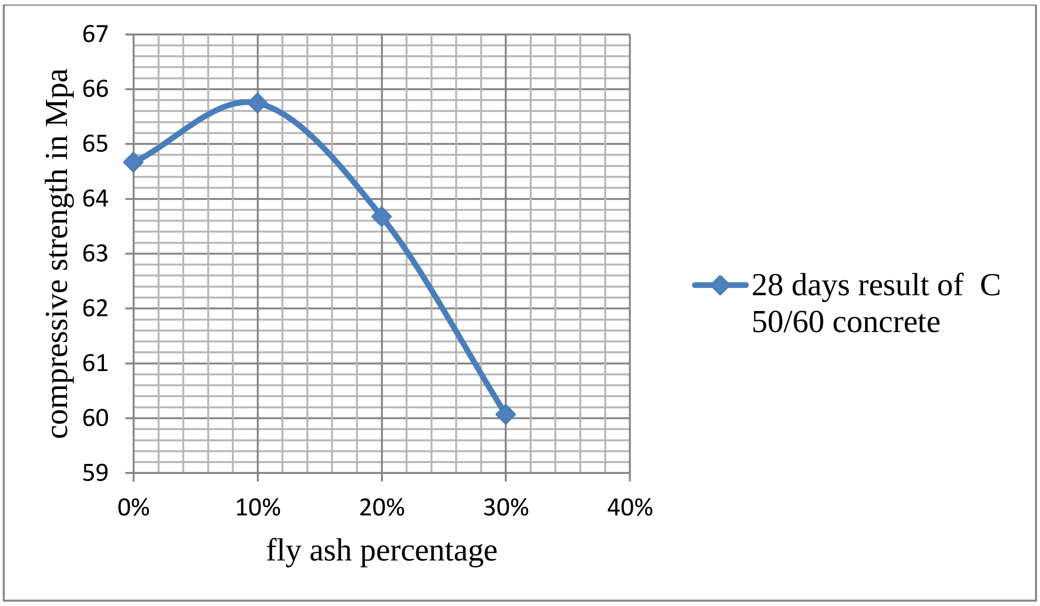

Fig 4. 2 Compressive strength test result of C50/60

For concrete grade C25/30 the compressive strength reaches maximum at 10% replacement cement by volume of Repi waste to energy plant fly ash which increases by 9% and starts decreasing as fly ash percentage increases. And for concrete grade C50/60 the compressive strength reaches maximum at 10% replacement cement by volume of Repi waste to energy plant fly ash which increases by 4% and as fly ash percentage increases compressive strength starts decreasing with high range.

For structural engineering, one of the most essential things in design of load bearing members understands of material strength and it is defined by in terms of compressive strength which is as the ability of structure to carry the loads on it without any crack or deflection and the most common performance attribute used by the engineer when designing structures, flexural strength also known as modulus of rupture defined as the stress in a material just before it yields in a flexure test it represents the highest stress experienced within the material at its moment of yield. Tensile strength is the maximum stress that a material can withstand while being stretched or pulled before breaking.

The Compressive strength of concrete cube test is very important to test that provides an idea about all the characteristics of concrete. (Bansal et al., 2015) studied the effect on compressive strength with partial replacement of fly ash and found that by 10% replacement of cement by fly ash, 20% and 50% decrease in compressive strength was observed at the age of 28 days. At 20% replacement, 11% increase in compressive strength was observed at the age of 28 days. In 30% replacement, 25% increase in compressive strength was observed at the age of 28 days. (Paul et al., 2019) conducted a series of tests on concrete containing various industrial and agricultural wastes as cement replacements. 6.8% increase in compressive strength was found in concretes produced with a cement substitution combination of 20% FA. Due to different chemicals amount and type of fly ash concretes with different fly ash exhibits different compressive strength at different percentages. In this research from lab results for both concrete grades(normal strength concrete C25/30 and high strength C50/60) the compressive strength of concrete mix increase with increasing the percentage of Repi waste to energy plant fly ash reaches 10% by volume of cement. For normal strength concrete C25/30 the compressive strength start decreasing when the Repi waste to energy plant fly ash quantity increased more than 10%, but still higher than the strength of normal mortar mix up to 15% replacement. When Repi waste to energy plant fly ash replacement is higher than 15%, the mix has lower strength than normal mix. In this thesis, Repi waste to energy plant fly ash used as a cement replacement material to minimize the cost of the mixture without affecting the strength, so it feasible to take max Repi waste to energy plant fly ash replacement which has same strength with the normal mix. In this case it can be taken 15% Repi waste to energy plant fly ash percentage as an optimum value which attends higher strength than the normal concrete mix. And for high strength C50/60 concrete after 10percent compressive strength starts decreasing with high range which implies it has to take care of replacement Repi waste to energy plant fly ash percentage and we take 10% Repi waste to energy plant fly ash percentage as an optimum value which attends higher strength than the control concrete mix.

4.3- Shrinkage of concrete

Shrinkage test of concrete was determined by using specimen a prism of 100mm *100mm*300mm were cast using mix proportions in section 3.3 with Repi waste to energy plant fly ash replace with 10%, 20%, 30% by volume of ordinary Portland cement and all mix has the same quantity of water content, fine aggregate and coarse aggregate as control group or 0% replace of cement and three specimens was prepared for each test condition.

Table 4.4: Shrinkage test results

C25/30			
day 14 test result			
FA (%)	Average length change	initial gage length in (mm)	Shrinkage (%)
0%	0.1275	300	0.0425
10%	0.109	300	0.03633
20%	0.0975	300	0.0325
30%	0.086	300	0.02867

C25/30			
day 28 test result			
FA (%)	Average length change	initial gage length in (mm)	Shrinkage (%)
0%	0.148	300	0.047
10%	0.12	300	0.04
20%	0.10467	300	0.03489
30%	0.09367	300	0.03122
C25/30			
day 56 test result			
FA (%)	Average length change	initial gage length in (mm)	Shrinkage (%)
0%	0.141	300	0.04933
10%	0.1247	300	0.04156
20%	0.115	300	0.03833
30%	0.104	300	0.03467
C50/60			
day 14 test result			
FA (%)	Average length change	initial gage length in (mm)	Shrinkage (%)
0%	0.07833	300	0.02611
10%	0.07367	300	0.02456

20%	0.046	300	0.01533
30%	0.02	300	0.00667
C50/60			
day 28 test result			
FA (%)	Average length change	initial gage length in (mm)	Shrinkage (%)
0%	0.114	300	0.038
10%	0.097	300	0.03233
20%	0.086	300	0.02867
30%	0.076	300	0.02533
C50/60			
day 56 test result			
FA (%)	Average length change	initial gage length in (mm)	Shrinkage (%)
0%	0.123	300	0.041
10%	0.10467	300	0.03489
20%	0.1	300	0.03333
30%	0.07967	300	0.02656

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on shrinkage of C25/30 concrete mix

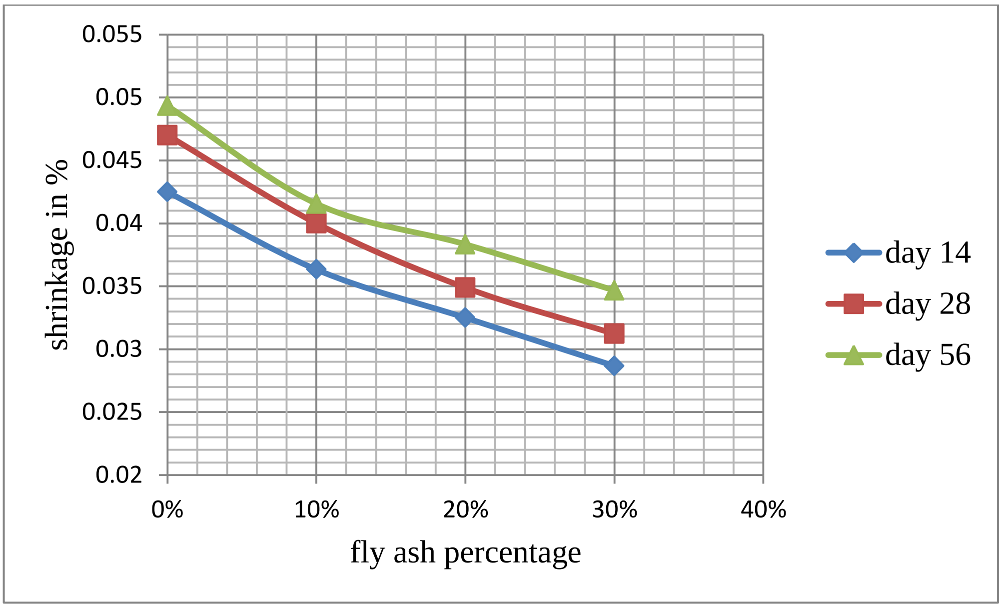

Fig 4. 3 Shrinkage test result of C25/30

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on shrinkage of C50/60 concrete mix

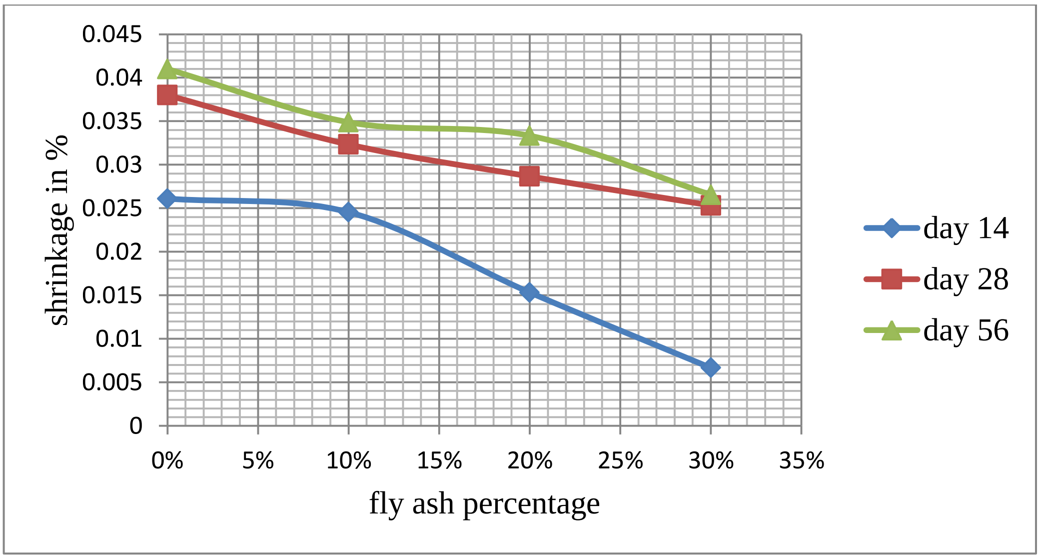

Fig 4. 4 Shrinkage test result of C50/60

From the above test results it can be concluded that Shrinkage of the concrete mix highly decreases with increasing replacement of cement with Repi waste to energy plant fly ash this may due to lower cement content and due to high fineness of Repi waste to energy plant fly ash particles, it coats the air bubbles and form stable air inside concrete. This decrease in shrinkage leads reducing the crack risk in concrete. As ages of the concrete increases decrease in shrinkage range also increases which may due to pozzolanic effect of the Repi waste to energy plant fly ash.

From the above test result it can be seen that initially high strength concrete mix C50/60 has small shrinkage than normal concrete grade C25/30. Shrinkage of concrete does not have co relation with corresponding strength of concrete according to the test results shown in Table 4.4 shrinkage decreases as fly ash amount increase regardless of concretes strength. Reduction in shrinkage percent leads to reduction in tensile stress in concrete that means cracking in concrete will mitigated in other word the serviceability, strength, and durability of concrete will increase.

From ASTM C157 Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete Length change measured has maximum shrinkage of 500microstrain (0.05%) at 28 days of drying and test results of this research has maximum shrinkage of 0.049% for control group or 0% replacement of C25/30 this limit is typically specified when shrinkage or associated cracking can impair intended functionality or reduce service of life often specified for floor slabs, bridges members, structural members that require dimensional stability, and for environmental engineering structures.

4.4- Tensile splitting test

The two grades of concretes namely C25/30 and C50/60 were considered. The test specimens were cast with and without fly ash. For the first 28 days, the specimens were cured in water. After 28 days curing, Thin, plywood bearing strips are used so that the load is applied uniformly along the length of the cylinder and then applying a diametric compressive force along the length of a cylindrical concrete specimen at a rate that is within a prescribed range until failure occurs. The test results are presented in Table below.

Table 4.5: Splitting tensile strength test result of C25/30

C25/30				
FA in %	max load(KN)	pace rate(KN/s)	dimension(m)	stress(Mpa)
0%	236.195	11	0.3x0.15	3.352
10%	248.008	11	0.3x0.15	3.51067
20%	236.8	11	0.3x0.15	3.477
30%	228.345	11	0.3x0.15	3.23233
C50/60				
FA in %	max load(KN)	pace rate(KN/s)	dimension(m)	stress(Mpa)
0%	409.029	11	0.3x0.15	6.46633
10%	462.978	11	0.3x0.15	6.55367
20%	441.62	11	0.3x0.15	6.25133
30%	455.808	11	0.3x0.15	4.43867

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on splitting tensile strength of C25/30 concrete mix

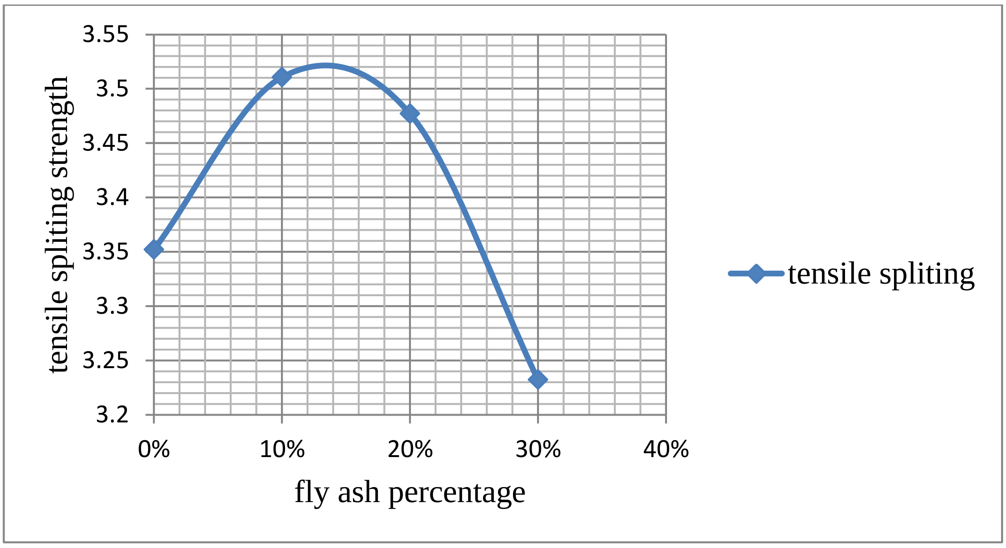

Fig 4. 5 Splitting tensile strength test result of C25/30

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on splitting tensile strength of C50/60 concrete mix

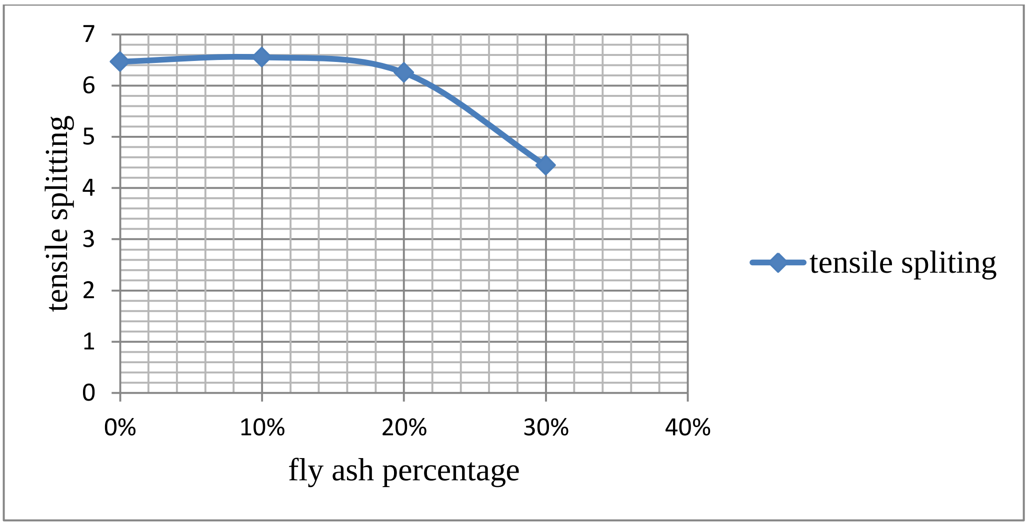

Fig 4. 6 Splitting tensile strength test result of C50/60

For concrete grade C25/30 the tensile strength reaches maximum at 10% replacement cement by volume of Repi waste to energy plant fly ash which increases by 5% and starts decreasing as fly ash percentage increases. And for concrete grade C50/60 the tensile strength reaches maximum at 10% replacement cement by volume of Repi waste to energy plant fly ash which increases by 1% and as fly ash percentage increases compressive strength starts decreasing with high range.

From test result shown for normal strength concrete C25/30 concrete grades the tensile strength of concrete mix increase with increasing the percentage of Repi waste to energy plant fly ash reaches 10% by volume of cement and then starts decreasing when the Repi waste to energy plant fly ash quantity increased more than 10%, but still higher than the strength of normal mortar mix up to 20% replacement. When Repi waste to energy plant fly ash replacement is higher than 20%, the mix has lower strength than normal mix. In this case, Repi waste to energy plant fly ash used as a cement replacement material without affecting the tensile strength, In this case we take 15% Repi waste to energy plant fly ash percentage as an optimum value which attends higher strength than the normal concrete mix and can withstand while being stretched or pulled before breaking Without affecting the compressive strength. For high strength C50/60 concrete after 10percent tensile strength starts decreasing which implies it has to take care of replacement Repi waste to energy plant fly ash percentage and we take 10% Repi waste to energy plant fly ash percentage as an optimum value which attends higher tensile strength than the control concrete mix.

4.5- Flexural strength

Flexural strength test of concrete was determined by using specimen a prism of 100mm *100mm*500mm were cast using mix proportions in section 3.4 with Repi waste to energy plant fly ash replace with 10%, 20%, 30% by volume of ordinary Portland cement and all mix has the same quantity of water content, fine aggregate and coarse aggregate as control group or 0% replace of cement and three specimens was prepared using suitable mixing machine for each test condition. During molding the specimens were vibrated by table vibrator after molding the concrete was remolded and subjected to curing in water for 28days. The specimen was tested for flexural strength using a flexural testing machine of 100 KN capacities. Flexural strength is in N/mm^2.

Table 4.6: Flexural strength test result of C25/30

C25/30				
FA in %	max load(KN)	pace rate(KN/s)	dimension(m)	stress(Mpa)
0%	11.011	11	0.1x0.1 x0.5	5.50533
10%	11.317	11	0.1x0.1 x0.5	5.65883
20%	10.744	11	0.1x0.1 x0.5	5.37225
30%	10.633	11	0.1x0.1 x0.5	5.31673
C50/60				
FA in %	max load(KN)	pace rate(KN/s)	dimension(m)	stress(Mpa)
0%	21.4003	11	0.1x0.1 x0.5	10.6945
10%	21.7473	11	0.1x0.1 x0.5	10.8738
20%	21.0813	11	0.1x0.1 x0.5	10.5315
30%	19.87	11	0.1x0.1 x0.5	9.93497

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on flexural strength of C25/30 concrete mix

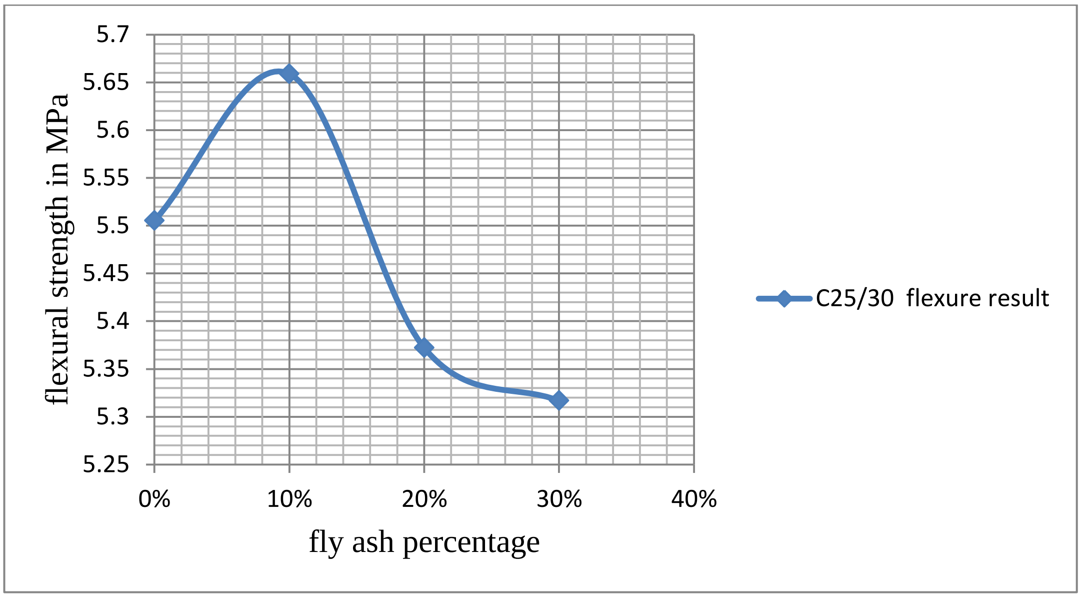

Fig 4. 7 Flexural strength test result of C25/30

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on flexural strength of C25/30 concrete mix

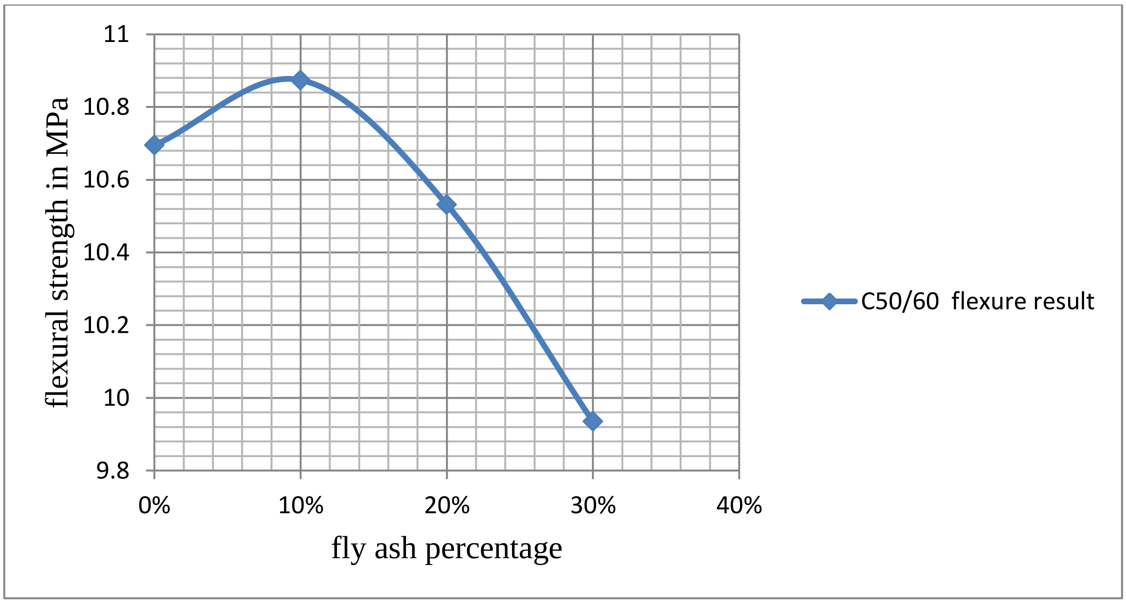

Fig 4. 8 Flexural strength test result of C50/60

For concrete grade C25/30 the flexural strength reaches maximum at 10% replacement cement by volume of Repi waste to energy plant fly ash which increases by 3% and starts decreasing as fly ash percentage increases. And for concrete grade C50/60 the flexural strength reaches maximum at 10% replacement cement by volume of Repi waste to energy plant fly ash which increases by 2% and as fly ash percentage increases compressive strength starts decreasing with high range.

From the test results in this research the flexural strength for both concrete grades (normal strength concrete C25/30 and high strength C50/60) exhibits above 15% of compressive strength. The flexural strength of concrete mix increases with increasing the percentage of Repi waste to energy plant fly ash reaches 10% by volume of cement. For normal strength concrete C25/30 the flexural strength start decreasing when the Repi waste to energy plant fly ash quantity increased more than 10%, but still higher than the strength of normal mortar mix up to 15% replacement. When Repi waste to energy plant fly ash replacement is higher than 15%, the mix has lower flexural strength than normal mix. In this case we take 15% Repi waste to energy plant fly ash percentage as an optimum value which attends higher strength than the normal concrete mix. 15% of fly ash can be used as cement replacement.

For high strength concrete C50/60 after 10percent fly ash replacement flexural strength starts decreasing with high range which implies it has to take care of replacement Repi waste to energy plant fly ash percentage and it can be taken 10% Repi waste to energy plant fly ash percentage as an optimum value which attends higher strength than the control concrete mix.

4.6- Sulphuric acid attack test

To study the effect of Sulphuric acid attack, the two grades of concretes namely C25/30 and C50/60 were considered. The test specimens were cast with and without fly ash. For the first 28 days, the specimens were cured in water. After 28 days curing, cube surfaces were cleaned and weighed. The identified specimens were then immersed in 3% H_2SO_4 (Sulphuric acid) solution for 90 days. The percentage weight loss of the sample and compressive strength was determined. The test results are presented in Table and table.

Table 4.7: Sulphuric acid attack test result

C25/30			
fly ash replacement in %	day 28	day 56	day 90
	weight(Kg)	weight(Kg)	weight(Kg)
0%	7.825	7.905	7.125
10%	7.76	7.85	7.08
20%	7.22	7.315	6.585
30%	7.055	7.14	6.45
C50/60			
fly ash replacement in %	day 28	day 56	day 90
	weight(Kg)	weight(Kg)	weight(Kg)
0%	7.815	7.93	7.21
10%	7.39	7.465	6.675
20%	7.355	7.425	6.635
30%	7.215	7.37	6.575

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on weight change of C25/30 concrete mix due to 3% Sulphuric acid attack.

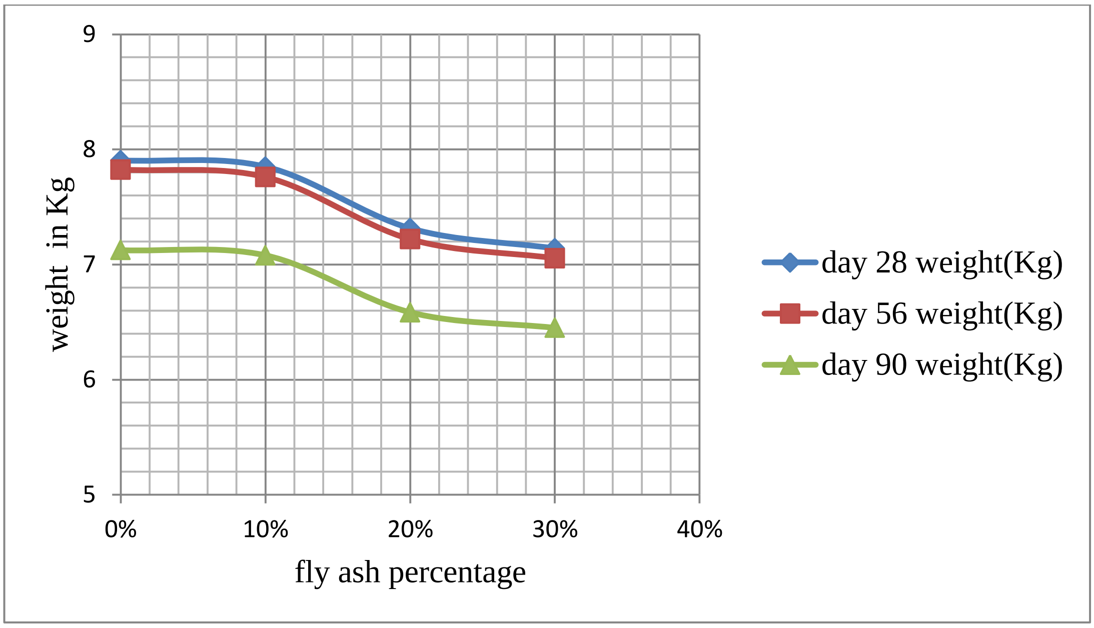

Fig 4. 9 Sulphuric acid attack test result of C25/30

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on weight change of C50/60 concrete mix due to Sulphuric acid attack.

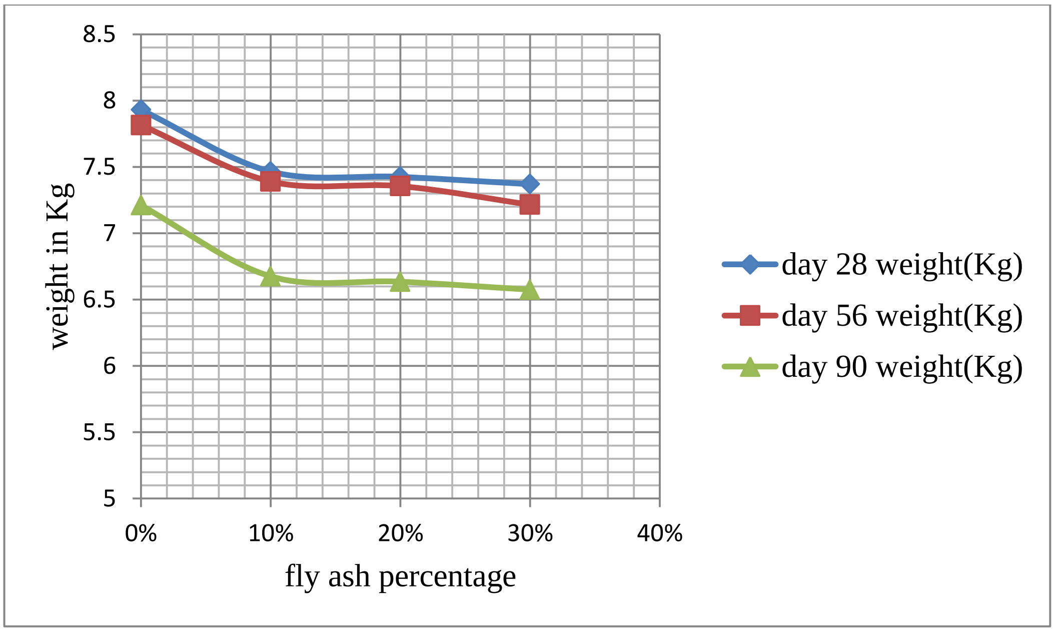

Fig 4. 10 Sulphuric acid attack test result of C50/60

From the above test result shown in table and charts weight decreases as immersion day increases after it gets its maximum value at 56 day of immersion of 3% Sulphuric acid. After 90 days immersion of 3% Sulphuric acid average strength in (Mpa)

Table 4.8: Sulphuric acid attack test result

fly ash replacement in %	Average strength in (Mpa)	
	C25/30	C50/60
0	33.307	59.94
10	30.964	57.569
20	30.707	53.338
30	28.44	53.036

From the above test result shown in table for concrete grade C50/60 strength decreases up to 44% and for concrete grade C25/30 strength decreases 32% from this it can be concluded that it is better to use replacement for lower concrete grades.

It can be concluded that as fly ash percentage increases Sulphuric acid resistance decreases and for smaller grades of concrete strength loss due to Sulphuric acid attack is better than those of high strength concretes.it will recommended that using this fly ash for areas of lesser Sulphuric acid exposed.

4.7- Water absorption test

Water absorption (WA) test was carried out as per ASTM C642 after 28 days of curing. The specimens were taken out from curing tank and dried in an oven at a temperature of 110°C for 24 hours, then cooled to ambient temperature and weighed accurately (dry weight). Dried specimens were then immersed in water.

Table 4.9: Water absorption test result

C25/30			
FA replacement in %	Average Weight in water	Average Oven Dry Weight	Average WA at 28 days in %
0	7.235	6.873	5.267
10	7.275	6.97	3.876
20	7.38	7.057	4.077
30	7.145	6.785	4.806

C50/60			
FA replacement in %	Average Weight in water	Average Oven Dry Weight	Average WA at 28 days in %
0%	8.49333	8.13833	4.36207
10%	8.48167	8.14167	4.17605
20%	8.27167	7.92567	4.36556
30%	8.14	7.767	4.80237

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on water absorption of C25/30 concrete

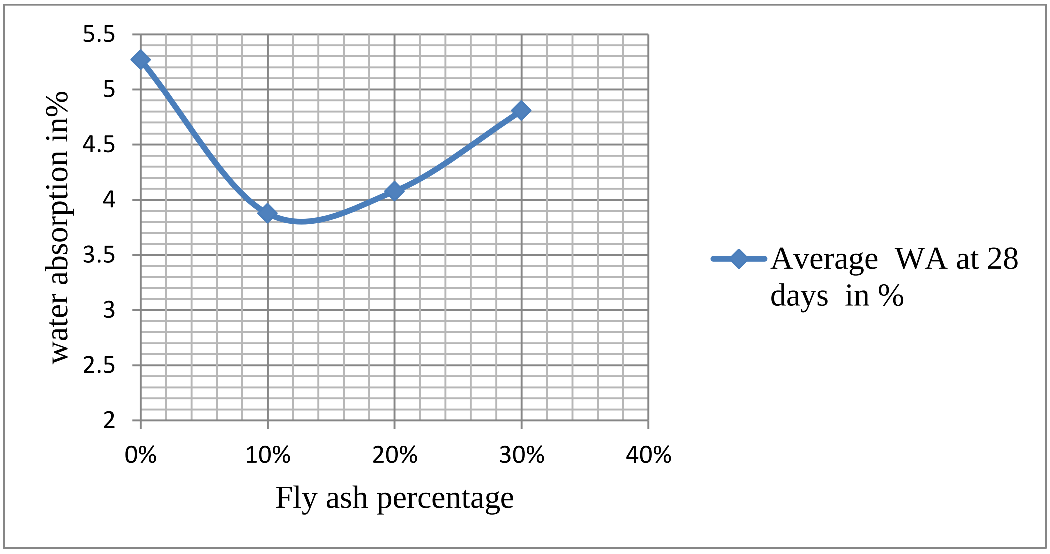

Fig 4. 11Water absorption test result

The chart shown below summarizes the effect of Repi waste to energy plant fly ash on water absorption of C50/60 concrete

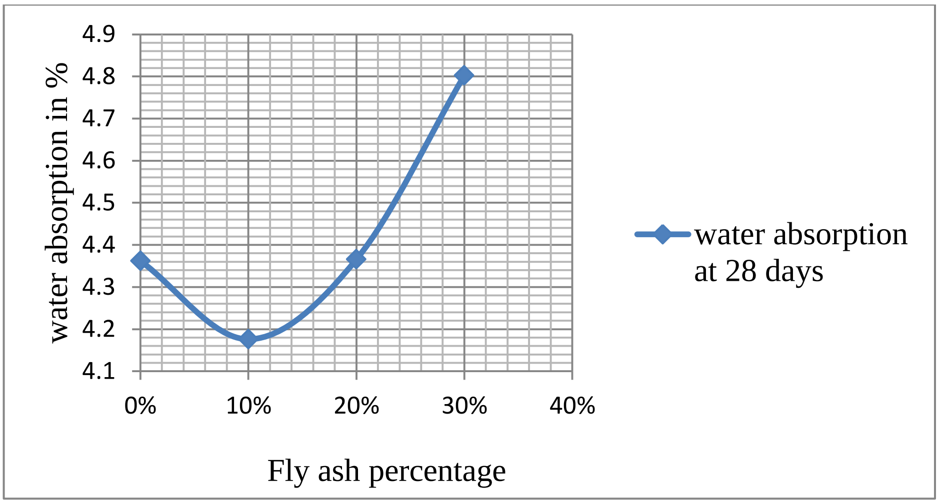

Fig 4. 12 Water absorption test result of C50/60 concrete

For normal strength concrete C25/30 from the above test results the water absorption decreases as fly ash percentage is 10% and starts increasing as fly ash percentage increases but for maximum fly ash percentage in this thesis water absorption is smaller than the control concrete mix.

For high strength C50/60 concrete water absorption decreases as fly ash percentage is 10% and starts increasing as fly ash percentage increases and at 20% of fly ash replacement, water absorption becomes equal to the control mix.

For normal strength concrete C25/30 from the above test results the water absorption decreases as fly ash percentage is 10% and starts increasing as fly ash percentage increases but for maximum fly ash percentage in this thesis water absorption is smaller than the control concrete mix. For high strength C50/60 concrete water absorption decreases as fly ash percentage is 10% and starts increasing as fly ash percentage increases and at 20% of fly ash replacement, water absorption becomes equal to the control mix. Relations between Water Absorption and Compressive Strength After being cured for 28 days, compressive strength was measured, and Figure 4.1 and 4.2 present results of compressive strength and Figure 4.11 and 4.12 shows results of water absorption test. Samples with good compressive strength have low water absorption.

Moreover, low water absorption of concrete can improve resistance to the penetration of water and other harmful substances which caused chemical attack Furthermore; durability of concrete is mainly dependent on the capacity water absorption.

CHAPTER 5- CONCLUSION AND RECOMMENDATION

5.1- Conclusion

In this research, significant past research works were reviewed on concretes with fly ash, and mix proportions were designed based on literature review. Laboratory tests were conducted to analyze mechanical properties, shrinkage and durability of concretes with fly ash. In past practices, fly ash was used as cement replacement material in concrete, whereas in this experiment fly ash from Repi waste to energy plant fly ash is used as partial cement replacement material.

All the above works are done to check a suitability, property and feasibility of plain concrete containing Repi waste to energy plant fly ash. From laboratory tests conducted by using Repi waste to energy plant fly ash as a cement replacement material, the following conclusions are forwarded:

1- Repi waste to energy plant fly ash can be used as cement replacement material up to 15% and 10% by volume of cement in normal strength concrete and in high strength concrete respectively without decreasing the mechanical properties (i.e., compressive strength, flexural and tensile strength).

2- Replacement of cement with 10% of Repi waste to energy plant fly ash slightly improves mechanical properties of concretes such as compressive strength, flexural strength and tensile strength for normal strength those mechanical properties is greater than normal concrete without fly ash and for high strength after 10% replacement compressive strength, tensile and flexural strength decreases.

3- Addition of Repi waste to energy plant fly ash in concrete significantly reduces shrinkage in normal strength concrete by30.6% and for high strength concrete by 35.4%.

4- Addition of Repi waste to energy plant fly ash in concrete significantly reduces water absorption for normal strength by 26.6% and for high strength concretes water absorption decreases by 3% at 10% of fly ash.

5- Addition of Repi waste to energy plant fly ash in concrete reduces Sulphuric acid resistance. From acid resistance resulted from weight loss test normal strength concrete weight losses by 8.8% and high strength concrete weight loses by 9.5%. Acid resistance resulted from compressive strength test results normal strength concrete with 30% of fly ash decreases compressive strength by 15% from normal strength concrete without fly ash and high strength concrete with 30% of fly ash decreases compressive strength by 11.5% from high strength concrete without fly ash.

5.2- Recommendations

The production of concrete with Repi waste to energy plant fly ash in concrete can easily adopt in non-acidic environment in current construction sectors without high investment production cost, advantages on problem solving with environmental degradation and by having good strength and durability.

REFERENCE

A.p.aroumugame, V.S.Sethuraman, A.Vallavan, L.K.rex, “a comparative study on flexural strength of high strength concrete using silica fume”, international journal of science and research, issn 2395-0072, volume:03, issue 12, dec -2016, pp 289-295.

ACI committee 211 (2008). Guide for selecting proportions for High-Strength concrete using Portland cement and other cementitious materials, ACI 211.4R-08, December.

Ash, F., & Co, C. (1982). Lane, R. 0., and Best, J. F., Properties and Use of Fly Ash in Portland Cement Co. 0.

Attiogbe, E. K., & Rizkalla, S. H. (1989). Response of Concrete to Sulfuric Acid Attack. 85, 481–488.

Aydin, E. (2009). Sulphate resistance of high volume fly ash cement paste composites. Concrete Repair, Rehabilitation and Retrofitting II - Proceedings of the 2nd International Conference on Concrete Repair, Rehabilitation and Retrofitting, ICCRRR, March, 91–92. https://doi.org/10.1201/9781439828403.ch13

Balakrishnan, B., & Awal, A. S. M. A. (2014). durability properties of concrete containing high volume malaysian fly ash. m, 529–533.

Bansal, R., Singh, V., & Pareek, R. K. (2015). Effect on Compressive Strength with Partial Replacement of Fly. 6(1), 1–6.

Bilodeau, A., & Mohan Malhotra, V. (2000). High-volume fly ash system: Concrete solution for sustainable development. ACI Structural Journal, 97(1), 41–48. https://doi.org/10.14359/804

Concrete, C., Concrete, C., Cabinets, M., & Rooms, M. (2009). Standard Test Method for Length Change of Hardened Hydraulic-Cement Mortar and. 1–7.

Dote, R., Code, P. O., Nome, S. A., Notoa, S., & Code, S. A. (1986). effectiveness of fly ash replacement in the reduction of damage due to alkali-aggregate reaction in concrete by josef farbiarz and ramon l . carrasquillo research report No . Research Project No . " Alkali-Aggregate Reaction in Concrete Containing Fly Ash. 2.

Fly, C., Concrete, A., & Sp--, A. C. I. (1983). Yuan, R. L., and Cook, J. E., Study of a Class-C Fly Ash Concrete, ACI SP-79-15. 79.

Folliard, K. (2009). Effects of Texas Fly Ash on Air-Entrainment in Concrete: Comprehensive Report (FHWA/TX-08/0-5207-1).

Hadchiti, K. M., & Carrasquillo, R. L. (1988). P .... 3.

Halstead, W. J. (n.d.). Use of fly ash in concrete (Issue October 1986).

Kawai, K., Yamaji, S., & Shinmi, T. (2005). Concrete Deterioration Caused by Sulfuric Acid Attack. April.

Kearsley, E., & Wainwright, P. J. (2001). The effect of high fly ash content on the compressive strength of foamed concrete. Cement and Concrete Research, 31, 105–112. https://doi.org/10.1016/S0008-8846(00)00430-0

Luo, X., Si, Y., & Gu, W. (2019). Effect of Silica Fume on Mechanical Properties of Concrete Incorporating Steel Slag Powder. Wuhan University Journal of Natural Sciences, 24(1), 86–92. https://doi.org/10.1007/s11859-019-1372-z

Marthong, C., & Agrawal, T. P. (2012). Effect of Fly Ash Additive on Concrete Properties. 2(August), 1986–1991.

Murali, B. (2019). Concrete Technology by A M Neville. June.

Mustafa, M., Bakri, A., Kamarudin, H., & Sandu, A. V. (2013). Sulfuric Acid Attack on Ordinary Portland Cement and Geopolymer Material. July 2014.

Oliveira, M., Ribeiro, B., & Branco, F. (2014). Combined Effect of Expansive and Shrinkage Reducing Admixtures to Control Autogenous Shrinkage in Self-Compacting Concrete. Construction and Building Materials, 52, 267–275. https://doi.org/10.1016/j.conbuildmat.2013.11.033

Othman, N. Y. (n.d.). Computing the Compressive Strength of Concrete Cubes at (7 or 28 days) by Using a Multi Forms Program.

Paul, S. C., Mbewe, P. B. K., Kong, S. Y., & Šavija, B. (2019). Agricultural solid waste as source of supplementary cementitious materials in developing countries. Materials, 12(7). https://doi.org/10.3390/ma12071112

Pitroda, J. (2013). Flexural Strength of Beams by Partial Replacement of Cement with Fly Ash and Hypo Sludge in Concrete. 2(1), 173–179.

Rathi, V. R., & Modhera, C. D. (2007). An overview on the Influence of Nano Materials on Properties of Concrete. International Journal of Innovative Research in Science, Engineering and Technology (An ISO Certified Organization), 3297(2), 17–24. www.ijirset.com

Rezvani, M., Proske, T., Hainer, S., & Graubner, C. (2014). limestone-rich cements for sustainable concrete structures – limestone-rich cements for sustainable concrete structures – mechanical properties. January.

Sahoo, S., Das, B. B., Rath, A. K., & Kar, B. (2015). Acid , Alkali and Chloride Resistance of High Volume Fly Ash Concrete. August. https://doi.org/10.17485/ijst/2015/v8i19/7

Sennour, M. L., Carrasquillo, R. L., & Division, T. P. (1989). Po.,. DOT P 1700.7. 2.

Thomas, R., Lezama, D., & Peethamparan, S. (2016). On drying shrinkage in alkali-activated concrete: Improving dimensional stability by aging or heat-curing. Cement and Concrete Research, 91. https://doi.org/10.1016/j.cemconres.2016.10.003

Vissers, L. J. L. (1997). Fly Ash Concrete Waste Materials in Construction Effect of different concrete materials on the corrosion of the embedded rein- forcing steel Coal combustion products in green building.

Wankhede, P. R., & Fulari, V. A. (2014). Effect of Fly ash on Properties of Concrete. 4(7).

APPENDIX A- LABORATORY TEST RESULTS

Appendix A- I Materials Laboratory Test Results

1- Tests for coarse aggregate

i- Determination of Moisture Content of Coarse Aggregate

The following data were found from the test.

For Normal strength concrete C 25/30

Description	Var.	Weight in gm.
Weight of wet sample	M1	1115.6
Weight of the oven dried sample	M2	1109.4

For high strength concrete C 50/60

Description	Var.	Weight in gm.
Weight of wet sample	M1	835.6
Weight of the oven dried sample	M2	830.1

The moisture content as a percentage of the dry mass can be calculated from the following equation.

$$\text{Moisture Content, \%} = \frac{(\text{M1} - \text{M2})}{\text{M2}} * 100\%$$

Where

A= Weight of wet sample excluding container

B= Weight of oven dry sample excluding container

For normal strength concrete,

$$\text{Moisture Content}, \% = \frac{(1115.6 - 1109.4)}{1109.4} * 100\% = 0.56\%$$

For high strength concrete,

$$\text{Moisture Content}, \% = \frac{(835.6 - 830.1)}{830.1} * 100\% = 0.66\%$$

ii- Determination of Bulk Unit Weight of Coarse Aggregate

Calculation and Observation:

The following data are the results of the test.

For Normal strength concrete C 25/30

Description	Var.	Weight in gm.
Weight of container, Kg	A	1.1
Weight of aggregate plus container, Kg	B	17.5
Volume of the container, m^3	C	0.01

For high strength concrete C 50/60

Description	Var.	Weight in gm.
Weight of container, Kg	A	657.6
Weight of aggregate plus container, Kg	B	5325.4
Volume of the container, m^3	C	0.003

$$\text{Bulk unit weight} = \frac{(\mathrm{B} - \mathrm{A})}{\mathrm{C}}$$

Where:

A= Weight container.

B= Weight of aggregate plus container.

C= volume of aggregate.

For normal strength concrete,

$$\text{Bulk unit weight} = \frac{(5.325 - 0.658)}{0.003} = 1640\mathrm{Kg/m^3}$$

For high strength concrete,

$$\text{Bulk unit weight} = \frac{(17.5 - 1.1)}{0.01} = 1556\mathrm{Kg/m^3}$$

iii- Determination of Specific Gravity and Absorption of Coarse Aggregate

Calculations and Observations:

The following data were found from the test.

For Normal strength concrete C 25/30

Description	Var.	Weight in gm
Weight of oven dry sample in air	A	1109.4
Weight of saturated-surface dry sample in air	B	1126.4
Weight of saturated-surface dry sample in water	C	712.8

For high strength concrete C 50/60

Description	Var.	Weight in gm
Weight of oven dry sample in air	A	996.7
Weight of saturated-surface dry sample in air	B	1016.5
Weight of saturated-surface dry sample in water	C	644.1

Bulk specific gravity for saturated surface dry is calculated as:

$$\text{Bulk Sp. Gr. (SSD)} = \frac{B}{(B - C)}$$

$$\text{Absorption, \%} = \frac{(B - C)}{A}$$

Where

A= Weight of oven dry sample in air

B= Weight of saturated -surface dry sample in air

C= Weight of saturated -surface dry sample in water

For normal concrete,

$$\text{Bulk Sp. Gr. (SSD)} = \frac{1126.4}{(1126.4 - 712.8)} = 2.73$$

$$\text{Absorption, \%} = \frac{(1126.4 - 1109.4)}{1109.4} \text{x}100\% = 1.54\%$$

For high strength concrete,

$$\text{Bulk Sp. Gr. (SSD)} = \frac{1016.5}{(1016.5 - 644.1)} = 2.73$$

$$\text{Absorption, \%} = \frac{(1016.5 - 996.7)}{996.7} \text{x}100\% = 1.99\%$$

2- Tests for fine aggregate

i- Determination of Bulk Unit Weight of Fine Aggregate

Observation and Calculation:

Weight of container = 2981.7g

Weight of aggregate + container =8007.1g

Volume of container = $0.003m^3$

$$\text{Bulk Unit Weight} = \frac{\text{Mass of fine aggregate}}{\text{Volume of Container}}$$

$$= \frac{8007.1 - 2981.7}{0.003\text{m}^3}$$

$$= \frac{5.0254\text{Kg}}{0.003\text{m}^3}$$

$= 1675\ kg/m^3$

ii- Determination of Specific Gravity of Fine Aggregate

Test Results:

A= Weight of the sample, SSD = 510g

B= Pycnometer water = 2103.8g

C= Pycnometer + sand+ water = 2427.8g

Calculation:

$$\text{Bulk specific gravity (SSD Basis)} = \frac{\mathrm{A}}{\mathrm{A+B-C}} = \frac{510}{510 + 2103.8 - 2427.8} = 2.74$$

iii- Determination of Absorption of Fine Aggregate

Test Results:

A= Weight of the SSD sample in air = 600g

B= Weight of the oven dried sample in air = 589.5g

Calculation:

$$\text{Absorption}, \% = \frac{(\mathrm{A-B})}{\mathrm{B}} * 100\% = \frac{(600 - 589.5)}{589.5} * 100\% = 1.78\%$$

iv- Determination of Moisture Content of Fine Aggregate

Test Results:

A = weight of original sample= 840.4g

B = weight of oven dry sample=810.70g

Calculation:

$$\text{Moisture content}, \mathrm{w}\ (\%) = \frac{\mathrm{A-B}}{\mathrm{B}} * 100$$

$$\mathrm{w}\ (\%) = \frac{840.4 - 810.70}{810.70} \mathrm{x}100 = 3.66\%$$

v- Determination of Silt Content of Fine Aggregate

Test Results:

A = weight of original sample of sand in air = 810.7g

B = weight of washed and oven dried sample of sand in air = 780.9g

Calculation:

$$\text{Silt Content (\%)} = \frac{(\mathrm{A} - \mathrm{B})}{\mathrm{B}} * 100 = \frac{810.7 - 780.90}{780.9} \mathrm{x}100 = 3.82\%$$

	NATIONAL CEMENT SHARE COMAPNY	NC/QC	
Form Title	CHEMICAL ANALYSIS FOR BOTTOM ASH AND FLY ASH	Issue No. 1	Page 1 of 1

DATE: 7/5/2019

FLY ASH	BOTTOM ASH
SiO_2= 34.08	SiO_2=14.33
Al_2O_3=11.54	Al_2O_3=3.17
Fe_2O_3=10.27	Fe_2O_3=2.27
CaO= 25.65	CaO=17.27
MgO=3.13	MgO=3.37
SO_3=1.47	SO_3=4.31
K_2O=0.64	K_2O=4.94
Na_2O=3.22	Na_2O=1.60
MOISTURE=16.15	MOISTURE=29.2

ANALYSED BY:-------------------------------

CHECKED BY:-------------------------------

APPROVED BY:----------------------------- 07/05/19

ናሽናል ሲሚንቶ አ.ማ.
NATIONAL CEMENT S.C.

አማኑኤል ታደሰ
ም/ዋ/ሥራ አስፈፃሚ
ፋብሪካ ኦፕሬሽን

Appendix A-II Mix design calculations

1- Normal Strength Concrete(C-25)

The mix design for C-25 normal strength concrete is done as per ACI 211.1.

Important data for mix design are:

i- Properties of coarse aggregate

- Maximum size = 28mm
- Unit weight = 1640 kg/m^3
- Specific gravity = 2.72
- Absorption= 1.54%
- Free moisture content = 0.56%

ii- Properties of fine aggregate

- Unit weight =1675 kg/m^3
- Fineness modulus =2.54
- Specific gravity = 2.74
- Absorption= 1.78%
- Free moisture content =3.66%

Step 1: Slump

25 - 50mm (minimum slump possible) is selected.

Step 2: Maximum size of aggregate

Maximum size is fixed to be 28mm.

Step 3: Target mean strength calculation

When no test data is available, 8.5MPa shall be added to get mean strength.

f_m=25+8.5=33.5MPa

Step 4: W/C ratio

For 27.6MPa, W/C ratio is 0.57 and for 34.5MPa, W/C ratio is 0.48. The W/C ratio can be found by interpolation as follows:

$$\frac{\mathrm{W}}{\mathrm{C}} = \frac{(.57 - .48)}{(27.6 - 34.5)}(33.5 - 27.6) + 0.57 = 0.49$$

Step 5: Mixing water amount

For maximum size of aggregate of 28mm, slump 25 to 50mm (minimum range) and non-air entrained concrete the mixing water requirement can be interpolated between maximum size of aggregate of 25mm and 37.5mm.

$$\text{mixing water} = \frac{(160 - 180)}{(40 - 25)}(28 - 25) + 180 = 176\ \mathrm{kg/m^3}$$

$$\text{entraped air} = \frac{(1 - 1.5)}{(40 - 25)}(28 - 25) + 1.5 = 1.4\%$$

Step 6: Cement Amount

Cement content = 176/0.49 = 359 kg/m^3

Step 7: Course aggregate amount

For maximum size aggregate=30mm and sand fineness modulus of 2.54 the dry bulk volume can be interpolated between size of 25mm and 40mm and fineness modulus of 2.4 and 2.6 that is

$$\begin{bmatrix} 0.71 & 0.69 \\ x1 & x2 \\ 0.75 & 0.73 \end{bmatrix}$$

$$x1 = \frac{(0.71 - 0.75)}{(25 - 40)}(28 - 25) + 0.71 = 0.72$$

$$x2 = \frac{(0.69 - 0.73)}{(25 - 40)}(28 - 25) + 0.69 = 0.70$$

$$\text{Dry bulk volume} = \frac{(.70 - .72)}{(2.4 - 2.6)}(2.54 - 2.4) + .7 = 0.71\ \mathrm{m^3/m^3}$$

Coarse aggregate amount = 0.71*1640=1164 kg/m^3

But 1640kg/m3 is air dry bulk unit weight and it has to be adjusted to air dry condition and back to SSD by dividing by total moisture and multiplying by absorption respectively.

i.e. (1164/1.0056)*1.008 =1167kg/m^3.

Step 8: Fine aggregate amount

$$\text{Fine aggregate} = 2.74\left[1000 - \left(176 + \frac{359}{3.15} + \frac{1167}{2.72} + 14\right)\right] = 732\ \mathrm{kg/m^3}$$

2- High Strength Concrete(C-60)

Mix design for high strength concrete is done as per ACI 211.4R-08 guide for selecting proportions for high-strength concrete using portland cement and other cementitious materials.

i- Properties of coarse aggregate

- Maximum size =10mm
- Unit weight air dry =1556kg/m^3
- Specific gravity =2.73
- Absorption =1.99%
- Total moisture content=0.66%

ii- Properties of fine aggregate

- Unit weight air dry =1675 kg/m^3
- Fineness modulus =2.54
- Specific gravity =2.74
- Absorption =1.78%
- Total moisture content=3.66%

Target mean strength at 28^{th} day, f_{cr} = 1.1*60+4.83 = 71.8MPA = 10414.51psi < 12,000psi (maximum limit of ACI high strength table).

Step 1: Slump selection

Slump of 25 to 50mm (lower range) is selected.

Step 2: Maximum size selection

For strength greater than 9000 (62Mpa), recommended maximum size of coarse aggregate is 10mm to 12.5mm without HRWRA admixture. If HRWRA is used, aggregate size greater than 12.5mm can be used but should not be greater than 25mm anyways. However, to ensure adequate strength 10 mm is selected as maximum size of aggregate.

Step 3: Optimum coarse aggregate amount selection

The fineness modulus of fine aggregate is 2.54 which are acceptable since it is in the range 2.5 to 3.2 of ACI recommended range. For maximum size of 10 mm, volume of coarse aggregate is, VCA=0.68.

Mass of CA = 0.68*1556=1058kg/m^3 air dry mass, but 0.68 is dry volume allowing for 1.99% absorption, 0.66% for total moisture mass of CA will be 1.0199*1058/1.0066=1072kg/m^3.

Step 4: Water and air content

For slump 25-50mm and maximum size of aggregate of 10 mm, mixing water requirement before adding admixture will be calculated as:

Mixing water amount=295lb/yd^3*0.593(kg/m^3)/(lb/yd^3)=175kg/m^3

Void ratio of fine aggregate, V= (1-1675/2740)*100%=38.9%

Water requirement adjustment is (38.9-35)*4.7=18.4kg/m^3

Corrected mixing water amount is 175+18.3=193. 4kg/m^3

Air content=2.0% when using HRWRA

Step 5: W/C ratio selection

For maximum size aggregate of 10mm, and required target mean strength 71.8MPA or 10414.51psi, 28th day strength and using HRWRA, the W/C can be interpolated between 12,00psi and 10,000 with a corresponding 0.27 and 0.30 water-cement ratio. That is,

$$\mathrm{W/C} = \frac{(0.27-0.3)}{(12000-10000)}(10414.51-1200)+0.27 = 0.131782$$

Step 6: Cementing material calculation

Cement content = 193.4/0.131782= 1467.575kg/m^3

Step 7: Fine aggregate calculations

FA amount = 2740(1-2 /100-1072/2730-193/1000-705/3150) = 467kg/m^3.

Appendix A-III Concretes Laboratory Test Results

Table A. 1: Compressive strength test result

C 25/30				
Control group (0% cement replacement)	Identification mark			Average
	Sample1	Sample 2	Sample 3	
Load(kN)	753.826	734.326	739.226	742.459
Strength(Mpa)	33.591	32.689	32.907	33.0623
density (kg/m^3)	2440	2537.778	2577.778	2518.519
10% cement replacement				
Load(kN)	763.926	728.826	743.926	745.559
Strength(Mpa)	34.004	34.444	34.116	34.188
density (kg/m^3)	2451.852	2410.37	2514.074	2458.765
20% cement replacement				
Load(kN)	744.226	703.826	691.426	713.159
Strength(Mpa)	33.129	32.33	31.982	32.4803
density (kg/m^3)	2482.963	2423.704	2469.63	2458.765
30% cement replacement				
Load(kN)	779.326	708.726	699.326	729.126
Strength(Mpa)	34.689	31.551	31.133	32.4577
density (kg/m^3)	2413.333	2405.926	2416.296	2411.852
C 50/60				
Control group(0% cement replacement)	Identification mark			average
	Sample1	Sample 2	Sample 3	

Load(kN)	1423.92	1454.7	1486.3	1454.97
Strength(Mpa)	63.284	64.653	66.058	64.665
density (kg/m^3)	2537.778	2496.296	2515.556	2516.543
10% cement replacement				
Load(kN)	1442.4	1459.3	1490.9	1464.2
Strength(Mpa)	64.107	65.858	67.263	65.7427
density (kg/m^3)	2530.37	2494.815	2514.074	2513.086
20% cement replacement				
Load(kN)	1414.8	1437.5	1469.1	1440.47
Strength(Mpa)	62.88	63.889	64.249	63.6727
density (kg/m^3)	2503.704	2414.815	2434.074	2450.864
30% cement replacement				
Load(kN)	1238.5	1392.6	1424.2	1351.77
Strength(Mpa)	55.044	61.893	63.262	60.0663
density (kg/m^3)	2413.333	2405.926	2416.296	2411.852

Table A. 2: Shrinkage test result of C25/30 of concrete

C 25/30					Shrinkage (%)
	day 14 test result			Average length change	
Control group	Identification mark				
(0% cement replacement)	Sample1	Sample 2	Sample 3		
0%	0.124	0.131	0.128	0.1275	0.0425
10%	0.109	0.109	0.109	0.109	0.03633
20%	0.09	0.105	0.098	0.0975	0.0325
30%	0.097	0.075	0.086	0.086	0.02867
C 25/30					Shrinkage (%)
	day 28 test result			Average length change	
Control group	Identification mark				
(0% cement replacement)	Sample1	Sample 2	Sample 3		
0%	0.149	0.147	0.148	0.148	0.047
10%	0.12	0.12	0.12	0.12	0.04
20%	0.1	0.109	0.105	0.10467	0.03489
30%	0.103	0.084	0.094	0.09367	0.03122
C 25/30					Shrinkage (%)
	day 56 test result			Average	

Control group	Identification mark			length change	
(0% cement replacement)	Sample1	Sample 2	Sample 3		
0%	0.204	0.078	0.141	0.141	0.04933
10%	0.124	0.125	0.125	0.12467	0.04156
20%	0.106	0.117	0.122	0.115	0.03833
30%	0.1	0.108	0.104	0.104	0.03467

Table A. 3: Shrinkage test result of C 50/60 of concrete

C50/60					Shrinkage (%)
	day 14			Average length change	
Control group	Identification mark				
(0% cement replacement)	Sample1	Sample 2	Sample 3		
0%	0.07	0.085	0.08	0.07833	0.02611
10%	0.084	0.06	0.077	0.07367	0.02456
20%	0.102	-0.01	0.046	0.046	0.01533
30%	0.013	0.027	0.02	0.02	0.00667
C50/60					Shrinkage (%)
	day 28			Average length change	
Control group	Identification mark				
(0% cement replacement)	Sample1	Sample 2	Sample 3		

0%	0.109	0.118	0.115	0.114	0.038
10%	0.132	0.062	0.097	0.097	0.03233
20%	0.098	0.074	0.086	0.086	0.02867
30%	0.098	0.054	0.076	0.076	0.02533
C 50/60					Shrinkage (%)
Control group	day 56			Average length change	
	Identification mark				
(0% cement replacement)	Sample1	Sample 2	Sample 3		
0%	0.095	0.151	0.123	0.123	0.041
10%	0.125	0.084	0.105	0.10467	0.03489
20%	0.126	0.072	0.102	0.1	0.03333
30%	0.077	0.082	0.08	0.07967	0.02656

Table A. 4: Splitting tensile strength test result

C25/30				
0% replace	Identification numbers			Average
	Sample1	Sample2	Sample3	
max load(kN)	231.361	245.49	233.549	236.8
pace rate(kN/s)	11	11	11	11
stress(Mpa)	3.275	3.475	3.306	3.352
dimension(m)	0.3x0.15	0.3x0.15	30.3x0.15	

10% replace	Sample1	Sample2	Sample3	Average
max load(kN)	246.972	248.526	248.526	248.008
pace rate(kN/s)	11	11	11	11
stress(Mpa)	3.496	3.518	3.518	3.510667
dimension(m)	0.3x0.15	0.3x0.15	0.3x0.15	

20% replace	Sample1	Sample2	Sample3	Average
max load(kN)	245.629	252.649	210.307	236.195
pace rate(kN/s)	11	11	11	11
stress(Mpa)	3.477	3.977	2.977	3.477
Dimension(m)	0.3x0.15	0.3x0.15	0.3x0.15	

30% replace	Sample1	Sample2	Sample3	Average
max load(kN)	226.202	233.408	225.425	228.345
pace rate(kN/s)	11	11	11	11
stress(Mpa)	3.202	3.304	3.191	3.23233
dimension(m)	0.3x0.15	0.3x0.15	0.3x0.15	

C50/60

0% replace	Identification numbers			Average
	Sample1	Sample2	Sample3	
max load(kN)	444.0335	456.714	466.675	455.8075
pace rate(kN/s)	11	11	11	11
stress(Mpa)	6.328	6.465	6.606	6.466333
dimension(m)	0.3x0.15	0.3x0.15	0.3x0.15	

10% replace	Sample1	Sample2	Sample3	Average
max load(kN)	453.323	460.458	475.152	462.9777
pace rate(kN/s)	11	11	11	11
stress(Mpa)	6.417	6.518	6.726	6.553667
dimension(m)	0.3x0.15	0.3x0.15	0.3x0.15	
20% replace	Sample1	Sample2	Sample3	Average
max load(kN)	453.818	426.973	444.068	441.6197
pace rate(kN/s)	11	11	11	11
stress(Mpa)	6.424	6.044	6.286	6.251333
dimension(m)	0.3x0.15	0.3x0.15	0.3x0.15	
30% replace	Sample1	Sample2	Sample3	average
max load(kN)	356.682	423.5112	446.894	409.0291
pace rate(kN/s)	11	11	11	11
stress(Mpa)	5.049	5.995	6.326	4.438667
dimension(m)	0.3x0.15	0.3x0.15	0.3x0.15	0.3x0.15

Table A. 5:Flexural strength test result

C25/30				
0% replace	Sample1	Sample2	Sample3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	11.28	10.814	10.94	11.01133
strength(N/mm^2)	5.64	5.407	5.469	5.505333
10% replace	Sample1	Sample2	Sample3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	11.248	11.309	11.395	11.31733
strength(N/mm^2)	5.624	5.655	5.6975	5.658833
20% replace	Sample1	Sample2	Sample3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	10.959	10.694	10.579	10.744
strength(N/mm^2)	5.479537	5.347382	5.289823	5.372247
30% replace	S1	S2	S3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	10.958	10.198	10.744	10.63333
strength(N/mm^2)	5.479	5.099	5.3722	5.316733
C50/60				
0% replace	Sample1	Sample2	Sample3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	20.92	21.387	21.894	21.40033
strength(N/mm^2)	10.464	10.69361	10.92599	10.69453

10% replace	Sample1	Sample2	Sample3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	21.2068	21.785	22.25	21.74727
strength(N/mm^2)	10.6033	10.89291	11.1253	10.87384
20% replace	Sample1	Sample2	Sample3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	20.8007	21.1437	21.29954	21.08131
strength(N/mm^2)	10.40035	10.56724	10.62678	10.53146
30% replace	Sample1	Sample2	Sample3	average
pace rate(kN/s)	11	11	11	11
maximum load(kN)	18.209	20.474	20.927	19.87
strength(N/mm^2)	9.104278	10.2371	10.46353	9.934972

Table A. 6: Sulphuric acid attack test result

C25/30			
fly ash replacement in %	day 28	day 56	day 90
	weight(Kg)	weight(Kg)	weight(Kg)
0%	7.825	7.905	7.125
10%	7.76	7.85	7.08
20%	7.22	7.315	6.585
30%	7.055	7.14	6.45

C50/60			
fly ash replacement in %	day 28	day 56	day 90
	weight(Kg)	weight(Kg)	weight(Kg)
0%	7.815	7.93	7.21
10%	7.39	7.465	6.675
20%	7.355	7.425	6.635
30%	7.215	7.37	6.575

Table A. 7: After 90 Days Immersion Of 3% Sulphuric Acid Compressive Strength Test Result

fly ash replacement in %	average strength in (Mpa)	
	C25/30	C50/60
0	33.307	59.94
10	30.964	57.569
20	30.707	53.338
30	28.44	53.036

Table A. 8: Water absorption test result

C25/30			
FA replacement in %	Average Weight in water	Average Oven Dry Weight	Average WA at 28 days in %
0	7.235	6.873	5.267
10	7.275	6.97	3.876
20	7.38	7.057	4.077
30	7.145	6.785	4.806

C50/60			
FA replacement in %	Average Weight in water	Average Oven Dry Weight	Average WA at 28 days in %
0%	8.493333	8.138333	4.362072
10%	8.481667	8.141667	4.176049
20%	8.271667	7.925667	4.365563
30%	8.14	7.767	4.802369

APPENDIX B PHOTOGRAPHS

Figure B. 1 Casted specimens

Figure B. 2 Deterioration due to Sulphuric acid attack

Figure B. 3 Oven Dried Samples

Figure B. 4 Compressive strength test cube specimens

Figure B. 5 Compressive strength test

Figure B. 6 Shrinkage test

Figure B. 7 Tensile splitting test

Figure B. 8 Flexural strength test

Figure B. 9 Sulphuric acid effect

Figure B. 10 Fly ash disposal area