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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

ENHANCING STRENGTH IN CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY FLY ASH AND BASALTIC DUST

A Thesis Is submitted to the Department of Civil and Environmental Engineering to be presented in Partial Fulfillment of the Requirement for the Degree of Master of Science in Civil Engineering (Structural Engineering)

By:

WAKAYO GEMEDA MIDADU

ADVISOR:

ABRAHAM GEBRE (PhD)

January, 2021

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WAKAYO GEMEDA MIDADU

A THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

ADDIS ABABA UNIVERSITY, INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE IN CIVIL ENGINEERING

(STRUCTURAL ENGINEERING)

January, 2021

DECLARATION

I, the here undersigned, declare that research work titled as ***"Enhancing Strength in Concrete with Partial Replacement of Cement by Fly ash and Basaltic Dust***" is my original work and has not been presented for a degree in any other university and all sources of material used for this thesis have been properly acknowledged.

Candidate Name: Wakayo Gemeda Midadu

Signature: _____________

Place: Addis Ababa University Institute of Technology

School of civil and Environmental Engineering

Date of Submission: January, 2021

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ADVISOR'S APPROVAL SHEET

This is to certify that the Thesis entitled **"*Enhancing Strength in Concrete with Partial Replacement of Cement by Fly ash and Basaltic Dust*"** Submitted in partial fulfillment of the requirements for the Degree of Master of Science with specialization in Structural Engineering, the Graduate Program of the Department of Civil and Environmental Engineering, and has been carried out by **Wakayo Gemeda, I'd. No; GSR/2427/10**, under my mentorship and supervision. Therefore, I recommend that the student has fulfilled the requirements and hence hereby can submit the Thesis to the department.

Dr. Abraham Gebre	____________________	____________________
Advisor	Signature	Date

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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

A Thesis entitled with "***Enhancing Strength in Concrete with Partial Replacement of Cement by Fly Ash and Basaltic Dust***" Submitted to the School of Graduates Studies of Addis Ababa University in partial fulfillment of the requirement for Master of Science in Civil Engineering (Structural Engineering).

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ABSTRACT

Owning to its local resource availability and its adaptability to prevailing environment, construction industry using concrete is common here in our country, Ethiopia. Therefore, enhancing strength in concrete structures has a lot of advantages over prevailing country's socio- economics. Presently large amount of fly ash is generated in thermal power plants as a waste material with an improper impact on environment and humans. Fly ash, a waste generated by thermal power plants is as such a big environmental concern like 'Reppi Electric power Station' here in our country, Ethiopia. Therefore, economic concern and green environment issue should be addressed as many last studies shows as reduction of CO_2 emissions and waste materials like fly ash and basaltic dust are being used instead of cement as cementations materials recently.

Hence, using waste materials, fly ash and basaltic dust will improve structural strength of concrete than the conventional concrete production one in addition to its cost and make green environment by depleting above mentioned wastes, fly ash and basaltic dust.

The cement has been replaced by fly ash and basaltic dust accordingly in the range of 0% (without fly ash and basaltic dust), 10%, 20%, 30%, 40% and 50% by weight of cement for OPC, C-30. These tests were carried out to evaluate the mechanical or structural properties of the concrete for the test results of Compressive Strength, Split Tensile Strength and Flexural Strength for 7days, 14days and 28days respectively.

Based up on the test result obtained, Cement partial replacement by both fly ash and basaltic dust with 30% with slump test of 35-36.5mm induced best result in Compressive strength (42.47MPa) and attractive structural properties of the concrete with respect to the conventional one and higher results of Split tensile strength (2.94MPa) and Flexural strength (4.63MPa) were obtained with 20% partial replacement of cement with fly ash and basaltic dust while maintaining constructability by using water to cement ratio of 0.54. Hence it would minimize construction cost, avoid delay in construction as early strength can be obtained earlier, and enhance structural strength of the prevailing concrete and keeping the environment green from CO_2 emissions and fly ash disposal pollutions.

Key words: *Basaltic Dust and Fly Ash, Compressive Strength, Constructability, Enhancing Strength, Flexural Strength, In Situ Cast, Split Tensile Strength, Precast.*

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List of Abbreviations and Symbols

ABC	Accelerated Bridge Construction
Ac	Cross-sectional area of the concrete member
ACI	American Concrete Institute
ACT	Accelerated Construction Techniques
As	Arsenic
ASTM	American Society for Testing and Materials
ASTM	TYPE-III-OPC
ASTM	TYPE-II-PPC
Ba	Barium
C-30	Ultimate Characteristic Cubic Compressive Strength of Concrete (30Mpa)
CA	Coarse Aggregate
Ca_3S_2	Tri Calcium di Silicate
$Cacl_2$	Calcium Chloride/ Accelerator Admixture
CC	Coefficient of Curvature
Cd	Cadmium
CEM	Cement
CO_2	Carbon di Oxide
Cu	Copper
D60	Is the diameter of the sand particles for which 60% of the particles are finer
E.C.W.C	Ethiopian Construction Works Corporation
EBCS	Ethiopian Building Code Standards
ERA	Ethiopian Roads Authority
FA	Fine Aggregate
FST	Final Setting Time
fck	Characteristic Cylindrical Compressive Strength of Concrete
Hg	Mercury
IST	Initial Setting Time
MSW-I	Municipality Solid Waste Phase-I
OPC	Ordinary Portland Cement
Pb	Lead

PPC	Portland Pozzolana Cement
SCMs	Supplementary Cementations Material
UC	Uniformity Coefficient
Zn	Zinc
ρ	Loose Unit Weight/ Loose Density
σ	Normal Stress

CHAPTER ONE

1. INTRODUCTION

Recently, construction industry is the booming industry in the world. Specially, construction industry is still on the way in African countries. It consumes country's budget in large aspect as it requires huge resources during its accomplishments. Construction of structural elements can be from Concrete Structures, Steel Structures and Timber Structures. Among these, owning to its local resource availability and its adaptability to prevailing environment, construction industry using concrete is common here in our country, Ethiopia. Buildings, bridges, dams, irrigation canals and rigid pavements can be constructed by concrete because of local availability of its ingredients like sand, coarse aggregate, binding material and water.

As studies show cement industry contributes to production of about 7% of all CO_2 generated in the world. Every ton of cement production release nearly one ton of CO_2 to atmosphere. Thus, the concrete and cement industry change the environment appearance and influences it very much. Therefore, it has become very important for construction industry to focus on minimizing the environmental impact, reducing energy consumption and limiting CO_2 emission. The need to meet these challenges has spurred an interest in the development of a Portland cement in which the amount of clinker is reduced and partially replaced with mineral additives supplementary cementations materials (SCMs). Many researchers have studied the possibility of using another mineral powder in mortar and concrete production. The addition of marble dust, basalt powder, bag ash, sawdust, kaolin and rice ash and granite or limestone powder positively affects some properties of cement mortar and concrete.

By reducing the on-site activities, Accelerated Construction techniques reduce the overall construction time, which results in economic savings. Accelerated Construction techniques also create safer roadway conditions and reduce traffic delays when compared to conventional concrete construction techniques. One common technology used with ACT is prefabricated Concrete elements and systems. For example, when this technology is utilized for ACT, structural components of the bridge are built offsite or adjacent to the alignment. When the structural components of the bridge are prefabricated, they can be fabricated concurrently with other construction activities and transported to the site. This is unlike conventional construction methods, in situ cast, where structural members are constructed on sites sequentially (i.e. the pier columns and caps must be built before the beams and decks are placed, etc.).

The prefabricated structural members are the components of ACT technology which allows for a reduction in construction time and cost (Beer man 2016). Prefabricated components are joined on site with small volume closure pours using high performance materials, commonly comprised of steel and concrete.

Concrete closure pours must ensure adequate load transfer between structural components before the bridge/structure is in use by developing high strengths in concrete within a short period of time. Currently, most materials used for closure pours contain proprietary components, such as Ordinary Portland Cement (OPC), Accelerated chemical admixture, $Cacl_2$ or rapid setting concrete that contains proprietary cements. To provide a most economical concrete, it should be easily adopted in field:

- To reduce the cost of construction.
- To reduce construction period
- To promote green and non-pollutant environment
- To find the optimum strength of the partial replacement of concrete.
- To make the maximum usage of locally available materials or wastes like fly ash and basaltic dust instead of Portland cement.

1.1 Problematic statements of the prevailing study

Developing strength in concrete structures without affecting its durability should be first concern in any civil structures construction. Make a Road, Building or Bridge passable or operational after its construction or maintenance within short period of time is also another critical issue here in our country.

Environmental pollution by waste disposals like Qoshe fly ash and CO_2 emission to the environment because of cement production and its hydration is another serious issue needs immediate response to avails hygiene of our environment.

Keeping environmental hygiene is both national and global concern. Saving construction material cost by using wastes, fly ash and basaltic dust cost is also another relevant issue to be solved in construction industry.

1.2 General Objective of the Study

General objective of this research is how to develop strength in concrete structures like Buildings, Dams, Bridges, High way (Rigid pavements), Irrigation canals and any pertinent civil structure by inducing cement partial replacement by basaltic dust and fly ash which can be considered as green environment and CO_2 emissions to the environment reduction.

1.3 Specific Objective of the Study

The main objective of this research is to develop and validate concrete mixtures and Ingredients that develop the following;

- To develop strength in concrete structures by using wastes, fly ash and basaltic dust as cement partial replacement and conducting structural properties of the concrete like compressive strength, split tensile strength and flexural strength of the concrete without affecting its long-term performance.
- To minimize construction cost and its construction period by using wastes, fly ash and basaltic dust.
- To create green environment and minimize its pollution because of disposals and dusts.
- Adopting wastes, fly ash and basaltic dust as partial replacement materials.
- Create sustainable construction scenario by consuming the wastes as cementations materials.
- This study will present enhancing strength in concrete structures when replacing cement by basaltic dust and fly ash from 0%, 10%, 20%, 30%, 40% and 50% in step by step.
- The concrete mixtures designed for this study was developed for use in accelerated construction trends in Ethiopia, Case study in Ethiopian Construction Works Corporation, ECWC was investigated on Gelan Rigid Pavement construction project around Taff oil.

1.4 Scope and Limitations of Study

The concrete mixtures that developed in this research were having a primary goal of achieving strength in concrete while maintaining constructability with w/c ratio of 0.54. The concrete mixtures was designed by C-30 Dangote cement and its partial replacement by basaltic dust and fly ash in addition to chemical accelerator, $Cacl_2$ to achieve a characteristic compressive strength of 21MPa (70%) within7days as confidence interval value by using trial batches and hence to arrive on the intended goal, the aggregate of maximum nominal size of 19mm was used. The structural properties of the concrete tests performed under this study were: Characteristic compressive strength of the concrete, split tensile strength test, flexural strength test and slump test for workability of the prevailing mixes.

The secondary goal of the concrete that developed in this research was to be durable. Measures have taken during the development of the concrete mixture designed to generate a mixture that also has durable properties. But, because of the long-term nature of these tests and/or the need for specialized equipment and also failure of air compressor in lab, it did not perform as part of this study. (Long term performance/Permeability test) remains open for further study. River sand from Mathahara was used as conventional regardless of its physical properties having silt content of 1.67%, CC of 1.07, UC of 2.50, FM of 3.38 and hence it is categorized as V-Curve type/ poorly graded while Concrete aggregate was from Awash with Nominal size of 19mm, FM of 3.66, UC of 2.16, CC of 0.99 and similarly categorized as V-curve type/poorly graded.

Details of fly ash and basaltic dust silicate analysis/chemical properties, its heavy metals constituents has been done while its effects on the long term performance strength of the concrete could not been addressed owning to time and some other constraints.

1.5 Significance of the Research

The importance of this research will be:-

- It helps to increase structural strength of the concrete than the conventional one.
- It also decreases construction cost by effective partial replacement of cement by wastes, fly ash and basaltic dust.
- It can minimize the delay of construction as early strength can be obtained with this partial replacement in addition to admixture, $Cacl_{2.}$
- It decreases environmental pollution as wastes are being used as cementations materials.
- It induces green environment as Co_2 emission to the prevailing environment decreases and so on.

1.6 Prevailing Research Organization

The thesis consists of five chapters and two sub-titles as References and Appendix

- Chapter One- Introduction/Background of the study
- Chapter Two- Literature Review and post studies results
- Chapter Three- Methodology and Materials of Study
- Chapter Four- Result Analysis and Discussions
- Chapter Five- Conclusions and Recommendations
- References- Different sources for study
- Appendix- Some activity details and Annexes

CHAPTER TWO

2. LITERATURE REVIEW

A literature review was performed on each of the constituents that will be considered in the development of the strength in concrete mixture designs.

2.1 Characteristic Compressive Strength of Concrete

(1) For the purpose of this Code, ES EN 1992.1-1: 2015, compressive strength of concrete is determined from tests on 150mm cubes at the age of 28 days in accordance with Ethiopian Standards.

(2) The characteristic compressive strength is defined as that strength below which 5% of all possible strength measurements may be expected to fall. In practice, the concrete may be regarded as complying with the grade specified for the design if the results of the tests comply with the acceptance criteria laid down.

(3) Cylindrical or cubic specimens of other sizes may also be used with conversion factors determined room a comprehensive series of tests. In the absence of such tests the conversion factors given in Table 2.1 may be applied to obtain the equivalent characteristic strength on the basis of 150mm cubes.

Table 2.1 Conversion Factors of Strength

Size and Type of Test Specimen	Conversion Factor
Cube (200 mm)	1.05
Cylinder (150 mm diameter 300 mm height)	1.25

Table 2.2 Grades of Concrete and Characteristic Cylinder Compressive Strength fck

Grades of Concrete	C15	C20	C25	C30	C40	C50	C60
fck	12	16	20	24	32	40	48

Hence fck = 0.8*fcu, where fck is characteristic cylindrical compressive strength of the concrete and fcu is characteristic cubic compressive strength of the concrete.

And also, fcu= 1.25*fck and vice versa.

2.2 Concrete Ingredients

2.2.1 Fly ash

Fly ash is a heterogeneous by-product material produced in the combustion process of coal or wastes used in power stations. It is a fine grey colored powder having spherical glassy particles that rise with the flue gases (Brown 1980). As fly ash contains pozzolanic materials components which reach with lime to form cementations materials. Thus, fly ash is used in concrete, mines, landfills and dams as environmental benefits related to the disposal of waste materials and to reduce carbon dioxide emissions.

Based on past studies carried out by few researchers it is revealed that even while using blended cement content in concrete, the proportion of cement can be reduced by addition of pozzolanic material like fly ash as partial replacement of PPC. It is reported that it is possible to produce low-cost high-performance concrete (HPC), with 90-day strength in the range of 70 N/mm2, using low quality fly ash. It is possible to replace up to 40% of cement by low-quality fly ash. In the study carried out by Harrison et al, 2014 PPC was replaced by fly ash accordingly in the range of 0 to 60 % by weight of PPC at water cement ratio 0.48 for M-25 mix design and reported that, up to 30% replacement level compressive strength is more and almost equal to the referral concrete at 56 days, further increase in replacement of PPC by fly ash results in gradual decrease in compressive strength of concrete. Parveen, et al, 2015 carried out an experimental work in which cement and fine aggregate were partially replaced by fly ash at the replacement levels of 10%, 20%, 30%, 40% and 60% by weight of cement for M-25 Mix Concrete mix. The specimens were molded, tested and compared in terms of compressive and split tensile strength.

2.2.1.1 Physical properties of fly ash

2.2.1.2 Fineness

The fineness of fly ash is important because it affects the rate of pozzolanic activity and the workability of the concrete. Specifications require a minimum of 66 percent passing the 0.044 mm (No. 325) sieve.

2.2.1.3 Specific gravity

Although specific gravity does not directly affect concrete quality, it has value in identifying changes in other fly ash characteristics. It should be checked regularly as a quality control measure, and correlated to other characteristics of fly ash that may be fluctuating.

2.2.1.4 Chemical composition

The reactive aluminosilicate and calcium aluminosilicate components of fly ash are routinely represented in their oxide nomenclatures such as silicon dioxide, aluminum oxide and calcium oxide. The aluminosilicate components react with calcium hydroxide to produce additional cementations materials. Fly ashes tend to contribute to concrete strength at a faster rate when these components are present in finer fractions of the fly ash (ACI Committee 232 2003).

Figure2.1: fly ash

2.2.2 Basaltic dust or quarry dust

Waste basalt powder was obtained from Asphalt batch mix plant. Asphalt mixture production leads to formation of significant amounts of by-product in the form of mineral powder. Mineral aggregate used in asphalt mixture production is dried at the temperature of about 200°C. An exhaust leaves the dryer with a particle of powder. Coarser fractions of powder are collected in a special separator but very fine fractions deposit in a filter of the dryer. This very fine material is treated as a waste, by-product or locally so-called filler. The quantity of this waste powder is about 5% of aggregate mass used to production of asphalt mixture. Mineral powder used in this study is the origin of basalt hence it is defined as a basalt powder or basaltic dust.

The quarry dust can be defined as residue, tailing or other non-voluble waste material after extraction and processing of rocks to form fine particles less than 4.75 mm. usually, quarry rock dust is mostly used in highways as surface finishing materials and also used for manufacturing of hollow blocks.

2.2.2.1 Physical properties of quarry dust

Physical properties are specific gravity, bulk density, porosity, water absorption, gradation or particle size distribution and fineness modules of the prevailing basaltic dust
(I Rohini et al. 2016).

Table 2.3 Physical properties of quarry dust

S/No.	Properties	Values
1	Specific gravity	2.68
2	Bulk density (kg/m^3)	2.10
3	Fineness Modulus	2.70
4	% of voids	21.50
5	Water absorption	0.60

2.2.2.2 Chemical composition of basaltic or quarry dust

The particle diameters are in the range of 1.5 to 200 µm. The largest volume, i.e. ca. 51%, is occupied by particles of about 19.89 µm in diameter. The specific gravity of powder is 2.68 g/cm3 and Blaine specific surface is 3500 cm2/g. Chemical composition is typical for basalt rock, i.e. Silica and alumina oxide dominate, which is in about 51% and calcium and iron oxide.

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3 [%]	K_2O	Na_2O	Cl^-	P_2O_5	LOI
BP	38.16	12.68	15.88	15.16	7.66	0.2	0.83	2.91	0.07	1.02	4.16

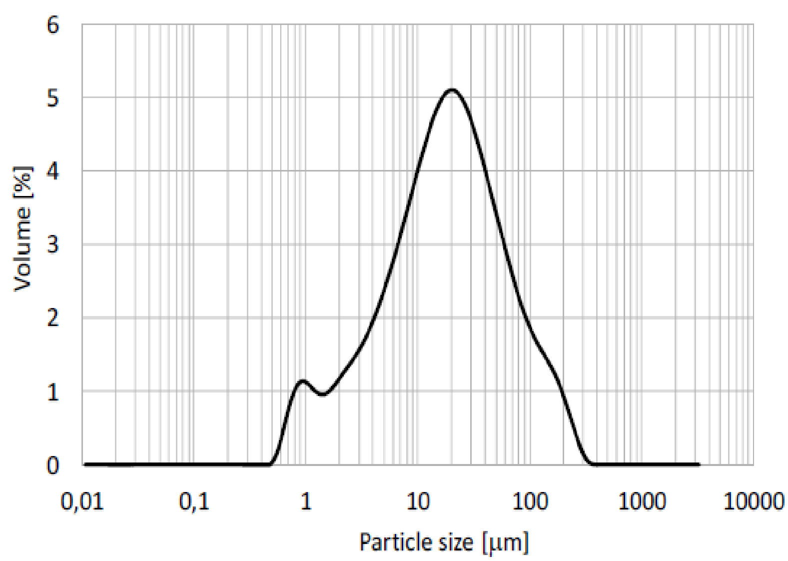


Figure2.2: Chemical composition of basaltic or quarry dust

As previous research shows, the replacement of cement by basalt powder does not affect the normal consistency of binder cement paste. The amounts of water required to obtain a cement paste of normal consistency were found as 29%, 27%, 27%, 28% and 30% for CEM I 42.5R (OPC), CEM II/A-S 42.5R, CEM II/A-V 42.5R, CEM II/BV32.5R and CEM II/B-V 42.5N respectively. The powder basalt has comparable specific surface to cement so the increase of powder content does not change the normal consistency. Effects of basalt powder as the cement replacement on initial (IST) and final setting time (FST) of blended cement paste are presented in the following table, the initial and final setting time were generally prolonged for cement pastes with addition of basalt powder with some exceptions.

The initial setting time was shortened for CEM II/A-S 42.5R, CEM II/A-V 42.5R, CEM II/B-V 32.5R and CEM II/B-V 42.5N with replacement ratios of 3%, 6 and 8%, 1 and 2%, 1 and 2%, respectively.

Table 2.4 Cement Initial and Final Setting Time

	Paste	Setting time [min]	
		IST	FST
CEM I 42.R	P0	140	174
	P1	150	167
	P2	142	225
	P3	164	225
	P4	146	228
	P6	164	249
	P8	166	232
	P10	170	265
CEM II/A-S 42.5R	P0	188	272
	P1	193	276
	P2	190	288
	P3	186	287
	P4	190	289
	P6	201	291
	P8	203	296
	P10	202	311
CEM II/A-V 42.5R	P0	221	311
	P1	230	305
	P2	226	310
	P3	226	308
	P4	235	288
	P6	192	302
	P8	203	330
	P10	246	324
CEM II/B-V 32.5R	P0	215	322
	P1	205	329
	P2	200	344
	P3	220	335
	P4	225	340
	P6	218	353
	P8	236	349
	P10	232	372
CEM II/B-V 42.5N	P0	191	246
	P1	185	252
	P2	180	258
	P3	207	253
	P4	205	260
	P6	192	267
	P8	207	265
	P10	202	262

Previous studies show that the addition of basalt powder to a cement paste does not affect a water demand to obtain a normal consistency. Both, basalt and cement particles have similar finesses so replacement of cement by basalt powder does not make a significant impact on specific surface area of the grains.

It is a main reason that normal consistency has not changed with the increase of the basalt powder content. Basalt powder has retardation effect on the hydration process of cement paste. The initial and final setting time were prolonged with the increase of the basalt content. The replacement of cement by basalt powder leads to dilution effect on cement in blended pastes and the reduction of tricalcium silicate Ca_3S_2 which gives the hardening at early age of cement paste.

2.2.3 Hydraulic Cements

Several studies have investigated the effect of cement type on of early strength development in concrete. Many types of cement that are used to produce early strength concrete mixture are proprietary, such as Ultimax Cement and Ordinary Portland Cement. The compressive strength of concrete containing Ultimax Cement was determined to be 20 to 40% higher than concrete containing ASTM Type I/II Cement (Pozzonala Portland cement) , without chemical or mineral admixtures being added to any mix (Al-manaseer et al. 2000).

Other proprietary cement types have shown similar effects on strength gain of concrete (Balaguru and Bhatt 2001). The objective of this research was to develop a mix using non-proprietary materials; therefore, the use of these proprietary cements was not considered as an option.

Non-proprietary cement considered for this project was ASTM Type I, I/II, II and III. While ASTM Type I/II, (Pozzolana Portland Cement) is the most widely used and available, ASTM Type III, (OPC) cement is high early strength. So, it seemed the most appropriate for the requirements of early strength development in this study. ASTM Type III cement, OPC has shown to have the most significant strength gain increase at 1 day and earlier, compared to other non-proprietary cements (Freyne et al. 2004). During this study Freyne et al. also found that ASTM Type III cement reached the highest splitting tensile strength of the non-proprietary cements tested in their research. The early strength development of ASTM Type III cement has been attributed to a greater fineness of particles, which often exceeds 500 m2 surface areas per kg of cement (500m2/kg). The increased fineness of cement means results in a higher surface area of cement particles that interact with mixing water in the concrete mixture compared with normal strength cement (ASTM Type I/II), (PPC).

The larger surface area has a direct effect on the rate at which cement hydrates, predominantly during the early period of hydration, and therefore, the rate at which strength is gained (ACI Committee E-701 2013). Accordingly, ASTM Type III (OPC) was the hydraulic cement type selected for this research project.

2.2.4 Aggregates

Aggregate properties significantly affect the workability of fresh concrete, as well as the strength, durability, density and thermal properties of hardened concrete. The following sections discuss these effects.

2.2.4.1 Aggregate Texture and Aggregate Shape

The texture of aggregates is a property that alters the workability and strength of concrete mixtures. Surface texture of aggregates refers to the degree of irregularity or roughness of the aggregate particle surface. Terms such as rough or granular are used to define aggregate particles that have a large amount of irregularity in their surface. Alternatively, smooth or glassy are used to describe aggregate particles with very little surface irregularity. Studies have shown that there are benefits of both types of surface textures, depending of the desired properties of a concrete mixture. Smooth particles require less mixing water, and therefore require less cementations material at a fixed *w/cm* ratio and workability of concrete.

One of the functions of water in a fluid concrete mixture is to lubricate aggregate surfaces. So, aggregates with smooth surfaces require less lubrication to result in a workable mixture compared with aggregates having surface irregularities.

The ability to use less cementations material is an economical advantage; thus, the use of smooth aggregates is often a cost-efficient option. Using aggregates with rough surfaces have a strength benefit over using aggregates with smooth surfaces. This is due to the larger bonding area rough aggregate surfaces having with cement paste in comparison with smooth aggregate surfaces (ACI Committee E-701 1999).

2.2.4.2 Aggregate Size

The maximum aggregate size has a strong impact on the strength of concrete. The main reason for this is attributed to the change in bond strength between coarse aggregates and cement paste with different aggregate sizes (Xie et al. 2012). There is contradictory information that can be found regarding the optimal maximum coarse aggregate size.

There have been studies showing that concrete containing larger coarse aggregate sizes are stronger, and that coarse aggregates should be graded up to the maximum size that is practical based on constructability considerations (Transportation Research Board 2013; Xie et al. 2012). Other resources indicate that smaller maximum coarse aggregate sizes increase the strength of concrete (ACI Committee 211 2008; ACI Committee E-701 1999; Koehler and Fowler 2007). Although there is discrepancy about the optimal maximum aggregate size, there is agreement on the strong correlation between maximum aggregate size and bond strength between coarse aggregates and cement paste.

The bond strength between paste and aggregates, which develops at the interfacial transition zones, is not as high as the cement paste or aggregates alone. The interfacial transition zone is the portion of the cement paste that surrounds each aggregate within concrete. Generally, the interfacial transition zone is less dense than the bulk hydrated zone (non-interfacial transition zone) of the cement paste. The size difference between the cement particles and aggregates is significant in the transition zone forming a "wall effect", which has been identified as the main source for the transition zone weakness. The "wall effect" causes there to be a surplus of water and a deficiency of cement particles near the aggregate surface, relative to the bulk hydrated cement paste.

Due to this deficiency in the interfacial transition zone of concrete, a weak point forms in the concrete and provides a preferable pathway for the ingress of potentially harmful chloride ions, as shown in Figure 2-2 (Byard and Ries 2011).

The two arguments that can be made regarding the optimal maximum coarse aggregate size are the following: (1) by having larger coarse aggregates, the number of interfacial transition zones decrease, so larger coarse aggregates result in higher strength concrete (Xie et al. 2012); and

(2) stresses generated at the Schematic of Weak Interfacial Transition Zone Forming Pathway (Shane et al. 2000)interfacial transition zone are greater with larger coarse aggregate because of the greater size difference between the cement particles and aggregates, so using smaller coarse aggregates results in higher concrete strength (ACI Committee E-701 1999).

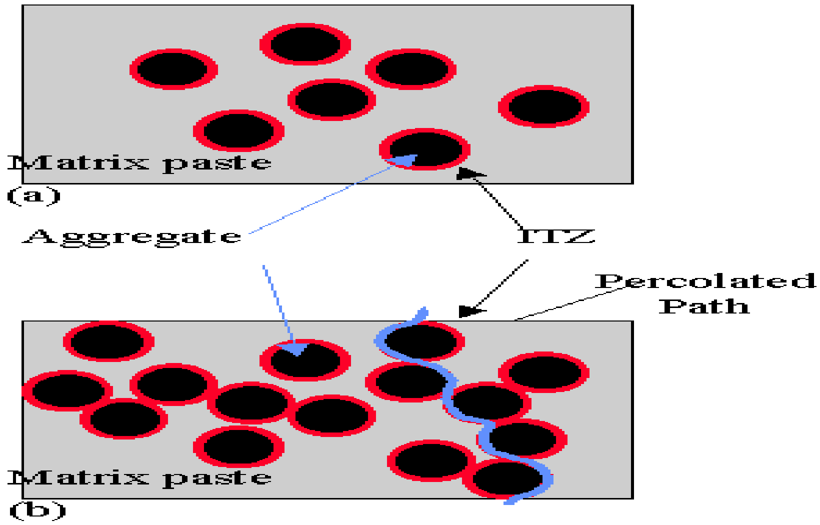


Figure2.3: Aggregate size and its matrix paste

Based up on the discrepancy in these arguments, trial batches were performed with 19mm Nominal maximum coarse aggregate size to determine the maximum strength of the concrete mixtures for this research.

2.2.4.3 Aggregate Gradation

Although the particle size distribution or gradation of aggregates within concrete has been proven to affect the workability and strength of concrete, a universally optimal gradation has not yet been established. There are several types of aggregate gradations. In general, continuously graded aggregate and gradations with high packing densities are favorable to develop high strength concrete (Koehler and Fowler 2006; Young et al. 1998). Gap gradations often result in a concrete with a more fluid consistency, which means less high-range water reducing (HRWR) admixture is required for a desired workability.

Gap gradation can also be beneficial to concrete strength because it can help reach high packing density (Koehler 2014).

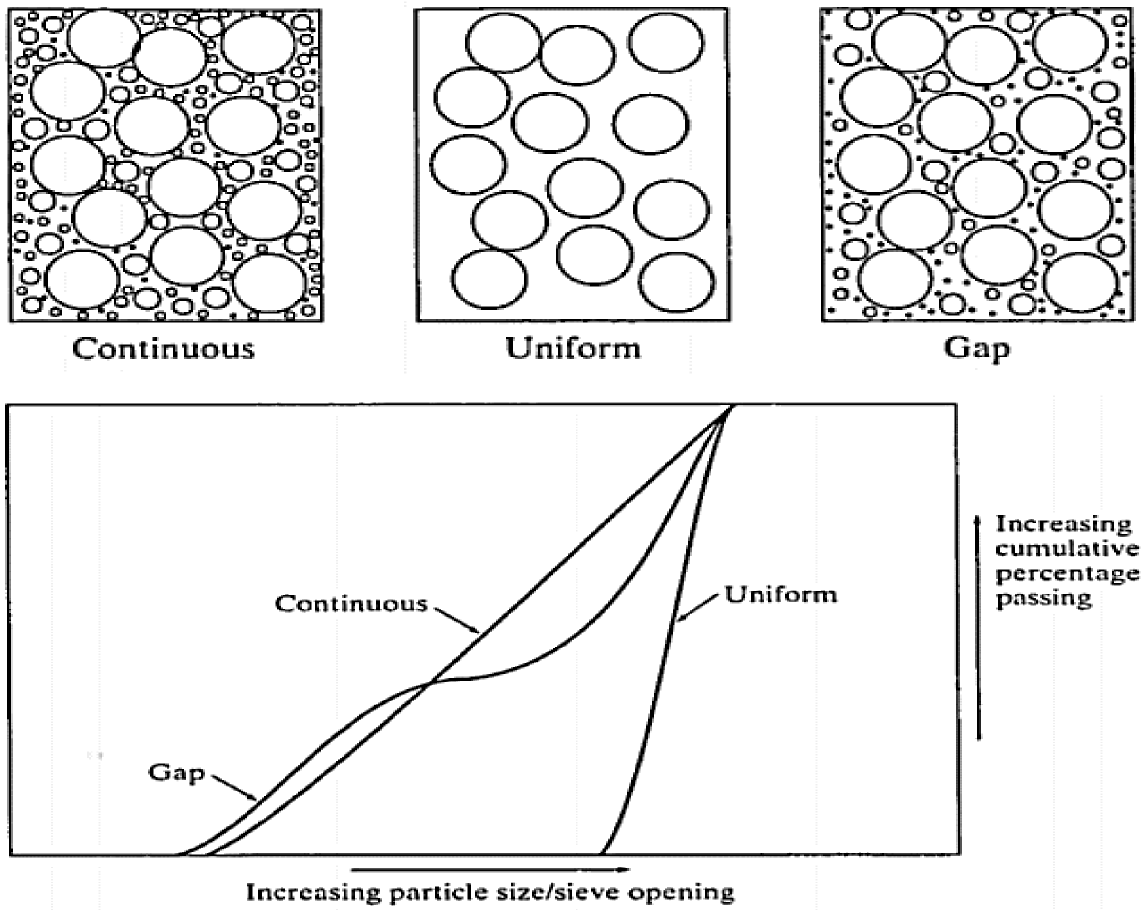


Figure2. 4: Aggregate Gradation Types

However, extreme gap gradation should be avoided, especially with large maximum coarse aggregate sizes, because it can lead to segregation between the cement paste and coarse aggregates. Schematic and gradation curves for continuous, uniform and gap-graded aggregates can be seen Figure 2.4.One way to ensure that gap gradation is avoided and a relatively uniform gradation is reached is by setting limits within the percent retained chart, which is defined in ASTM C136: Sieve analysis of fine and coarse aggregate. The percent of aggregates retained on any two consecutive sieves is greater than 10% and less than 35% of the total aggregates (Koehler 2014).

One method to determining maximum density aggregate gradation is by using the Fuller-Thompson maximum density (minimum void content) gradation curves (Young et al. 1998).

This method provides gradation curves for each maximum aggregate size that will produce the greatest density, as shown in Figure 2.4. To use this method, the proportion of fine aggregate to coarse aggregate is modified to best fit the appropriate curve for the maximum aggregate size.

Aggregates that are typically obtained commercially from an aggregate source (quarry) may not conform to these gradation curves; therefore, two or more aggregates with different gradation curves may have to be blended to obtain these results. There has also been some criticism of this method; stating that the parabolic gradations simply do not work and there needs to be a certain proportion of fine aggregate for workability purposes (Mindess and Young 1981).

Another method (a modified version of the Fuller-Thompson curves) used for determining maximum aggregate compaction is the Power .45 Curve. Percent passing versus size where the aggregate sizes are raised to the 0.45 power. A straight line is drawn between the No. 200 sieve (the smallest sieve size) and the maximum aggregate size sieve. This straight line is the maximum density gradation for this method. To reach maximum packing of aggregates, the gradation curve should be at the .45 power curve or finer (Koehler 2014).

2.2.5 Accelerating Admixtures

Accelerating admixtures are used to accelerate the rate of hydration that occurs in concrete, which accelerates the set time and the early strength development of concrete. There are many chemicals used to accelerate the rate of hydration, but calcium chloride is the one most commonly used in accelerating admixtures. Calcium chloride has been proven to shorten the set time and accelerate the early strength development. The increased rate of hydration will also result in other benefits including earlier finishing time, reduced bleeding, improved protection against early exposure to freeze thaw cycles and earlier use of a structure.

There are also some disadvantages with using calcium chloride as an accelerating admixture, including an increase in drying shrinkage, potential for causing corrosion of reinforcing steel, and discoloration of concrete. Calcium chloride accelerating admixtures should be used with caution. They should always be added to the concrete in a solution form, which can be achieved by mixing with water. Calcium chloride use should be avoided in reinforced concrete that is in a moist condition. Even with non-reinforced concrete, the amount of calcium chloride used should never exceed 2% by mass of cementations material (ACI Committee E-701 2003; Kosmatka et al. 2003). Other types of accelerating admixtures that do not contain chlorides are typically not as effective as those.

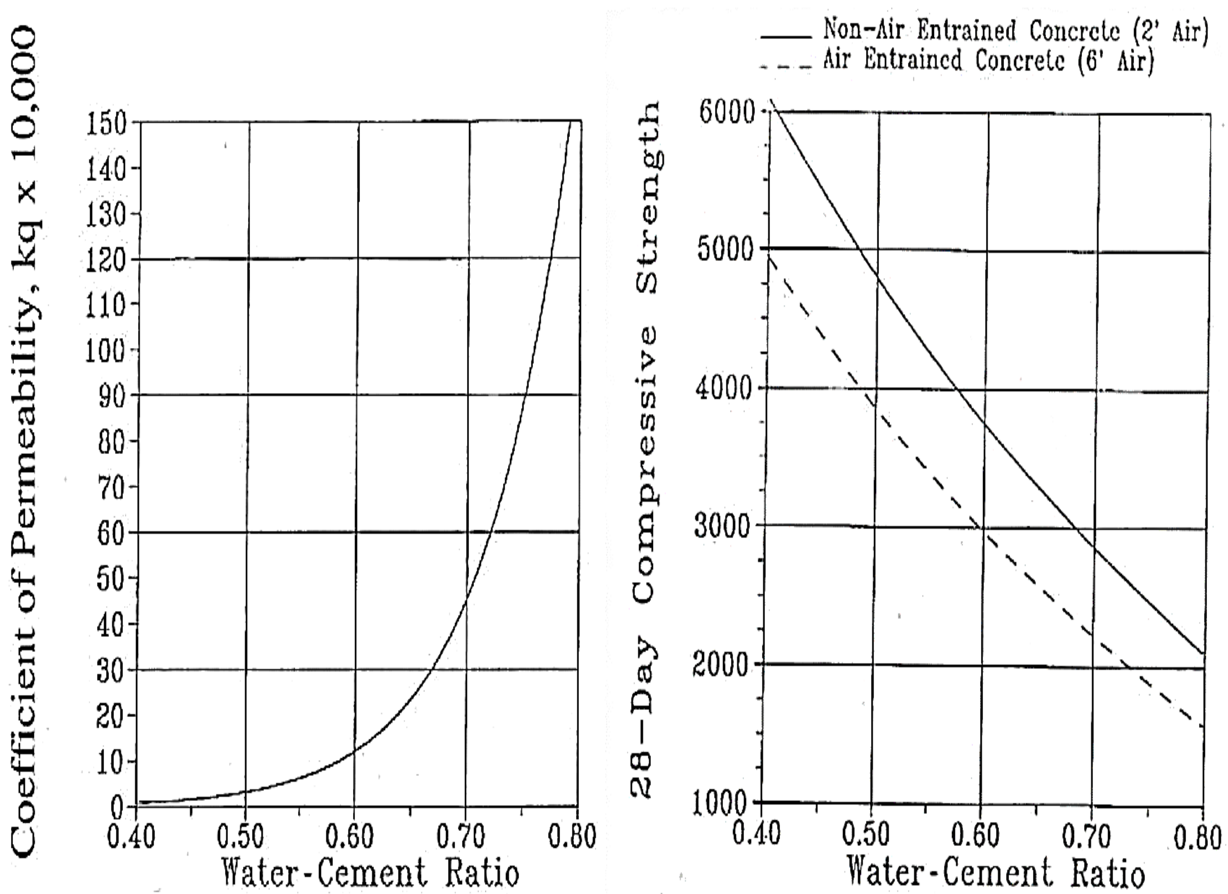
2.2.6 Proportioning

2.2.6.1 Water-to-Cementations Materials Ratio

The water-to-cementations materials ratio (w/cm) has a significant impact on many properties of plastic and hardened concrete. In fact, w/cm has been recognized as the most important quantity associated with strength and durability (Hover and Stokes 1995). Many studies have shown the correlation between compressive strength and permeability with w/cm, such as the one shown in Graph 2-1. Lower w/cm ratio results in higher compressive strength and lower permeability. By lowering the w/cm ratio, the water content is decreased and in turn, drying shrinkage and cracking is also reduced (Kosmatka et al. 2003).

Although low w/cm ratios have long-term as well as short-term benefits, low w/cm ratios have a negative effect on the workability of concrete. Lower slump results from having a low w/cm ratio in the mixture. To utilize the high strength and low permeability properties of low w/cm ratios without compromising workability, other cementations materials or chemical admixtures such as water reducers can be used.

Graph2. 1**:** Water-Cement Ratio



2.2.6.2 Volume of concrete Paste

The amount of cement paste in a concrete mixture must be determined to fill the voids between aggregates, as well as cover the aggregates and separate them to reduce inter-particle friction between aggregates while the concrete is in its fresh state (Koehler 2014; Kosmatka et al. 2003; Taylor et al. 2015). Air voids can be formed in concrete when the volume of cement paste in the concrete mixture is in sufficient ACI Committee 232 2003; Lane 1983).

2.2.6.3 Curing Conditions

The curing temperature of concrete is arguably the one parameter that has the most significant effect on the rate of hydration (Schindler 2004), and, therefore, has a highly significant effect on strength gain of concrete. Early strength of concrete is increased with higher curing temperatures due to the more rapid hydration. Alternatively, the ultimate strength of concrete typically decreases with higher curing temperatures (Mindess and Young 1981). Since early strength development is the priority in this research, higher curing temperatures are beneficial. For hot-weather curing, this will not be an issue. For cold-weather curing, there are measures that can be taken in the field to ensure the necessary curing temperature will be maintained, such as heating blankets. Heating blankets can be used to heat concrete up to 60°F and above ambient temperature at curing, as stated by Heat Authority, a heating blanket company (Heat Authority 2015).

2.2.7 Previous studies samples and results obtained by partial replacement of cement with fly ash and sand by quarry dust.

This research study presents the strength variations of concrete when replacing fine aggregate by quarry dust and cement by fly ash from 0%, 20%, 30%, 40% and 50% (Vetriselvan M, 2018).

Table 2.5. Compressive strength of FA and QD cubes with admixture.

% of FA & QD	Proteins %	Compressive strength in N/mm^2		
		7 th day	14 th day	28 thday
0	0.5	19.2	22.3	25.9
20	0.5	20.6	23.6	37.8
30	0.5	18.9	27.1	38
40	0.5	23.2	25.2	39
50	0.5	19.5	30.1	42.3

According to this study, by replacing cement by fly ash and fine aggregate by quarry dust and adding admixture, the maximum result was obtained with 50% partial replacement as 42.3MPa at 28th day (Vetriselvan M, 2018). It also shows as replacement can be up to 50%.

Table 2.6. Split tensile strength of FA and QD specimen with admixture.

% of FA & QD with admixture	Curing days		Split tensile strength(N/mm^2)	
	14 days	28 days	14 days	28 days
0	235	286	3.27	3.97
20	229	291	3.28	4.08
30	243	318	3.39	4,45
40	257	323	3.61	4.53
50	199	247	3.24	3.42

The maximum split tensile strength of the concrete with partial replacement of cement by fly ash and sand by quarry dust was 4.53 MPa at 28th day and obtained at 40% partial replacement. According to this study, as it can be observed from the above table 2.6, the replacement possibility was up to 50% (Vetriselvan M, 2018).

Table 2.7. Flexural strength of FA and QD beam.

% of FA & QD	Load(KN)			Flexural Strength (N/mm^2)
	Trial 1	Trial 2	Trial 3	
0	12	10	11	4.4
20	16	12	14	5.6
30	15	17	16	6.4
40	13	16	14.5	5.8
50	14	17	15.5	6.2

For flexural strength with partial replacement of cement with fly ash and sand by quarry dust of 28^{th} day, the maximum value was 6.4MPa which obtained at 30% partial replacement as it has been shown in table 2.7. (Vetriselvan M, 2018).

2.2.8 Compressive strength of M30 concrete from partial replacement of cement by fly ash and quarry dust for sand

The results obtained from partial replacement of cement by fly ash and sand by quarry dust and its compressive strength test of conventional concrete and fly ash and quarry dust replacement for 7, 14 and 28 days are shown below. Compressive strength tests of conventional concrete as well as replacement of cement by fly ash, replacement of sand by quarry dust and replacement of cement and sand by fly ash and quarry dust respectively were conducted and the test results are presented below from previous studies (I Rohini et al. 2016).

Table 2.8. Compressive Strength of M30, Conventional concrete.

Sl. No.	No. of curing days	Number of specimen	Initial crack load(kN)	Ultimate load(kN)	Ultimate compressive strength(N/mm^2)
1	7	3	326.155	596.250	26.50
2	14	3	556.621	733.500	32.60
3	28	3	599.264	877.500	39.00

According to the above table 2.8, the maximum compressive strength of conventional concrete or without partial replacement at 28^{th} day was 39MPa.

2.2.8.1 Compressive strength of partial replacement of fly ash and quarry dust cubes at 14days

Table 2.9. Compressive strength of FA and QD cubes of 14 days.

Sl. No.	Partial replacement in %	Number of specimen	Initial crack load (kN)	Ultimate load(kN)	Ultimate compressive strength (N/mm^2)
1	20	3	523.254	774.675	34.43
2	30	3	559.213	793.350	35.26
3	40	3	609.652	822.600	36.56
4	50	3	549.264	771.525	34.29
5	60	3	483.658	735.750	32.70

2.2.8.2 Compressive strength of partial replacement of fly ash and quarry dust cubes at 14days

Table 2.10. Compressive strength of FA and QD cubes of 28 days.

Sl. No.	Partial replacement in %	Number of specimen	Initial crack load(kN)	Ultimate load(kN)	Ultimate compressive strength (N/mm^2)
1	20	3	680.655	951.750	42.30
2	30	3	685.262	968.175	43.03
3	40	3	696.254	981.450	43.62
4	50	3	675.652	963.000	42.80
5	60	3	653.155	941.400	41.84

According to this study, by replacing cement by fly ash and fine aggregate by quarry dust, the maximum result was obtained as 36.56MPa with 40% partial replacement at 14^{th} day and 43.62MPa with 40% partial replacement at 28^{th} day. Therefore, it can be concluded that 40% replacement of cement and fine aggregate by fly ash and quarry dust is further encouraging and acceptable (I Rohini et al. 2016).

Therefore, based up on the prevailing previous studies, the currently conducted study on partial replacement of the cement by wastes like fly ash and basaltic dust to induce strength in concrete with 0%, 10%, 20%, 30%, 40% and 50% in step by step was provides good result with respect to the previous one and its compressive strength, split tensile strength and flexural strength within 7days, 14days and 28 days were checked respectively.

CHAPTER THREE

3. METHODOLOGY AND MATERIALS OF STUDY

3.1 Materials and Methodology

To develop the concrete mixture designs intended for the application specified in research objective, a series of iterative trial batch concrete mixtures were conducted. The trial batch concrete mixtures have a goal of achieving adequate strength and constructability, while taking measures to generate a concrete mixture with durable properties. The iterative process of mixing and testing trial batch concrete mixtures leads to the development of two selected concrete mixture (The conventional and partially replaced one). Two of the concrete mixtures, which will satisfy the target strength and constructability properties, when selected for further testing. Once selected, a set of additional short-term tests were conducted.

For this research, short term tests refer to tests that take less than 30 days was completed. Finally, concrete mixture design specifications were developed for accelerated construction techniques, where guidelines are provided to develop concrete mixtures for this specific application. This chapter also discusses the trial batches which was mixed and tested, as well as the iterative process used to develop the concrete mixtures designs and concrete ingredients required for the research. In other words, this chapter covers up to the “selected concrete mixtures or ingredients”. A full report of trial batch test results and concrete ingredients was provided and test results of the selected concrete mixtures in the next chapter.

3.2 Materials Required for the Prevailing Research/ Concrete Ingredients

3.2.1 Cement

Several studies have investigated the effect of cement type on of early strength development in concrete. Many types of cement that are used to produce an early strength concrete mixture are proprietary, such as Ultimax Cement and Ordinary Portland Cement. Therefore, Ordinary Portland Cement (OPC) with grade of 42.5R, Dangote or C-30 has been used having fines modulus of 2.05, Specific gravity of 2.95, and Initial and final setting time of 92 minutes and 502 minutes respectively. But, it is expected that partial replacement of cement by wastes, fly ash and basaltic dust would retard both initial and final setting time of the cement as its glue mass to bind increases and reduction of tricalcium silicate Ca_3S_2 than the normal cement.

3.2.2 Fly ash

Fly ash was collected from Ethiopian 'Reppie Waste Electric Power Plant'. Fly ash is a heterogeneous by-product material produced in the combustion process of coal or wastes used in power stations. It is a fine grey colored powder having spherical glassy particles that rise with the flue gases. Fly ash contains pozzolanic materials components which reach with lime to form cementations materials. Thus, fly ash is used in concrete, mines, landfills and dams as environmental benefits related to the disposal of waste materials and to reduce carbon dioxide emissions.

The fineness of fly ash is important because it affects the rate of pozzolanic activity and the workability of the concrete. Specifications require a minimum of 66 percent passing the 0.044 mm (No. 325) sieve, specific gravity 2.3 and moisture content 3.05%. Some metals (e.g. Ba and Cr) are present at the same concentration level in all the residues, some (notably Cu) are usually enriched in the bottom ash, whereas Several heavy trace elements, particularly more volatile elements (e.g. Cd, Hg, As, Pb and Zn) are enriched in the fly ash and acid gas scrubbing residues.

However, currently the most common technique consists of the solidification/stabilization of residues through mixing with cement/ or inorganic binding agents. The primary drawback of such methods is the requirement for using a high binder/ash ratio resulting to an almost doubled amount of mass to be disposed. In addition, some elements like Cd, Cr, Mo and Zn may not sufficiently encapsulate to meet the required leaching standards.

Several, pre-treatment options have been proposed for the conversion of Municipality Solid Waste (MSWI) fly ash to a cementation's material without an excessive release of metals, including washing by nitric acid at pH4 and mixing by salts of phosphorous and etc.

Silicate analysis of fly ash has been done and the following result was obtained.

Analytical result is in percent (%) element to be determined major oxides and minor oxides

Table 3.1 Complete Silicate Analysis Report of Fly ash.

Collector's Code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI	Cl^{-1}
Fly ash	33.32	8.60	4.46	23.56	2.28	1.48	5.22	0.26	1.69	0.23	1.42	12.41	5.84

Silicate analysis of fly ash and basaltic dust blended together has been done to stabilize the fly ash as cl^{-1} is higher (5.84%) and the following result was obtained.
Analytical result is in percent (%) element to be determined major oxides and minor oxides

Table 3.2 Complete Silicate Analysis Report of Fly ash and Basaltic Dust/ Blended.

Collector's Code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI	Cl^{-1}
FA & BD	48.30	13.82	7.74	11.36	3.46	1.36	2.18	0.28	1.10	0.49	1.62	6.97	2.01

From the complete silicate analysis report of fly ash cl^{-1} is 5.84% which seems greater than the allowed value, (5.0- 0.1%) from CES 28-2013, Table B.1. Cement type-III (42.5R) may contain more than 0.10% chloride, but in such case it is necessary to declare the actual chloride content as more amount of chloride exists in reinforced concrete is not recommended hence it induces corrosion. Still one can use the blended amount (2.01%) of chloride as best option in case there is exposure of moist corrosion and water tight structures construction.

Figure 3. 1: Fly ash

3.2.3 Basaltic Dust

Waste basalt powder was obtained from Asphalt batch mix plant. Asphalt mixture production leads to formation of significant amounts of by-product in the form of mineral powder. Mineral powder used in this study is the origin of basalt hence it is defined as a basalt powder or basaltic dust. The quarry dust can be defined as residue, tailing or other non-voluble waste material after extraction and processing of rocks to form fine particles less than 4.75 mm. The particle diameters are in the range of 1.5 to 200 μm. The largest volume, i.e. ca. 49%, is occupied by particles of about 19.89 μm in diameter. The specific gravity of powder is 2.63 g/cm3 and Blaine specific surface is 3500 cm2/g. Chemical composition is typical for basalt rock, i.e. Silica and alumina oxide dominate, which is in about 49% and calcium and iron oxide.

It was collected from Ethiopian Construction Works Corporation, Alemgena District 'Sabbata Asphalt plant', with the following physical properties.

Table3. 3: Basaltic Dust and its physical properties

S/No.	Properties	Values
1	Specific gravity	2.63
2	Bulk density (kg/m^3)	2.15
3	Fineness Modulus	2.64
4	% of voids	20.25
5	Water absorption	0.75

Table 3.4. Complete Silicate Analysis Report of Basaltic Dust.

Analytical result is in percent (%) element to be determined major oxides and minor oxides

Collector's Code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI	Cl^{-1}
Basaltic D.	57.52	16.17	9.92	5.46	4.20	1.44	0.90	0.28	0.35	0.47	1.78	2.21	<0.10

From complete silicate analysis report of basaltic dust, cl^{-1} is < 0.10% and hence it is the best fit to be partially replaced (CES 28, 2013). It also helps us by being blended with fly ash to produce good cl^{-1} result as shown in table 3.2.

Figure 3. 2: basaltic dust

3.2.4 River Sand from Mathahara (FA)

As commonly known the key function of sand in concrete is to fill the voids. As attempted to be mentioned above, the prevailing sand is from Mathahara River with following gradation properties.

3.2.4.1 Sand Gradation analysis

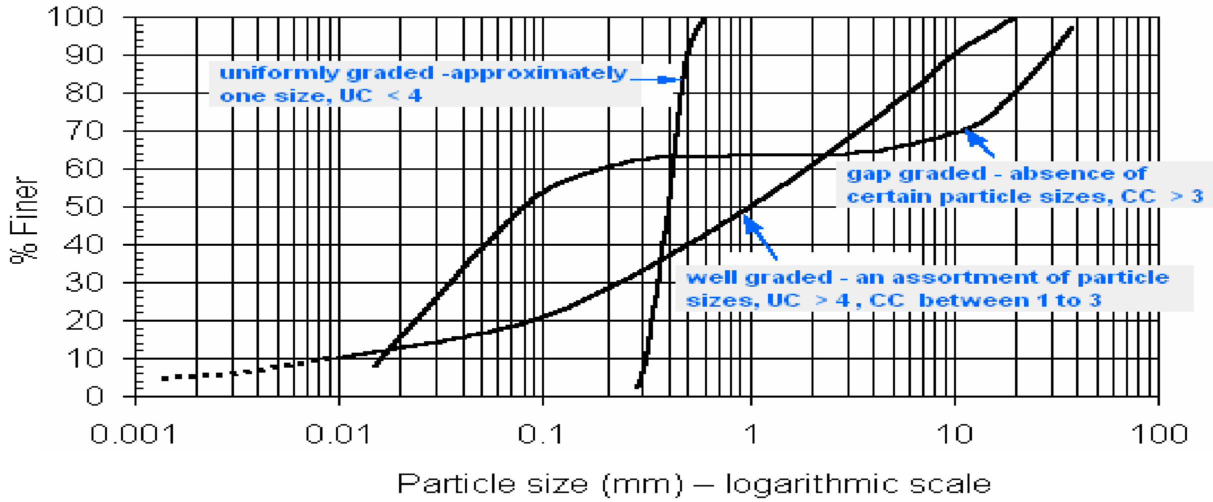
Total mass of dry sand (gm) = 1650.45

Table3. 5: Sand Gradation Analysis

S/N	Sieve Size (mm)	Mass Retained (gm)	Cumulative Mass Retained(gm)	Cumulative Mass Retained (%)	Mass Retained (%)	Percentage of Passing	Lower limits	Upper limits
1	9.5	0	0	0	0	100	100	100
2	4.75	17.5	17.50	1.05	1.05	98.95	85	100
3	2.36	49.8	67.30	4.03	2.98	95.97	68	86
4	1.18	146	213.30	12.78	8.75	87.22	47	65
5	0.6	437.8	651.10	39.00	26.23	61.00	27	42
6	0.3	749.3	1400.40	83.89	44.89	16.11	9	20
7	0.15	249.7	1650.10	98.85	14.96	1.15	0	7
8	0.075	0.1	1650.20	98.86	0.01	1.14	0	2.5
9	Pan	19.1						
10			**FM**	**3.38**				

FM- Fineness modulus is how coarser or finer the prevailing concrete aggregate is and hence based up on its value, the sand particle distribution is coarser and also based up on its percentage of passing of the sand with respect to its upper and lower limit it is poorly graded.

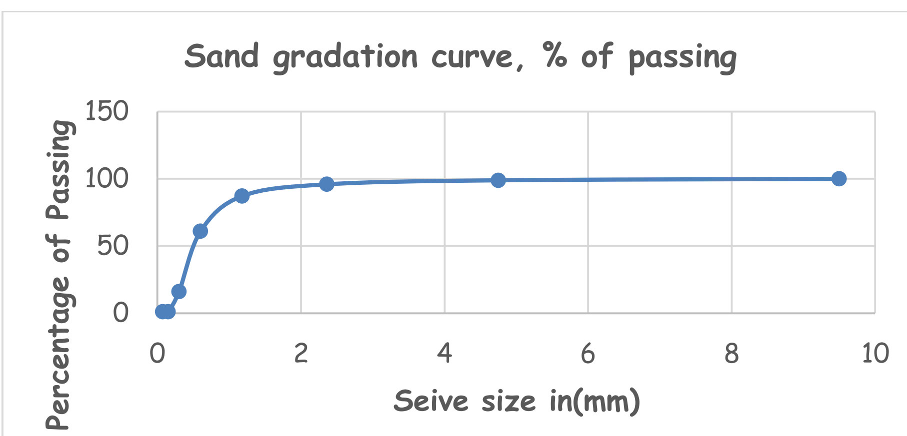
Graph3.1 Gradation Curve



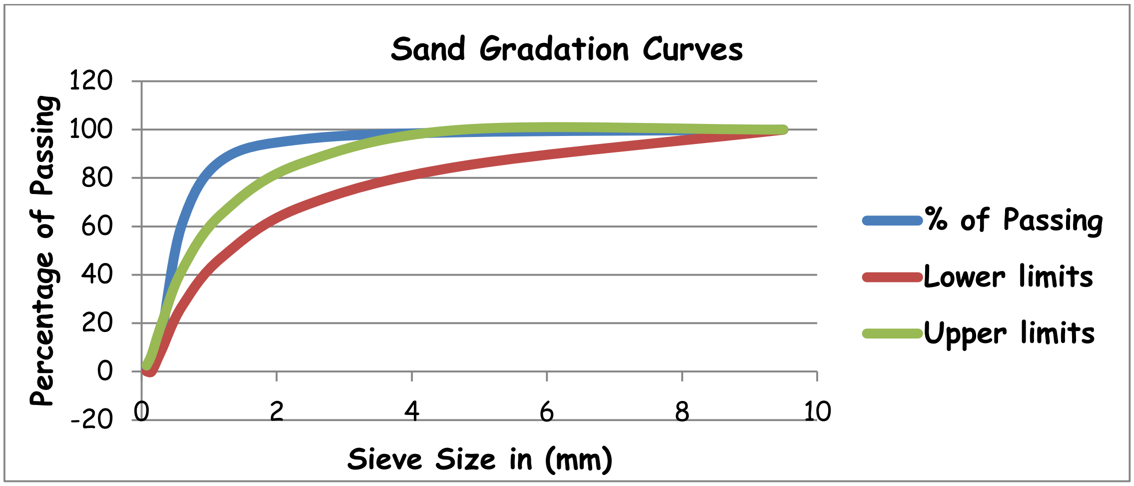
To classify the prevailing sand gradation type, based up on Fuller-Thomson gradation curves, it is calculated that UC=2.50 and CC=1.072, where $UC = \frac{D60}{D10}$ and $CC = \frac{D30^2}{D10*D60}$, where UC is Uniformity Coefficient and CC is Coefficient of Curvature and D10=0.24, D30=0.392 and D60=0.60, where DX is the diameter of the sand particles for which X% of the particles are finer.

Since Fineness modulus value shows us how finer or coarser the prevailing particles are and hence the sand is coarser and might needs to be blended with other source river sand to obtain the best quality or well graded sand. For this study, it was used as it is regardless of its uniformly graded.

Graph3.2: Sand Gradation Curve, % of passing



Graph3.3: Sand Gradation Curves with its limits



Percentage of passing or the prevailing sand percentage of passing is out of the range for sieve size of 4mmm-1.0mm with respect to its upper and lower limits and hence, thus why it is poorly graded. The addition physical properties of the sand are as follows (details are attached as appendix):

- Bulk Specific Gravity (dry basis) =1.824
- Bulk Specific Gravity (SSD basis) =1.934
- Absorption = 6.045%
- Moisture Content = 7.348%
- Fines Modulus of Fine Aggregate = 3.38
- Silt Content of the Sand = 1.67%
- Uniformity Coefficient =2.50
- Coefficient of Curvature =1.072
- Gradation Type V-Curve/Poor Graded/Uniformly Graded

Figure 3. 3: Sieve sizes and prevailing river sand

3.2.5 Coarser Concrete Aggregate (CA) from Awash

Concrete gets its compressive strength from the coarser aggregate. The concrete aggregate used for the research is purely basaltic and the nominal maximum aggregate size is 19mm.

Other physical and mineralogical properties of aggregate must be known before mixing concrete to obtain a desirable mixture. These properties include shape and texture, size gradation, moisture content, specific gravity, reactivity, soundness and bulk unit weight. These properties along with the water/cementations material ratio determine the strength, workability and durability of concrete.

Most natural sands and gravel from riverbeds or seashores are smooth and rounded and are excellent aggregates. Crushed stone produces much more angular and elongated aggregates, which have a higher surface-to-volume ratio, better bond characteristics but require more cement paste to produce a workable mixture.

3.2.5.1 Concrete Aggregate Gradation Analysis

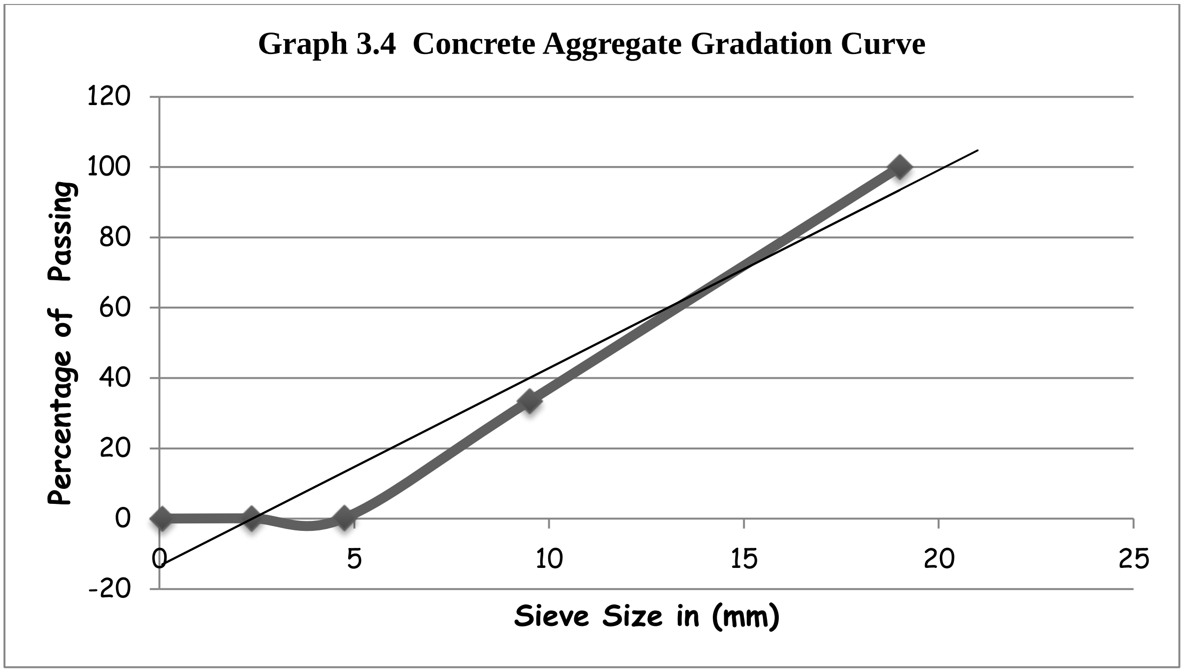
Total mass of dry Coarser Aggregate (gm.) = 6115.025

It can be observed that its percentage of passing with respect to its upper and lower limits shows the type of the prevailing coarser aggregate as well as its quality.

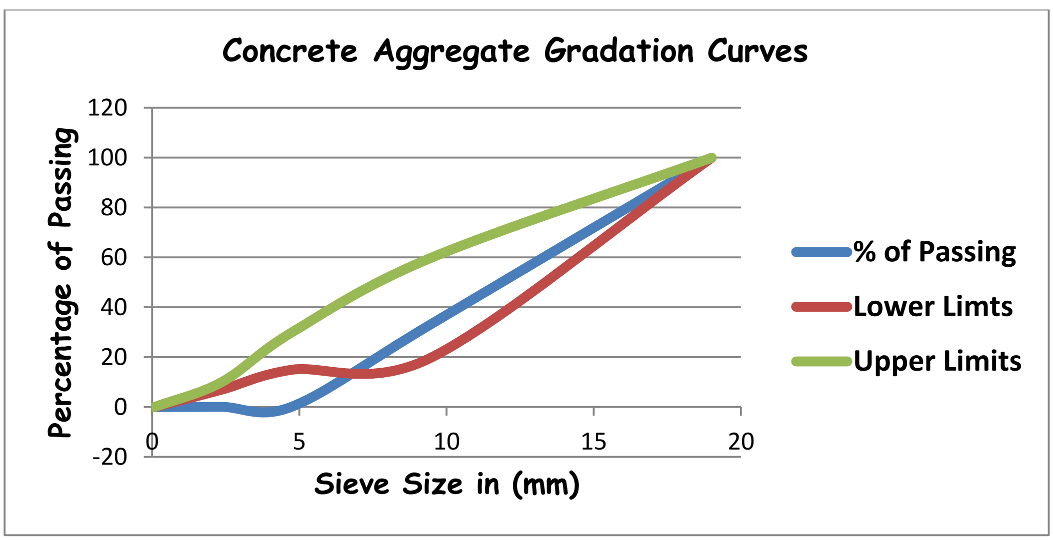
Table3.6: Concrete Aggregate Gradation Analysis

S/N	Sieve Size (mm)	Mass Retained(gm)	Cumulative Mass Retained(gm)	Cumulative Mass Retained (%)	Mass Retained (%)	Percentage of Passing	Lower limits	Upper limits
1	19	0	0	0	0	100	100	100
2	9.5	4070	4070.00	66.56	66.56	33.44	20.00	60
3	4.75	2035	6105.00	99.84	33.28	0.16	15.00	30
4	2.36	5	6110.00	99.92	0.08	0.082	7.00	10
5	0.075	5	6115.00	100.00	0.08	0		
6	Pan	0						

Fineness Modulus **3.66**



Graph3.5: Concrete Aggregate Gradation Curves with its limits

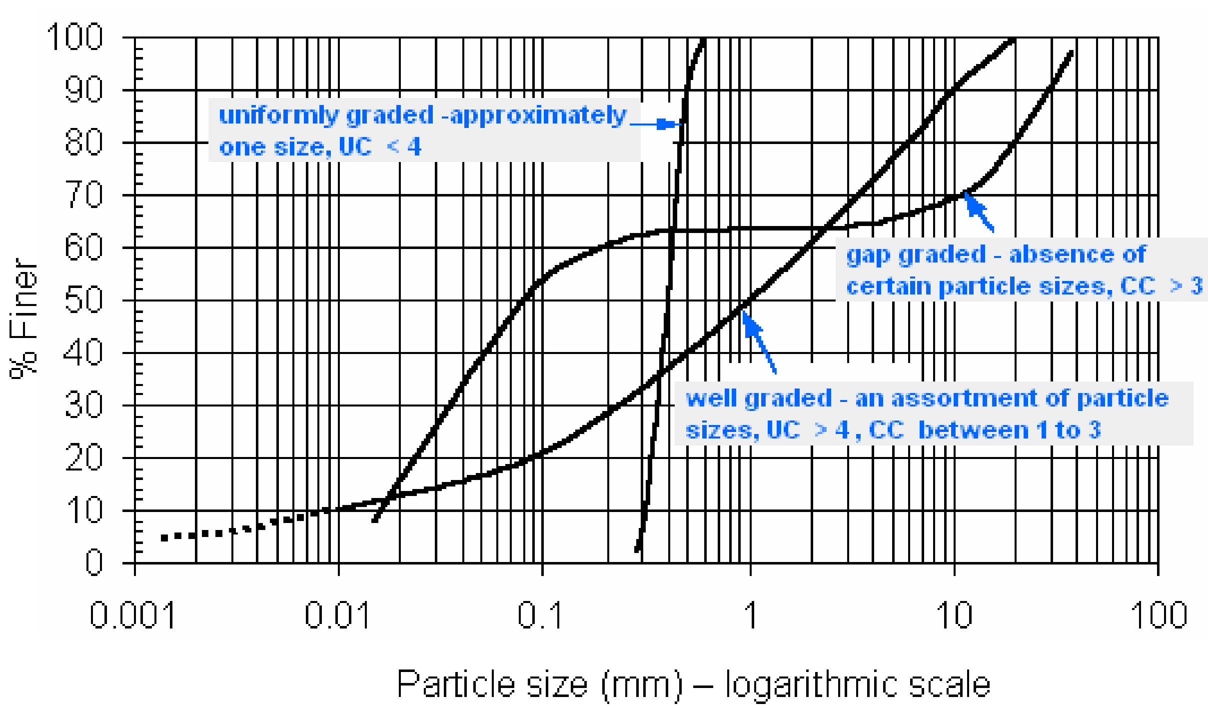


Based up on the gradation analysis that has done above, concrete aggregate with nominal size of 19mm contains finer aggregate particles and thus expected to be blended with other size aggregate to obtain best quality aggregate. But, it has been used as it is regardless of its FM.

Furthermore, to classify the prevailing concrete aggregate, it is calculated that UC=2.16 and CC=0.992, where $UC = \frac{D60}{D10}$and $CC = \frac{D30^2}{D10*D60}$, hence UC is Uniformity Coefficient and CC is Coefficient of Curvature and D10=6.1544, D30=9.01 and D60=13.291, Where DX is the diameter of the aggregate particles for which X% of the particles are finer.

Since Fineness modulus value shows us how finer or coarser the prevailing particles are and hence the aggregate is finer and might needs to be blended with other crushed aggregates to obtain the best quality or well graded concrete aggregate. For this study, it was used as it is regardless of its uniformly graded/poor graded as per Fuller-Thomson Gradation Curves.

Graph 3.6 Gradation Curves limits



The addition physical properties of the coarser aggregate are as follows (details are attached as appendix):

- Bulk Specific Gravity (dry basis) = 2.877
- Bulk Specific Gravity (SSD basis) = 2.907
- Absorption = 1.055%
- Moisture Content = 0.735%
- Fines Modulus of Fine Aggregate = 3.66
- Uniformity Coefficient =2.160
- Coefficient of Curvature =0.992
- Gradation Type V-Curve/Poor Graded/Uniformly Graded

Figure 3. 4: Prevailing Coarser Concrete Aggregate Quartering

3.2.6 Accelerating/Curing Admixture

Accelerating admixtures are used to accelerate the rate of hydration that occurs in concrete, which accelerates the set time and the early strength development of concrete. There are many chemicals used to accelerate the rate of hydration, but calcium chloride is the one most commonly used in accelerating admixtures. Calcium chloride has been proven to shorten the set time and accelerate the early strength development. The increased rate of hydration will also result in other benefits including earlier finishing time, reduced bleeding, improved protection against early exposure to freeze thaw cycles and earlier use of a structure.

From the literature review, accelerating admixtures have shown to cause increased drying shrinkage in concrete mixtures. So, although the accelerating admixtures will help to reach the early strength goal of this research, it has its own adverse impact unless otherwise used accordingly.

As commonly known, the main function of Accelerator Admixture is to enhance early strength of the concrete and accelerate curing time. Most researches show that the usage of accelerator admixture is 2% by mass of cementing material, cement (ACI Committee E-701 2003; Kosmatka et al. 2003). But, for the need of reality beyond working scenario like manually and mechanically, the recommended amount of accelerator admixture is half of liter for $1m^3$ of concrete mixture and hence to minimize its drawbacks like corrosion of reinforcement around moist area and early shrinkage of the concrete.

The currently used accelerator is calcium chloride, $Cacl_2$ in solution form.

3.3 Methodology and Validity of the Prevailing Research Results

- How to check the structural properties of the concrete after prepared in laboratory?

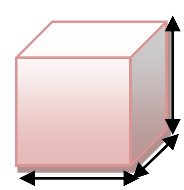
3.3.1 Compressive Strength of the Concrete

Compressive strength of the concrete is the major strength that concrete structures should have primarily and usually for axial members like Column, Piers, Shear or structural walls and so on. Compressive strength can be calculated as the normal stress of the concrete, when the critical force/load is applied to the cross-sectional area of the concrete structure, Area should be perpendicular to the applied load/force.

$\text{Stress} = \frac{Force}{Area}$, Where Force is the critical load applied, crack causing force and Area is the cross-sectional area of the concrete, calculated as A= length * width.

Hence the used cubes samples are 15cm*15cm*15cm. Therefore,

$A = 0.15m * 0.15\ m = \underline{\underline{0.0225m^2}}$



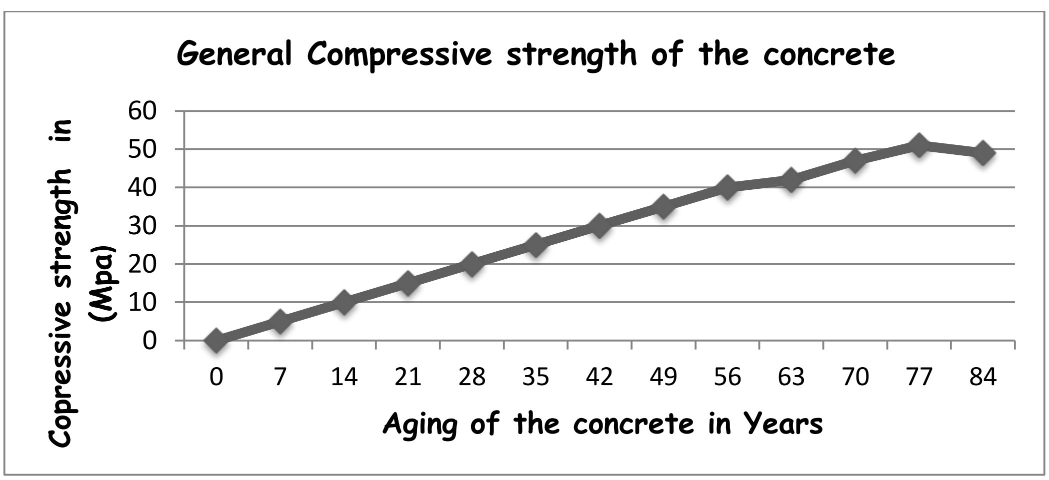
3.3.2 Confidence Interval of compressive strength of concrete result (C-30)

Experimentally obtained results were compared to the conventional strength of the concrete with respect to its aging as follows.

Table3. 7: Confidence Intervals of compressive strength of concrete result (C-30)

S/N	Quantity of Samples	Cement Replacement. In %	Compressive Strength of the prevailing Concrete (C-30) Samples (Mpa)				Comments
			Age of Concrete samples in days				
			7 (69-70%)	14 (89-90%)	28 (100%)	56(Durability)	Consider 30%
			21	27	30	Permeability	
1	9	0	33.27	34.35	36.50	"	Valid
2	9	10	33.77	35.62	39.33	"	"
3	9	20	35.51	37.33	40.98	"	"
4	9	30	35.92	38.10	42.47	"	"
5	9	40	20.01	22.76	28.26	"	"
6	9	50	15.25	16.81	19.42	"	**Not**
7	9	60					

Graph3. 7: General Compressive strength of the concrete



3.3.3 Split Tensile Strength of the Concrete

Split tensile strength of the concrete is indirect tensile strength of the concrete required most of the time for fully supported concrete structures or less deflection, concrete bond strength usually for concrete structures like rigid pavements, mat foundations, ground slab, grade beams and others to check its brittle or crushing and crack resistance or bond strength. Furthermore, splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Samples are usually cylindrical and the intended strength was calculated as follows.

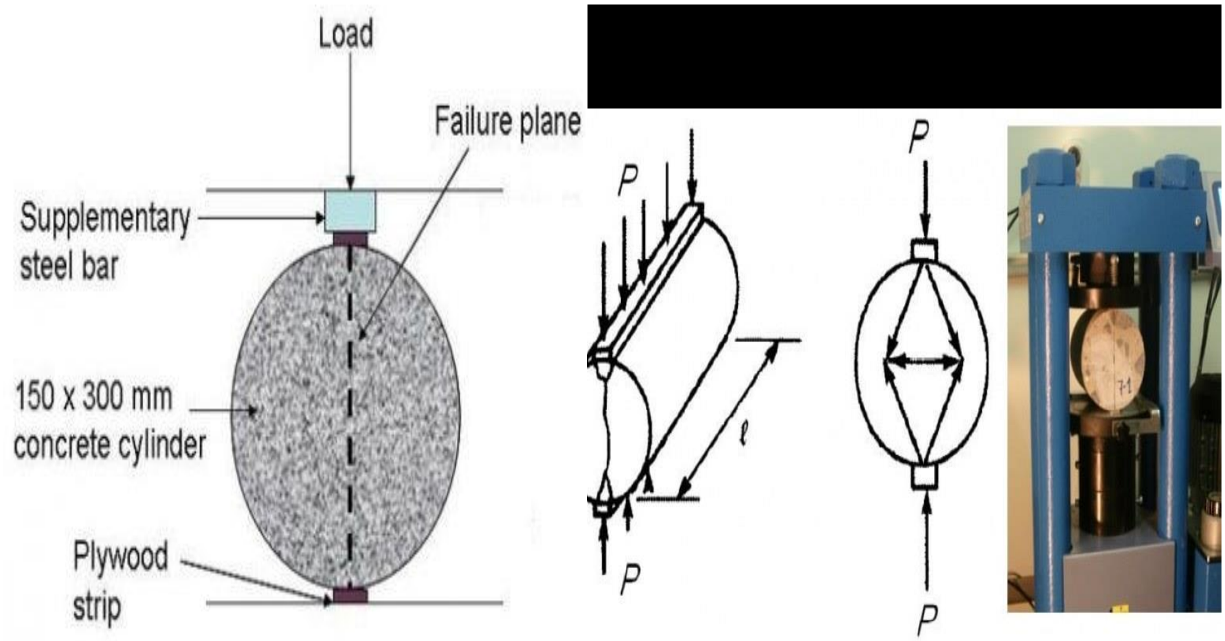


Figure 3.5: Load distribution of Split tensile strength of concrete

Split Tensile Strength $= \frac{2P}{\pi Øl}$, where P is crack forming load

Ø is diameter of cylinder

ℓ is the length of the cylinder

π is constant as 3.14

Hence from the prepared cylindrical samples, $\pi Ø \ell$ is surface area of concrete sample =0.1413m2

3.3.4 Flexural Strength of the Concrete

Flexural strength/ Modulus of rupture of the concrete or tensile strength of the concrete is the weakest side of the concrete structures and hence thus why we provide the reinforcement bars in tension zone of concrete structures. This type of test is usually for flexural members or out of plane members like slab, beams, Shear walls and Retaining walls for lateral loads. It can be either single loading system or center point loading and double loading system or two-point loading. Samples can be either 10cm*10cm*50cm or 15cm*15cm*70cm. But, in this particular study, the samples used were 10cm*10cm*50cm and Center point loading system.

Therefore, numerically the flexural strength or modulus of rupture of the concrete sample with 10cm*10cm*50cm is as follows:

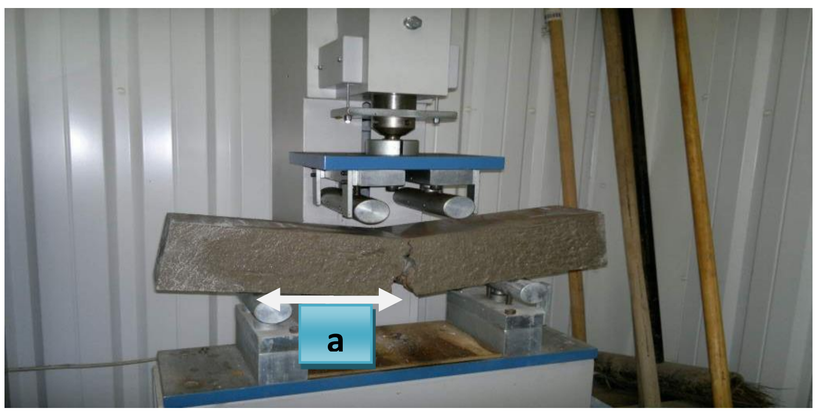


Figure 3. 6: Center point loading for flexural member

1.Flexural Strength/ Modulus of Rupture of concrete $= \frac{PL}{bd^2}$, for a ≥13cm or

2.Flexural Strength/ Modulus of Rupture of concrete $= \frac{3Pa}{bd^2}$, for 11cm< a ≤ 13.3cm

Where, **b** = Width of the beam in cm

d = Failure point depth in cm

L = Support length in cm

P = Maximum load applied to the beam in KN and

a = Distance between the line of fracture and the nearest support as shown in figure 3.6

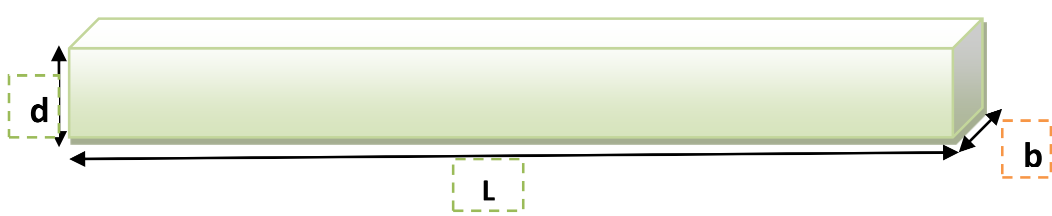
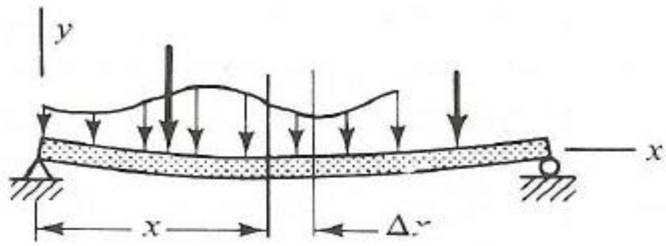


Figure 3.7: Prevailing beam model.

3.3.4.1 Flexural Stresses in Beams

A beam is a structural member whose length is large compared to its depth which is loaded and supported in the direction transverse to its axis/Flexural or out of plane loading. Lateral loads acting on the beam cause the beam to bend or flex, thereby deforming the axis of the beam into a curved line. Consider the stresses and strains associated with bending moments and beam subjected to an arbitrary transverse load.



After certain rearrangements, the flexural stress/ strength of the prevailing beam is as follows:

$\sigma = \frac{My}{I}$ Where, σ- Stress- Bending moment, I- Moment of inertia and y- Distance from neutral axis of the beam.

Numerically, for simply supported beam and center point loading:

$M = \frac{PL}{4}$, Where P is cracking load from the reading and L is span length of the beam

$I = \frac{bh^3}{12}$, Where b/h = 10/10, beam width and depth

y= h/2, Where y is the depth from neutral axis to the top fibers or bottom fiber

Hence y=d/2=10cm/2 = 5cm = 0.05m, L= 50cm =0.5m and $I=bh^3/12=0.1*0.13/12=\underline{\underline{8.33*10^{-6}}}m^4$

For example;

If P= 9.26KN (Maximum load on the beam for 20% partial replacement at 28^{th} day)

$$M = \frac{PL}{4} = \frac{9.26*0.5}{4} = \underline{\underline{1.157}}\ \text{KN.m}$$

$$\text{Therefore, } \sigma = \frac{My}{I} = \frac{1.157\text{KN.m}*0.05\text{m}}{8.33*10^{-6}\text{m}^4} = \underline{\underline{6.94}}\ \text{MPa}$$

Hence, the maximum expected flexural strength/stress of the prevailing beam, the confidence interval of hypothetical result would be up to 6.94 MPa).

Therefore, by using the above described concrete ingredients quality and specifications, cement, fly ash, basaltic dust, sand, concrete aggregate, calcium chloride and water, attractive results were obtained accordingly.

Samples preparation scenarios/molds

Figure3. 7: The molds used for the prevailing study, (108) samples were prepared

CHAPTER FOUR

4. RESULTS AND DISCUSSION

4.1 Experimental Result and its Analysis

The concrete ingredients used for this research were attempted to be clarified as per its quality and physical properties which has been done in laboratory thoroughly. Regardless of its poor quality, both fine and coarser aggregate, trial mix has been prepared by using already calculated mix ratio and mix design as attempted to be shown in chapter three.

By using the already calculated mix design and mix ratio, the following results were obtained as trial mix.

Figure 4.1: Dry mix preparation

Dry mix is recommended usually for experimental purpose and to be assured that all ingredients like coarser and fine aggregates, cement, fly ash and basaltic dust are mixed thoroughly before water is added. Once dry mix is ready, water added to the prevailing mix and the following slumps were obtained.

Figure 4.2: Prevailing Concrete Mix and Slump test of Conventional Concrete

Figure 4.3: Prevailing Concrete Mix and Slump test of 20% Cement partial replacement by Fly ash and Basaltic dust

It was observed that conventional concrete results more slump depth (37mm) than the partially replaced one (35mm). This implies that as partial replacement amount of wastes increases, slump depth decreases and also workability decreases while strength increases, due to increase in amount of binding materials, glue in mass until ultimate strength value reached.

Figure 4.4: Concrete samples preparation and its curing scenario with different replacement amount of wastes (fly ash and basaltic dust)

4.2 Structural Properties of the Concrete

4.2.1 Compressive Strength of the Conventional Concrete at 7 days

Table4.1: Compressive Strength of the Conventional Concrete at 7 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Compressive Strength(Mpa)
		Cubic	L	W	H					
1	7		150	150	150	0	8237	0.0225	747.80	33.24
2	7		150	150	150	0	8149	0.0225	722.80	32.12
3	7		150	150	150	0	8257	0.0225	774.80	34.44
Mean Value									**748.47**	**33.27**

Figure 4.5: Compressive Strength of the Conventional Concrete at 7 days

4.2.2 Trial Mix Validity of the Conventional Concrete Result (C-30)

Since the conventional concrete compressive strength at 7th days is expected to be 70% of the cubic compressive strength of C-30 and hence 0.7*30 = 21Mpa. But the mean result obtained from the prevailing mix is 33.27 MPa which is more than of 100% of C-30 which is 30Mpa. If the effect of accelerator 30% is considered, the expected result would be =1.3*21Mpa = 27.3MPa which is still less than the obtained value (33.27MPa). It implies that trial mix satisfies the confidence interval of the expected results.

4.2.3 Compressive Strength of the partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 7 days

Table4.2: Compressive Strength of the partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 7 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replacement Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Compressive Strength(Mpa)
		Cubic	L	W	H					
1	7		150	150	150	20	8086	0.0225	775.50	34.47
2	7		150	150	150	20	8080	0.0225	812.60	36.12
3	7		150	150	150	20	7992	0.0225	808.90	35.95
Mean Value									**799.00**	**35.51**

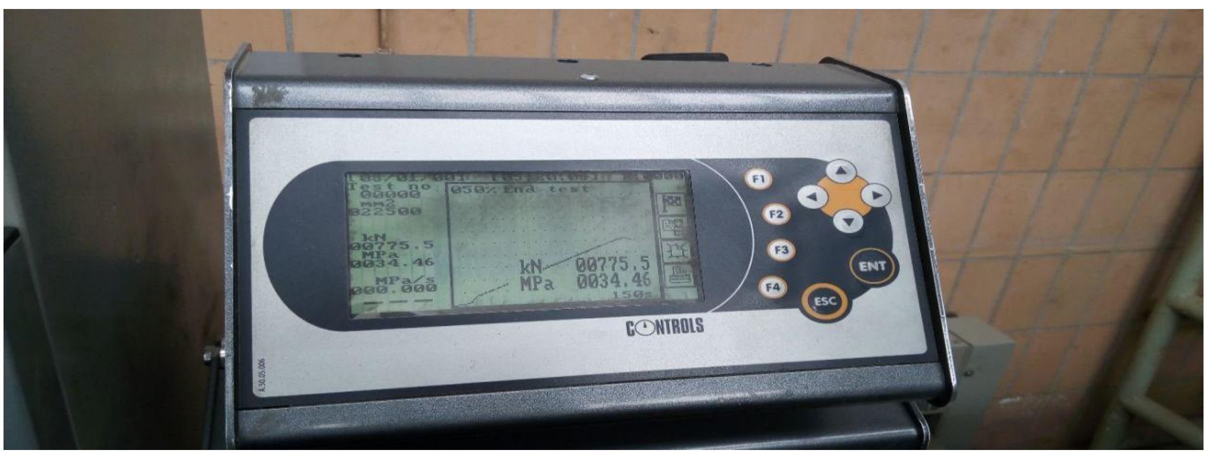


Figure 4.6: Compressive Strength of the partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 7 days.

4.2.3.1 Trial Mix Validity of the partially replaced (20%) Concrete Result (C-30)

Since the expected conventional concrete compressive strength at 7th days is 70% of the cubic compressive strength of C-30 and hence 0.7*30 = 21Mpa. But the mean result obtained from the prevailing partially replaced mix (20%) is 35.51 MPa which is more than of 100% of C-30 which is 30MPa. The result shows that partially replaced concrete induces higher result than the conventional one as there is mass glue increase and also it shows validity of trial mix as well.

4.2.4 Split Tensile Strength of the Conventional Concrete at 7 days

Table4.3: Split Tensile Strength of the Conventional Concrete at 7 day

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Split Tensile Strength(Mpa)
		Cylindrical		Ø	L					
1	7			150	300	0	12875	0.1413	203.80	2.88
2	7			150	300	0	12990	0.1413	179.50	2.54
3	7			150	300	0	12860	0.1413	193.70	2.74
Mean Value									**192.33**	**2.72**

4.2.5 Split Tensile Strength of the Partial replacement of cement by fly ash and basaltic dust of 20% of Concrete at 7 days

Table4.4: Split Tensile Strength of the Partial replacement of cement by fly ash and basaltic dust of 20% of Concrete at 7 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Split Tensile Strength(Mpa)
		Cylindrical		Ø	L					
1	7			150	300	20	12700	0.1413	184.20	2.61
2	7			150	300	20	12750	0.1413	195.10	2.76
3	7			150	300	20	12860	0.1413	190.90	2.70
Mean Value									**190.07**	**2.69**

4.2.6 Flexural Strength of the Conventional Concrete at 7 days

Table4.5: Flexural Strength of the Conventional Concrete at 7 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Volume (m3)	Failure Load(KN)	Flexural Strength(Mpa)	Comment 'a' in Cm
		Flexural	l	b	d						
1	7		500	100	100	0	12140	0.0010	8.70	3.00	11.50
2	7		500	100	100	0	12170	0.0010	8.10	3.04	12.50
3	7		500	100	100	0	12095	0.0010	7.50	2.93	13.00
Mean Value									**8.10**	**2.99**	

Figure 4.7: Flexural Strength of the Conventional Concrete at 7 days

4.2.7 Flexural Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 7 days

Table4.6: Flexural Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 7 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Volume (m3)	Failure Load(KN)	Flexural Strength(Mpa)	Comment 'a' in Cm
		Flexural	l	b	d						
1	7		500	100	100	20	11930	0.0010	7.50	2.70	12.00
2	7		500	100	100	20	11110	0.0010	8.20	2.83	11.50
3	7		500	100	100	20	11880	0.0010	8.00	3.12	13.00
Mean Value									**7.90**	**2.88**	

4.2.8 Confidence Interval of Flexural Strength Result (C-30)

The flexural strength (stress) of simply supported beam at 28days can be calculated as follows. Consider the simply supported beam (with 20% partial replacement of cement) and point load of (7.9 KN) applied at mid span of the beam with span length of 0.5m:

Since the pure flexural stress is $\sigma = \frac{My}{I}$, Where M = 0. 988 KN.m, y = d/2 = 0.1m/2 = 0.05m and I= $8.33*10^{-6}m^4$, $\sigma = \frac{0.988 \text{ KN.m}*0.05 \text{ m}}{8.33*10^{-6} \text{ m}^4}$ = 5.93Mpa is the expected maximum flexural strength/stress of the prevailing beam after 28days.

4.2.9 Compressive Strength of the Conventional Concrete at 14 days

Table4.7: Compressive Strength of the Conventional Concrete at 14 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Compressive Strength(Mpa)
		Cubic	L	W	H					
1	14		150	150	150	0	8243	0.0225	777.83	34.57
2	14		150	150	150	0	8225	0.0225	772.88	34.35
3	14		150	150	150	0	8283	0.0225	767.93	34.13
Mean Value									**772.88**	**34.35**

4.2.10 Compressive Strength of the Conventional Concrete at 28 days

Table4.8: Compressive Strength of the Conventional Concrete at 28 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Compressive Strength(Mpa)
		Cubic	L	W	H					
1	28		150	150	150	0	8175	0.0225	837.90	37.24
2	28		150	150	150	0	8127	0.0225	798.75	35.50
3	28		150	150	150	0	8095	0.0225	826.87	36.75
Mean Value									**821.17**	**36.50**

4.2.11 Compressive Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 14 days

Table4.9: Compressive Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 14 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Compressive Strength(Mpa)
		Cubic	L	W	H					
1	14		150	150	150	20	8219	0.0225	817.88	36.35
2	14		150	150	150	20	8255	0.0225	857.25	38.10
3	14		150	150	150	20	8285	0.0225	844.87	37.55
Mean Value									**840.00**	**37.33**

4.2.12 Compressive Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 28 days

Table4.10: Compressive Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 28 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replacement Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Compressive Strength(Mpa)
		Cubic	L	W	H					
1	28		150	150	150	20	8065	0.0225	902.70	40.12
2	28		150	150	150	20	7995	0.0225	946.57	42.07
3	28		150	150	150	20	8046	0.0225	916.65	40.74
Mean Value									**921.97**	**40.98**

4.2.13 Split Tensile Strength of the Conventional Concrete at 14 days

Table4.11: Split Tensile Strength of the Conventional Concrete at 14 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replacement Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Split Tensile Strength(Mpa)
		Cylindrical		Ø	L					
1	14			150	300	0	12770	0.1413	207.92	2.94
2	14			150	300	0	12610	0.1413	183.69	2.60
3	14			150	300	0	12950	0.1413	198.74	2.81
Mean Value									**196.78**	**2.79**

4.2.14 Split Tensile Strength of the Conventional Concrete at 28 days

Table4.12: Split Tensile Strength of the Conventional Concrete at 28 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replacement Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Split Tensile Strength(Mpa)
		Cylindrical		Ø	L					
1	28			150	300	0	12621	0.1413	216.74	3.07
2	28			150	300	0	12675	0.1413	196.25	2.78
3	28			150	300	0	12541	0.1413	209.13	2.96
Mean Value									**207.37**	**2.94**

4.2.15 Split Tensile Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 14 days

Table4.13: Split Tensile Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 14 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Split Tensile Strength(Mpa)
		Cylindrical		Ø	L					
1	14			150	300	20	12605	0.1413	193.79	2.74
2	14			150	300	20	12850	0.1413	196.41	2.78
3	14			150	300	20	12670	0.1413	197.32	2.79
Mean Value									**195.84**	**2.77**

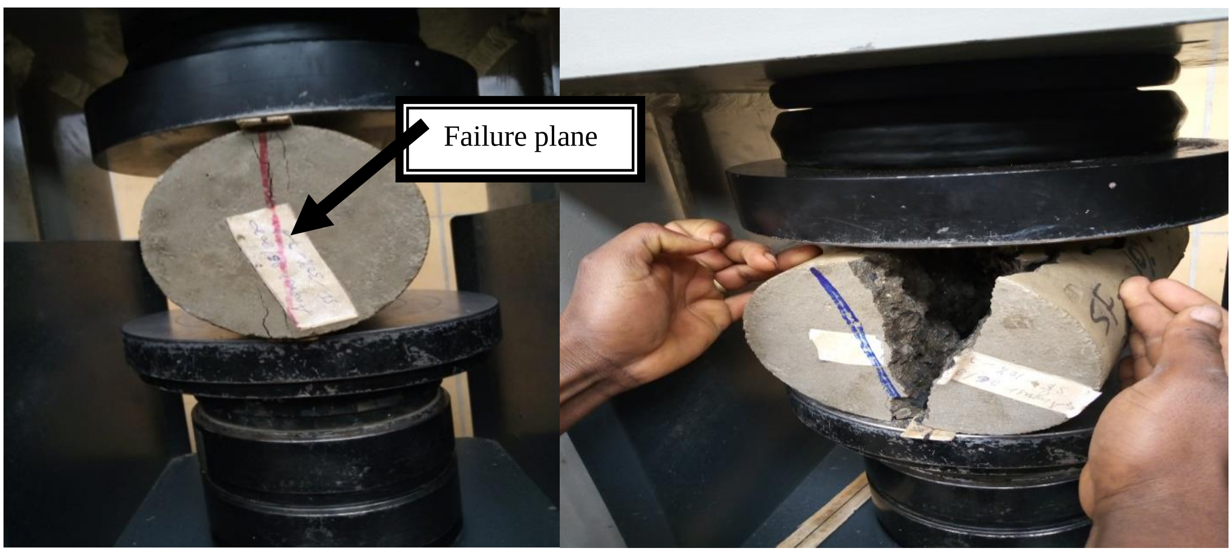


Figure 4.8: Structural test of split tensile strength of concrete

4.2.16 Split Tensile Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 28 days

Table4.14: Split Tensile Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 28 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Split Tensile Strength(Mpa)
		Cylindrical		Ø	L					
1	28			150	300	20	12612	0.1413	212.47	3.01
2	28			150	300	20	12601	0.1413	199.25	2.82
3	28			150	300	20	12705	0.1413	210.50	2.98
Mean Value									**207.41**	**2.94**

4.3 Flexural Strength of the Conventional Concrete at 14 days

Table4.15: Flexural Strength of the Conventional Concrete at 14 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Volume (m3)	Failure Load(KN)	Flexural Strength(Mpa)	Comment 'a' in Cm
		Flexural	l	b	d						
1	14		500	100	100	0	12220	0.0010	8.80	3.14	11.90
2	14		500	100	100	0	11450	0.0010	8.34	3.18	12.70
3	14		500	100	100	0	11670	0.0010	7.55	2.92	12.90
Mean Value									**8.23**	**3.08**	

4.3.1 Flexural Strength of the Conventional Concrete at 28 days

Table4.16: Flexural Strength of the Conventional Concrete at 28 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Volume (m3)	Failure Load(KN)	Flexural Strength(Mpa)	Comment 'a' in Cm
		Flexural	l	b	d						
1	28		500	100	100	0	12150	0.0010	9.00	3.43	12.70
2	28		500	100	100	0	12117	0.0010	8.82	3.44	13.00
3	28		500	100	100	0	12210	0.0010	7.64	2.89	12.60
Mean Value									**8.49**	**3.25**	

4.3.2 Flexural Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 14 days

Table4.17: Flexural Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 14 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Volume (m3)	Failure Load(KN)	Flexural Strength(Mpa)	Comment 'a' in Cm
		Flexural	l	b	d						
1	14		500	100	100	20	11800	0.0010	8.37	3.48	13.90
2	14		500	100	100	20	12250	0.0010	8.45	3.38	13.30
3	14		500	100	100	20	11972	0.0010	8.24	3.53	14.30
Mean Value									**8.35**	**3.46**	

4.3.3 Flexural Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 28 days

Table4.18: Flexural Strength of the Partial replacement of cement by fly ash and basaltic dust of (20%) of Concrete at 28 days

S/N	Test Age (days)	Cross-Sectional type	Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Volume (m3)	Failure Load(KN)	Flexural Strength(Mpa)	Comment 'a' in Cm
		Flexural	l	b	d						
1	28		500	100	100	20	11975	0.0010	10.11	5.06	14.00
2	28		500	100	100	20	11896	0.0010	8.94	4.47	13.50
3	28		500	100	100	20	11811	0.0010	8.73	4.37	13.00
Mean Value									**9.26**	**4.63**	

Hence, the result obtained in laboratory from the samples has checked with respect to the previous-mentioned techniques or pure flexural stress of the concrete beam. Therefore, the range of flexural strength, the confidence interval of hypothetical result would be up to 6 Mpa) and hence the obtained results were also included.

In the similar manner, summary of the results is in tabular form as follows:

Table4.19: Cubic, Split and Flexural Strength of the Partial Replacement of Cement by Fly Ash and Basaltic Dust of (0% & 20%) of Concrete at 7 Days

S/N	Test Age (days)	Cross-Sectional type			Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Comp/Spl/Flex. Strength(Mpa)	Comment 'a' in Cm
		Cubic	Cylindrical	Flexural	L	W	H						
1	7	X			150	150	150	0	8237	0.0225	747.8	33.24	
2	7	X			150	150	150	0	8149	0.0225	722.8	32.12	
3	7	X			150	150	150	0	8257	0.0225	774.8	34.44	
Mean Value												**33.27**	
1	7		X			150	300	0	12875	0.1413	203.8	2.88	
2	7		X			150	300	0	12990	0.1413	179.5	2.54	
3	7		X			150	300	0	12860	0.1413	193.7	2.74	
Mean Value												**2.72**	
1	7			X	500	100	100	0	12140	0.0100	8.7	3.00	11.50
2	7			X	500	100	100	0	12170	0.0100	8.1	3.04	12.50
3	7			X	500	100	100	0	12095	0.0100	7.5	2.93	13.00
Mean Value												**2.99**	
1	7	X			150	150	150	20	8086	0.0225	775.5	34.47	
2	7	X			150	150	150	20	8080	0.0225	812.6	36.12	
3	7	X			150	150	150	20	7992	0.0225	808.9	35.95	
Mean Value												**35.51**	
1	7		X			150	300	20	12700	0.1413	184.2	2.61	
2	7		X			150	300	20	12750	0.1413	195.1	2.76	
3	7		X			150	300	20	12860	0.1413	190.9	2.70	
Mean Value												**2.69**	
1	7			X	500	100	100	20	11930	0.0100	7.5	2.70	12.00
2	7			X	500	100	100	20	11110	0.0100	8.2	2.83	11.50
3	7			X	500	100	100	20	11880	0.0100	8.0	3.12	13.00
Mean Value												**2.88**	

Table4.20: Cubic, Split and Flexural Strength of the Partial Replacement of Cement by Fly Ash and Basaltic Dust of (0% & 20%) of Concrete at 28 Days

S/N	Test Age (days)	Cross-Sectional type			Dimensions (mm)			Replacement Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Comp/Spl/Flex. Strength(Mpa)	Comment 'a' in Cm
		Cubic	Cylindrical	Flexural	L	W	H						
1	28	X			150	150	150	0	8175	0.0225	837.90	37.24	
2	28	X			150	150	150	0	8127	0.0225	798.75	35.50	
3	28	X			150	150	150	0	8095	0.0225	826.87	36.75	
Mean Value												**36.50**	
1	28		X			150	300	0	12621	0.1413	216.74	3.07	
2	28		X			150	300	0	12675	0.1413	196.25	2.78	
3	28		X			150	300	0	12541	0.1413	209.13	2.96	
Mean Value												**2.94**	
1	28			X	500	100	100	0	12150	0.0100	9.00	3.44	12.75
2	28			X	500	100	100	0	12117	0.0100	8.82	3.44	13.00
3	28			X	500	100	100	0	12210	0.0100	7.64	2.90	12.65
Mean Value												**3.26**	
1	28	X			150	150	150	20	8065	0.0225	902.7	40.12	
2	28	X			150	150	150	20	7995	0.0225	946.57	42.07	
3	28	X			150	150	150	20	8046	0.0225	916.65	40.74	
Mean Value												**40.98**	
1	28		X			150	300	20	12612	0.1413	212.47	3.01	
2	28		X			150	300	20	12601	0.1413	199.25	2.82	
3	28		X			150	300	20	12705	0.1413	210.50	2.98	
Mean Value												**2.94**	
1	28			X	500	100	100	20	11975	0.0100	10.11	5.06	14.00
2	28			X	500	100	100	20	11896	0.0100	8.94	4.47	13.50
3	28			X	500	100	100	20	11811	0.0100	8.73	4.37	13.00
Mean Value												**4.63**	

Table4.21: Cubic, Split and Flexural Strength of the Partial Replacement of Cement by Fly Ash and Basaltic Dust of (10% & 30%) of Concrete at 7 Days

S/N	Test Age (days)	Cross-Sectional type			Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Comp/Spl/Flex. Strength(Mpa)	Comment 'a' in Cm
		Cubic	Cylindrical	Flexural	L	W	H						
1	7	X			150	150	150	10	8085	0.0225	745.87	33.15	
2	7	X			150	150	150	10	8034	0.0225	754.65	33.54	
3	7	X			150	150	150	10	8065	0.0225	778.72	34.61	
Mean Value												**33.77**	
1	7		X			150	300	10	12722	0.1413	203.5	2.88	
2	7		X			150	300	10	12720	0.1413	176.1	2.49	
3	7		X			150	300	10	12842	0.1413	182.7	2.59	
Mean Value												**2.65**	
1	7			X	500	100	100	10	11949	0.0100	6.40	3.20	15.00
2	7			X	500	100	100	10	11883	0.0100	6.5	3.25	14.50
3	7			X	500	100	100	10	11952	0.0100	7.6	3.80	15.50
Mean Value												**3.42**	
1	7	X			150	150	150	30	7943	0.0225	793.12	35.25	
2	7	X			150	150	150	30	8042	0.0225	825.75	36.70	
3	7	X			150	150	150	30	7973	0.0225	805.95	35.82	
Mean Value												**35.92**	
1	7		X			150	300	30	12655	0.1413	145.90	2.07	
2	7		X			150	300	30	12596	0.1413	141.30	2.00	
3	7		X			150	300	30	12686	0.1413	148.80	2.11	
Mean Value												**2.06**	
1	7			X	500	100	100	30	11988	0.0100	6.80	3.40	15.00
2	7			X	500	100	100	30	11861	0.0100	8.60	4.30	15.25
3	7			X	500	100	100	30	11733	0.0100	7.26	3.63	14.50
Mean Value												**3.78**	

Table4.22: Cubic, Split and Flexural Strength of the Partial Replacement of Cement by Fly Ash and Basaltic Dust of (10% & 30%) of Concrete at 28 Days

S/N	Test Age (days)	Cross-Sectional type			Dimensions (mm)			Replacement Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Comp/Spl/Flex. Strength(Mpa)	Comment 'a' in Cm
		Cubic	Cylindrical	Flexural	L	W	H						
1	28	X			150	150	150	10	8091	0.0225	887.17	39.43	
2	28	X			150	150	150	10	7992	0.0225	931.50	41.40	
3	28	X			150	150	150	10	8085	0.0225	835.87	37.15	
Mean Value												**39.33**	
1	28		X			150	300	10	12926	0.1413	210.50	2.98	
2	28		X			150	300	10	12887	0.1413	185.00	2.62	
3	28		X			150	300	10	12902	0.1413	199.25	2.82	
Mean Value												**2.81**	
1	28			X	500	100	100	10	12158	0.0100	8.25	4.13	16.50
2	28			X	500	100	100	10	12160	0.0100	8.92	4.46	17.00
3	28			X	500	100	100	10	12178	0.0100	9.02	4.51	18.50
Mean Value												**4.37**	
1	28	X			150	150	150	30	7993	0.0225	967.50	43.00	
2	28	X			150	150	150	30	7953	0.0225	996.30	44.28	
3	28	X			150	150	150	30	8030	0.0225	902.93	40.13	
Mean Value												**42.47**	
1	28		X			150	300	30	12516	0.1413	215.00	3.04	
2	28		X			150	300	30	12586	0.1413	196.70	2.78	
3	28		X			150	300	30	12523	0.1413	208.55	2.95	
Mean Value												**2.93**	
1	28			X	500	100	100	30	11883	0.0100	8.54	4.27	17.50
2	28			X	500	100	100	30	11768	0.0100	8.40	4.20	18.00
3	28			X	500	100	100	30	11713	0.0100	10.25	5.13	16.00
Mean Value												**4.53**	

Table4.23: Cubic, Split and Flexural Strength of the Partial Replacement of Cement by Fly Ash and Basaltic Dust of (40% & 50%) of Concrete at 7 Days

S/N	Test Age (days)	Cross-Sectional type			Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Comp/Spl/Flex. Strength(Mpa)	Comment 'a' in Cm
		Cubic	Cylindrical	Flexural	L	W	H						
1	7	X			150	150	150	40	7928	0.0225	458.10	20.36	
2	7	X			150	150	150	40	7969	0.0225	454.40	20.20	
3	7	X			150	150	150	40	7930	0.0225	438.20	19.48	
Mean Value												**20.01**	
1	7		X			150	300	40	12575	0.1413	116.80	1.65	
2	7		X			150	300	40	12476	0.1413	88.70	1.26	
3	7		X			150	300	40	12603	0.1413	79.00	1.12	
Mean Value												**1.34**	
1	7			X	500	100	100	40	11724	0.0100	5.40	2.70	15.50
2	7			X	500	100	100	40	11956	0.0100	5.10	2.55	14.50
3	7			X	500	100	100	40	11827	0.0100	6.10	3.05	15.00
Mean Value												**2.77**	
1	7	X			150	150	150	50	7858	0.0225	336.70	14.96	
2	7	X			150	150	150	50	7925	0.0225	350.20	15.56	
3	7	X			150	150	150	50	7860	0.0225	342.50	15.22	
Mean Value												**15.25**	
1	7		X			150	300	50	12535	0.1413	80.50	1.14	
2	7		X			150	300	50	12482	0.1413	103.20	1.46	
3	7		X			150	300	50	12491	0.1413	65.90	0.93	
Mean Value												**1.18**	
1	7			X	500	100	100	50	11609	0.0100	5.70	2.85	19.00
2	7			X	500	100	100	50	11731	0.0100	5.00	2.50	18.00
3	7			X	500	100	100	50	11692	0.0100	5.10	2.55	16.00
Mean Value												**2.63**	

Table4.24: Cubic, Split and Flexural Strength of the Partial Replacement of Cement by Fly Ash and Basaltic Dust of (40% & 50%) of Concrete at 28 Days

S/N	Test Age (days)	Cross-Sectional type			Dimensions (mm)			Replace ment Amount in (%)	Weigth (gm)	Area (m2)	Failure Load(KN)	Comp/Spl/Flex. Strength(Mpa)	Comment 'a' in Cm
		Cubic	Cylinderical	Flexural	L	W	H						
1	28	X			150	150	150	40	7899	0.0225	652.70	29.01	
2	28	X			150	150	150	40	7932	0.0225	620.60	27.58	
3	28	X			150	150	150	40	7943	0.0225	634.50	28.20	
Mean Value												**28.26**	
1	28		X			150	300	40	12573	0.1413	166.10	2.35	
2	28		X			150	300	40	12592	0.1413	156.10	2.21	
3	28		X			150	300	40	12521	0.1413	154.40	2.19	
Mean Value												**2.25**	
1	28			X	500	100	100	40	11746	0.0100	6.70	3.35	16.50
2	28			X	500	100	100	40	11764	0.0100	6.50	3.25	18.00
3	28			X	500	100	100	40	11771	0.0100	7.00	3.50	22.00
Mean Value												**3.37**	
1	28	X			150	150	150	50	7894	0.0225	450.50	20.02	
2	28	X			150	150	150	50	7862	0.0225	437.20	19.43	
3	28	X			150	150	150	50	7945	0.0225	458.20	20.36	
Mean Value												**19.94**	
1	28		X			150	300	50	12443	0.1413	102.70	1.45	
2	28		X			150	300	50	12541	0.1413	94.40	1.34	
3	28		X			150	300	50	12505	0.1413	127.10	1.80	
Mean Value												**1.53**	
1	28			X	500	100	100	50	11724	0.0100	5.60	2.80	18.00
2	28			X	500	100	100	50	11565	0.0100	4.76	2.38	17.85
3	28			X	500	100	100	50	11595	0.0100	5.60	2.80	18.00
Mean Value												**2.66**	

4.3.4 Summary of Compressive Strength of Concrete with Fly Ash and Basaltic Dust of Cubes

Table4.25: Summary of Compressive Strength of concrete with fly ash and basaltic dust of cubes

Fly Ash Basaltic Dust (%)	Compressive Strength of concrete in (MPa)		
	7th day	14th day	28th day
0	33.27	34.35	36.50
10	33.77	35.62	39.33
20	35.51	37.33	40.98
30	35.92	38.10	42.47
40	20.01	22.76	28.26
50	15.25	16.81	19.42

Graph4.1: Compressive Strength of concrete with fly ash and basaltic dust of cubes

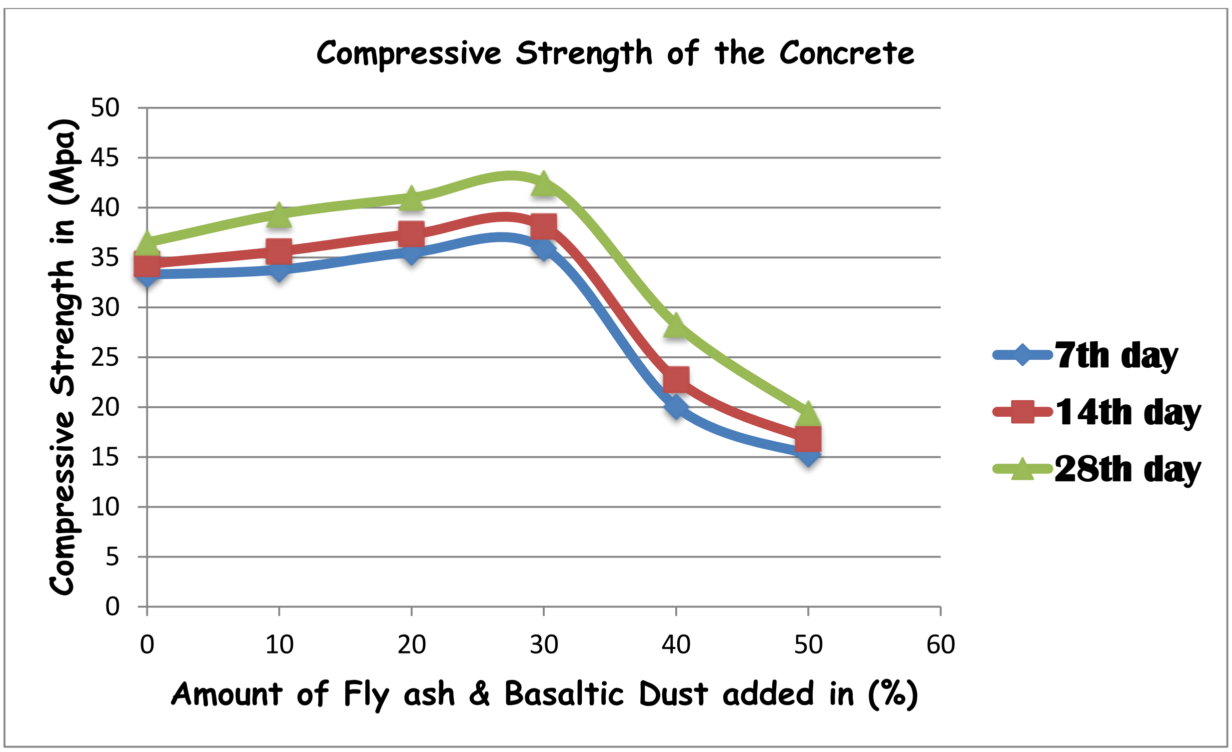
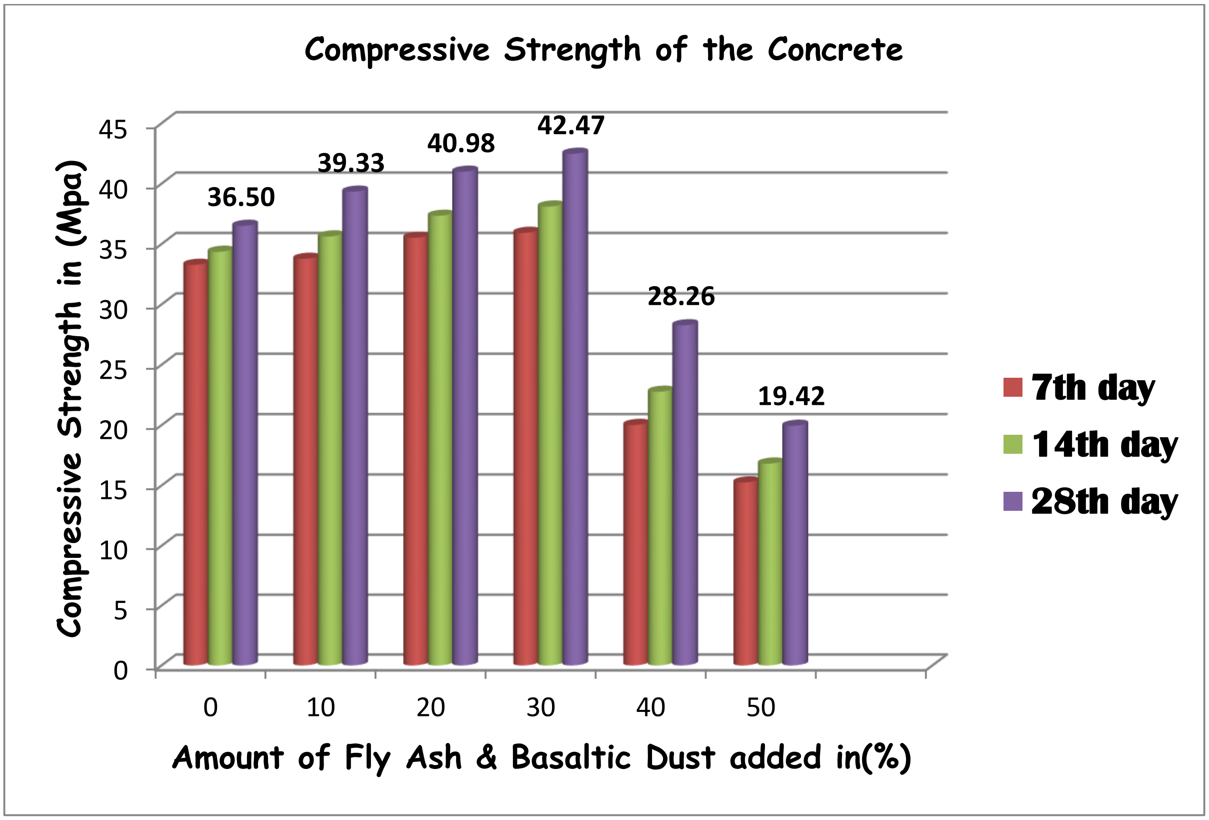


Chart4.1: Compressive Strength of concrete with fly ash and basaltic dust of cubes



It has been concluded that the maximum compressive strength value of concrete with partial replacement of cement by fly ash and basaltic dust was obtained at 30% replacement.

4.3.5 Summary of Split Tensile Strength of concrete with fly ash and basaltic dust of cylinders

Table4.26: Summary of Split Tensile Strength of concrete with fly ash and basaltic dust of cylinders

Fly Ash & Basaltic Dust (%)	Split Tensile Strength in (MPa)		
	7th day	14th day	28th day
0	2.72	2.79	2.94
10	2.65	2.70	2.81
20	2.69	2.77	2.94
30	2.06	2.35	2.93
40	1.34	1.64	2.25
50	1.18	1.30	1.53

Graph4.2: Split Tensile Strength of concrete with fly ash and basaltic dust of cylinders

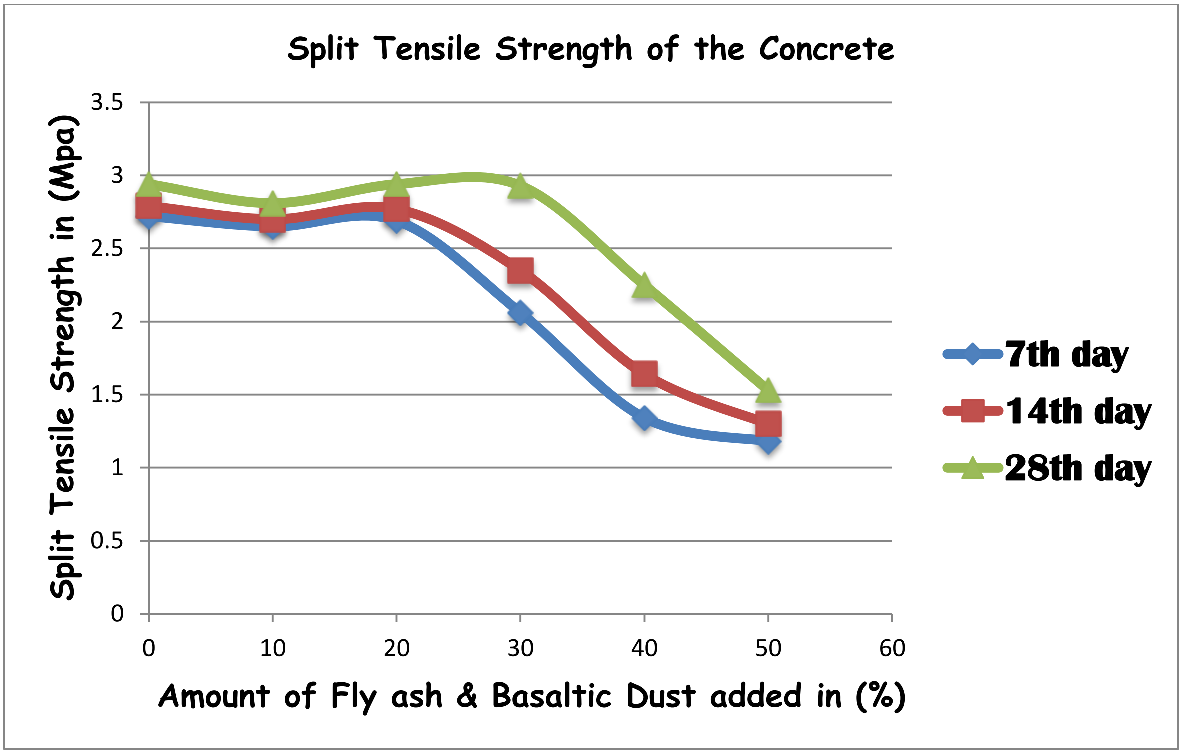
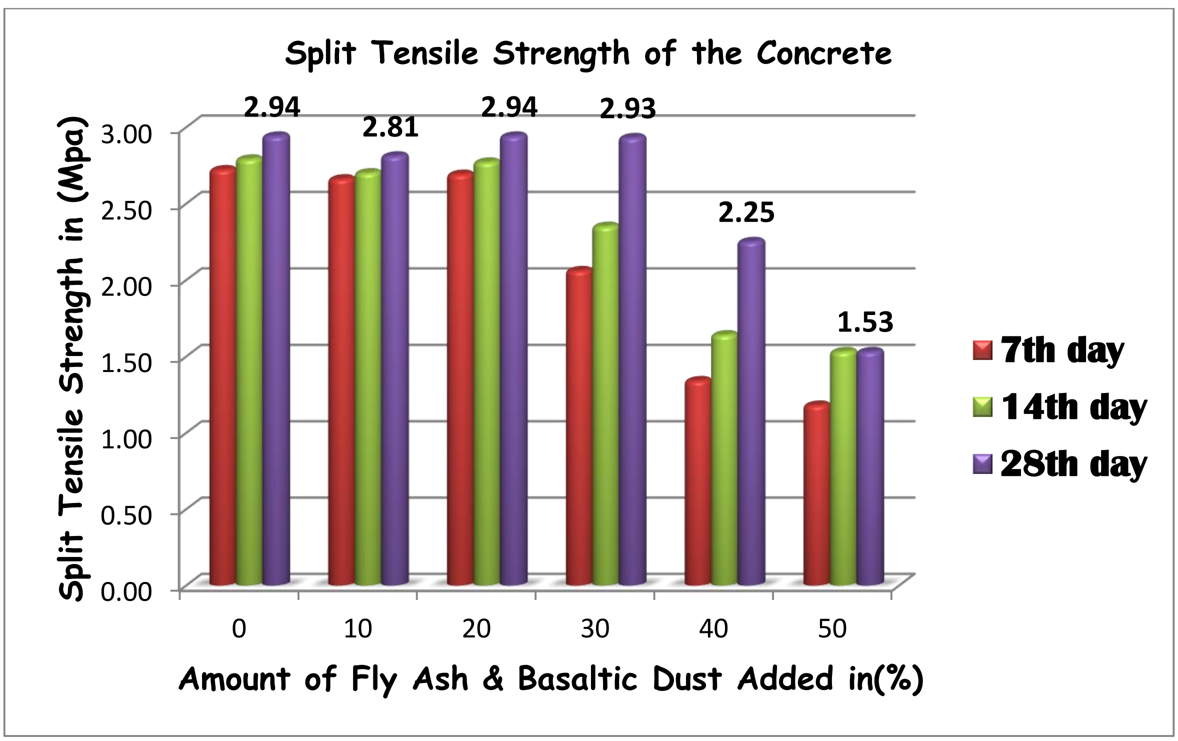


Chart4.2: Split Tensile Strength of concrete with fly ash and basaltic dust of cylinders



It can be summarized as the maximum split tensile strength value of concrete with partial replacement of cement by fly ash and basaltic dust was obtained at 20% replacement.

4.3.6 Summary of Flexural Strength of Concrete with fly ash and basaltic dust of beams

Table4.27: Summary of Flexural Strength of Concrete with fly ash and basaltic dust of beams

Fly Ash &Basaltic Dust (%)	Flexural Strength in (MPa)		
	7th day	14th day	28th day
0	2.99	3.08	3.26
10	3.42	3.74	4.37
20	2.88	3.46	4.63
30	3.78	4.03	4.53
40	2.77	2.97	3.37
50	2.63	2.64	2.66

Graph4.3: Flexural Strength of Concrete with fly ash and basaltic dust of beams

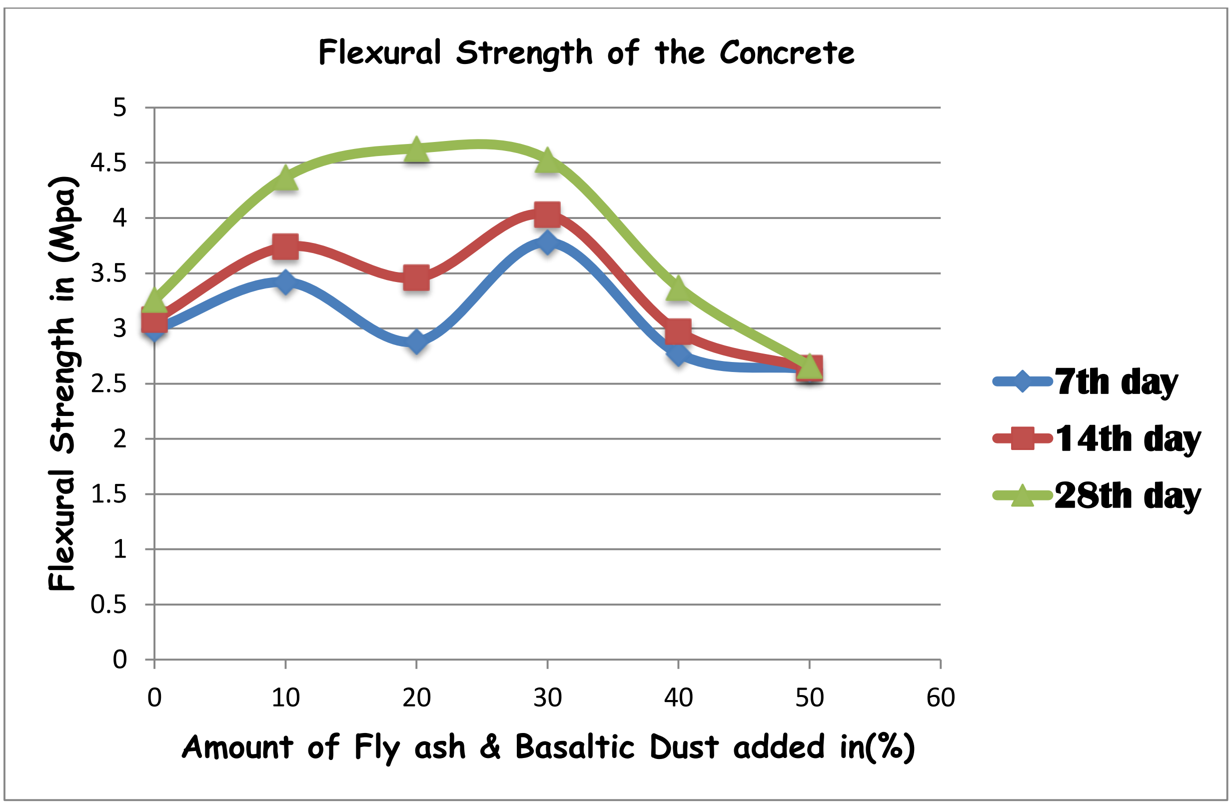


Chart4.3: Flexural Strength of Concrete with fly ash and basaltic dust of beams

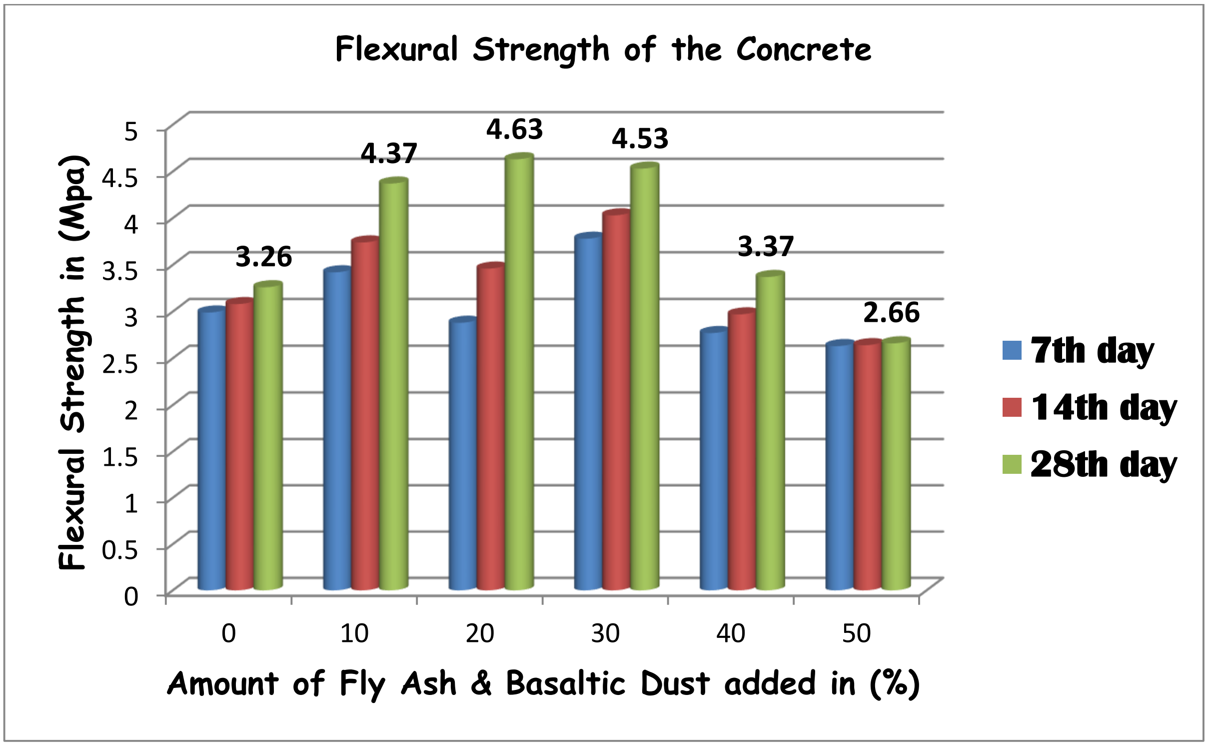


Figure 4.9: Prevailing Flexural and Split Tensile Strength Samples after crushed/smashed

It can be summarized as the maximum flexural strength value of concrete with partial replacement of cement by fly ash and basaltic dust was obtained at 20% replacement.

4.3.7 Concrete Permeability Test Theory

Different methods to measure the Concrete Durability or Permeability.

Among these, the common one are as follows:

1. Rapid Chloride Permeability Test
2. Water Permeability by Pressure and
3. Ponding with a Salt Solution

To check durability of the concrete by using Water Permeability by pressure, one can follow the following steps:

Water Permeability test for concrete by Pressure

This test is suited and applied to the concrete having high permeability. This test is also called water penetration test of concrete. This test is carried out using a disc of concrete and involves water flowing out through the disc at a steady rate. The concrete disc having a thickness of more than 20mm is cast and saturated. The apparatus consists of a permeameter and water collection jar.

Look at the following picture for more details.

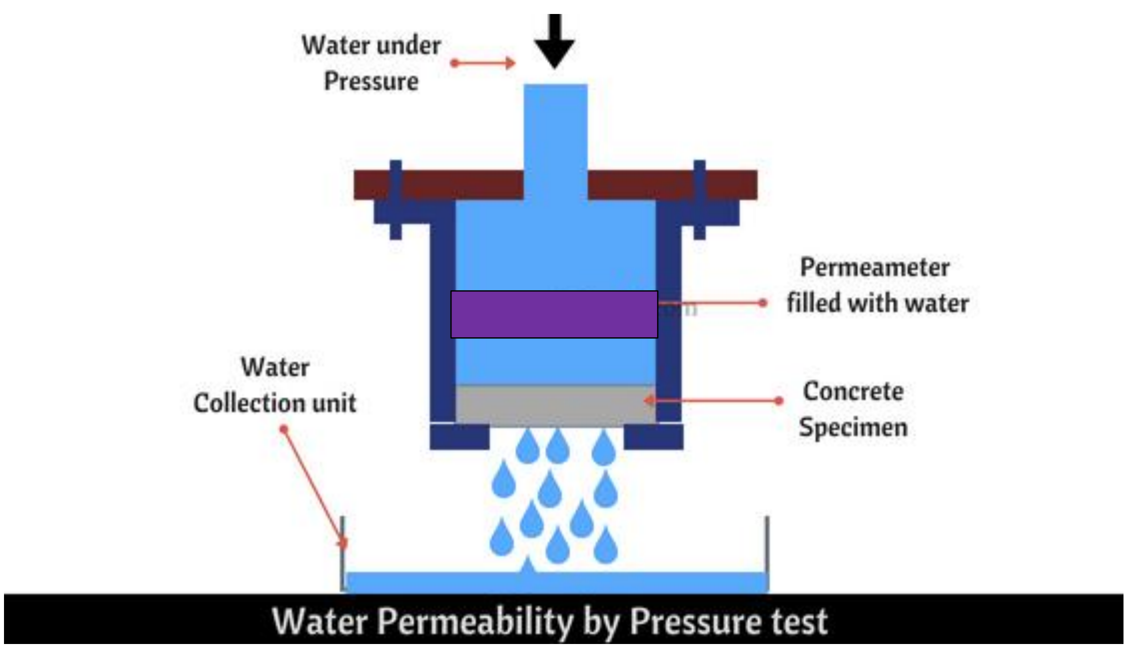


Figure 4.10: Water Permeability test for concrete by Pressure

Formula for water permeability by pressure test:

Coefficient of permeability “k” is calculated by using the following formula:-

$k = \frac{QL}{tAH}$ **,** Where k= Coefficient of permeability

Q= Discharge of water into collection unit

t= Elapsed time in seconds,

L= Top length of concrete specimen, for cubic section 15cm

A= Top area of concrete specimen and

H= Applied pressure head in ‘m’

Sometimes one can calculate concrete permeability by using water permeability via concrete by pressure for 3days (72hrs) and making its split test and simply measure its depth of water penetration h, likewise ‘h’ should be less than 25mm.

Unfortunately, in this study its long-term performance or durability was not been checked owning to lack of specialized equipment in laboratory.

4.4 DISCUSSION ON THE FINDINGS

Based up on the results obtained and checked structural properties of concrete like Compressive Strength, Split Tensile Strength and Flexural Strength one can use the wastes, fly ash and basaltic dust as partial replacement of cement up to 50%. By using these wastes as construction materials, it can enhance strength in concrete structures. It decreases construction delays, construction cost, and keeps green environment by decreasing CO_2 emissions in to the prevailing environment during cement production and hydration effects and consumption of its disposal.

Production of one tone of cement discharges nearly equal amount of CO_2 into atmosphere and causes a lot of harm to environment and society. These wastes, fly ash and basaltic dust can be used as partial cementations materials for both in situ cast and pre-cast concrete structures.

Structural properties of the concrete has been checked and compared with respect to the conventional one and hence it induces good result. Case study has been done on Gelan Rigid pavement to ensure its durability and performances.

Based up on the findings, it can be used for both in-situ and precast structures construction in order to enhance its early strength, decrease construction cost by using these wastes, decrease construction period as early strength can be obtained and keeps environment clean by consuming wastes as cementations materials and etc. It also helps in terms of construction material supply sustainability as there is always a waste, particularly around power plants.

Generally the maximum compressive strength of the concrete with partial replacement of cement by fly ash and basaltic dust is 42.47MPa with 30% partial replacement, Maximum value of split tensile strength of the concrete due to partial replacement is 2.94MPa with 20% partial replacement and also the maximum value of flexural strength of the concrete is 4.63Mpa with 20% partial replacement.

Therefore, these wastes, fly ash and basaltic dust can be used as construction or cementations materials for both in situ cast and pre-cast concrete structures as per the engineering modifications are considered.

4.5 Case Study at Gelan Town around Taff oil Rigid Pavement Construction

The prevailing Reinforced Concrete Rigid pavement was induced from 30% partial replacement of cement by fly ash and basaltic dust together with curing admixture and usual concrete ingredients. One pad, l*w*t (22m*3.5m*0.2m) has been investigated during and after construction.

Figure 4.11: Road in situ cast/ Rigid Pavement case study

The pad under investigation is still under good conditions with respect to the conventional one and there is no visible defects that have been observed yet.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The main objective of this research is how to develop strength in concrete for structures like Buildings, Dams, Bridges, High way (Rigid pavements), Irrigation canals and any pertinent civil structures by using cement partial replacement with basaltic dust and fly ash.

Therefore, by using these wastes fly ash and basaltic dust as partial cementations materials:

- It enhances strength in concrete by using fly ash and basaltic dust as partial replacement and accelerator admixture, calcium chloride.
- According to this study, it is possible to replace cement up to 40% by fly ash and basaltic dust for structures construction.
- Values, structural properties of the concrete are increasing up to 30% with partial replacement of cement by fly ash and basaltic dust and gradually decrease up to 50%.
- The maximum or optimum compressive strength was obtained with 30% partial replacement of cement by fly ash and basaltic dust.
- The maximum split tensile strength was obtained with 20% partial replacement of cement by fly ash and basaltic dust.
- The optimum flexural strength was also obtained with 20% partial replacement of cement by fly ash and basaltic dust.
- It decreases delays in construction industry as its early strength can be obtained earlier.
- Enhanced strength in concrete was obtained with cement partial replacement by fly ash and basaltic dust and its structural properties like compressive strength, split tensile strength, and flexural strength of the concrete was conducted and induced attractive results.

- By using or consuming these wastes, fly ash and basaltic dust as cementations materials besides of increasing structural strength of the concrete it is also cleaning the prevailing environment and decreases C02 emissions into the environment during cement production and curing scenario.
- It decreases material cost by using these wastes, fly ash and basaltic dust as cementations materials instead of cement.
- Create opportunity for construction material sustainability as there are always wastes, fly ash and basaltic dust around power plants and so on.
- Increase environmental hygiene, particularly “Qoshe” waste dump by consuming wastes as construction materials in our country, Ethiopia.
- This partial replacement of cement by fly ash and basaltic can be used for both high rise structures and low structures as per findings and engineering modifications.

5.2 RECOMMENDATIONS

Based up on the findings of this research, the following recommendations were provided.

- Based up on the prevailing study, one can replace cement up to 40% by fly ash and basaltic dust for high rise structures construction.
- The study can be applicable and used as the above findings and results.
- Construction firms can use the cement partial replacement by fly ash and basaltic dust as per the study.
- Construction industry main stakeholders like Contractors, Consultants and Clients should be informed and work together about the use of prevailing wastes (basaltic dust and fly ash as cement partial replacement).
- Further study on details of metal contents and chemical properties of fly ash basaltic dust long-term effects on concrete structures durability.
- Ministry of Science and Innovation and Construction Ministry should be involved in further study of this wastes and encouragement of using it as construction materials.
- Municipality Solid Waste Phase-I should work together with University research results and recommend further study on these cheap cementations materials, fly ash and basaltic dust.

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5.4 APPENDIX

Table 5.1: Specific Gravity calculation and Water absorption for CA

Sample No	(B) Mass of SSD Sample in Air(gm)	(BS.) Mass of Basket in water(gm)	Bs+C Basket + Sample in water(gm)	(C) Mass of Saturated Sample in water(gm)	(A) Mass of oven dry sample in air(gm)	Water Tempratur e (C°)	K	Bulk Sp.gravity(Oven dry)= Sd= A*K/(B-C)	Bulk Sp.gravity (SSD)= Ss= B*K/(B-C)	Apparent Sp.gravity (Sr)=Sr= A*K/(A-C)	C.A Water Absortion(%), Aw=(B-A)*100/A
1	1804.90	811.30		1184.00	1787.10	21	1	2.878	2.907	2.963	0.996
2	1597.60	811.30		1048.01	1580.00	21	1	2.875	2.907	2.970	1.114
3	Mean Value							**2.877**	**2.907**	**2.967**	**1.055**

Figure 5.1: Mass of Saturated Surface Dry Sample Calculations for CA

Table5.2: Specific Gravity Calculation and Water Absorption for FA

Sample No	(B) Mass of Pcnometer + water(gm)	(S) Mass of SSD Sample in air (gm)		(C) Mass of Pcnometer+water + Sample (gm)	(A) Mass of oven dry sample in air(gm)	Water Temprature (C°)	K	Bulk Sp.gravity(Oven dry)= Sd= A*K/(B+S-C)	Bulk Sp.gravity (SSD)= Ss= S*K/(B+S-C)	Apparent Sp.gravity (Sr)=Sr = A*K/(A+B-C)	F.A Water Absortion(%), Aw=(S-A)*100/A
1	733.30	300.00		878.80	283.10	20	1	1.832	1.942	2.057	5.970
2	733.30	300.00		877.60	282.70	20	1	1.816	1.927	2.043	6.120
3	**Mean Value**							**1.824**	**1.934**	**2.050**	**6.045**

5.5 Natural Moisture Content Calculation for both CA &FA

A	**Natural Moisture content for CA**				**Moisture content (%)**	
	weight of sample (gm)			1143.3	**0.735**	
	oven dry weight of sample(gm)			1134.9		
B	**Natural Moisture content for FA**				**Moisture content (%)**	
	weight of sample (gm)			375.6	**7.348**	
	oven dry w weight t of sample(gm)			348		

5.6 Concrete Mix Design and mix ratio computations; - C- 30 (-Dangote- OPC-42.5R

Input data Information:

Required average strength, Confidence interval result =30+8 =38 Mpa

- Slump = 25-75mm
- Nominal maximum size of Aggregate= 19mm
- Cement factory: Dangote OPC Cement
- Cement type: Ordinary Pozzolana cement with specific gravity 2.95
- Natural River Sand from Mathahara River sand 82+100 RHS offset 10 Km
- Concrete Aggregate from Awash 55+300, Awash Crusher
- Fly ash from Reppie Power Station
- Basaltic Dust from E.C.W.C Sabbata Asphalt Plant

Fine Aggregate (Sand) Physical Properties

- Bulk specific Gravity (dry basis) =1.824
- Bulk specific Gravity (SSD basis) =1.934
- Absorption = 6.0450%
- Moisture content = 7.348%
- Fineness Modulus of Fine Aggregate = 3.38
- Silt content 1.67%
- Uniformity coefficient =2.50
- Coefficient of Curvature =1.072
- Gradation type V-Curve/Poor graded/uniformly graded

Concrete Coarser Aggregate Physical Properties.

- Bulk specific Gravity (Dry basis) = 2.877
- Bulk specific Gravity (SSD basis) =2.907
- Absorption = 1.055%
- Dry rode unit weight = 1672Kg/m3
- Moisture content = 0.735 %
- Approximate amount of entrapped air in non-air entrapped concrete = 2%
- Uniformity coefficient =2.160
- Coefficient of Curvature =0.992
- Gradation type V-Curve/Poor graded/uniformly graded.

The quantity of coarse aggregate is estimate in table A 1.5.3.6 for fine aggregate having a Fineness modulus of 3.38 and 19 mm nominal maximum size of coarse aggregate is 0.60m^3

From table A1 5.3.7.1 which nominal maximum size of coarse aggregate is 19mm, estimate the mass of fresh concrete will be 2345 kg/m3.

Procedural steps

- Assume cement content will be 400kg/m3
- Natural River sand from Mathahara and crushed aggregate From Awash, 55+300 LHS.
- Slump: 25 -75 mm
- The aggregate to be used has a nominal maximum Size of 19 mm
- The concrete will be non-air entrained and cement content of 400kg/m3
- The w/c ratio for non-air entrained concrete with a strength of 38Maps is found from Table A1 5.3.4(a) to be = 0.54

From the information developed above, the required water content is found to be

= 0.54*400=216.0kg/m3

Quantity of dry rode coarse Aggregate. = 0.60 * 1672 = 1003.2 kg /m3

The Mass of fresh Concrete from table A.1.5.3.7.1 an Aggregate with Nominal Size 19mm

= 2345kg/m3.

Mass basis

- Water (Net mix) = 216.0kg/m3
- Cement = 400kg/m3
- Coarse Aggregate. =1003.2 kg/m3
- Total = 1619.20Kg/m3

The Mass of Fine Aggregate (Sand) =2345-1619.20= 725.80Kg/m3

Volume basis

- Volume of water=216/1000 =0.2160 m^3
- Volume of cement $= \frac{400}{(2.95*1000)} = 0.1356 m^3$
- Volume of coarse Aggregate $\frac{1003.2}{(2.907*1000)} = 0.3451 m^3$
- Volume of entrapped air = 2% of $1m^3$=0.02 m^3
- Total volume of Concrete ingredients except fine aggregate =0.7167m^3

Volume of fine Aggregate (Sand) = 1-0.7167m^3 = 0.2833m^3

Required weight of fine aggregate= 0.2833* 1.934*1000= 547.902Kg/m3

Batch masses per cubic meter of concrete calculated on the two bases are compared below:

	Based on estimated Concrete mass (kg)	Based on absolute of ingredients in (kg)
Water (net mix)	216.0	216.0
Cement	400	400
Course Aggr.	1003.2	1003.2
Fine Aggr.	725.8	547.902

The trial batch proportions based on assumed concrete absolute volume are used and the adjusted aggregate Masses becomes:

- Coarse Aggregate = 1003.2 * 1.00735 =1010.57kg
- Fine Aggregate =547.902* 1.07348 = 588.16kg
- Total amount of water added due to moisture content and absorption of course of fine and coarse aggregate =
  216.0- (588.16*0.01303) - (1010.57*0.0032) = 205Kg

The estimated batch masses for 1m3 of concrete were:

- Water = 176.78kg (Adjusted practically)
- Cement = 400kg
- Coarse Aggregate = 1010.57kg
- Fine Aggregate = 588.16kg
- Accelerator Admixture = 0.5lit

The estimated batch masses for cubic concrete cast (6 molds)

- Water = 176.78kg *0.0243 = 4.296kg
- Cement = 400kg*0.0243 = 9.720kg
- Coarse Aggregate= 1010.57kg*0.0243= 24.560kg
- Fine Aggregate = 588.16 kg*0.0243 = 14.292kg
- Accelerator Admixture = 12.15 ml

Adjusted weight of each ingredient per 1m3 of concrete

- Water to be added= 176.78 kg
- Cement = 400 Kg
- Coarse Aggregate = 1010.57 Kg
- Fine Aggregate = 588.16 Kg
- Accelerator Admixture =0.5lit

Weight of each component per 1bag of cement

- Water to be added = 22.098 Kg
- Cement (OPC) = 50Kg
- Fine Aggregate. = 73.52Kg
- Coarse Aggregate. =126.32Kg
- Accelerator Admixture = 62.5 ml

Mix Proportion by Weight/ Mix Ratio by Mass: 1:1.5:2.5

Loose unit weight (ρ) of each component:

- ρFA= 1574 kg/m3
- ρCA= 1672 kg/m3

Volume of each component per 1bag of cement

- Volume of cement =Mass of cement / ρ of cement = 50kg/2950kg/m3 = 0.01695m3
- Volume of sand= Mass of sand/ ρ of sand = 73.52kg/1574 kg/m3 = 0.0470 m3
- Volume of coarse aggregate =Mass of coarse aggregate /ρ of coarse aggregate =126.32kg/1672kg/m3=0.0756m3

Mix RatiobyVolume: 1:3:4.5

Box size determination per 1 bag of cement

- Sand:Volume of sand=l*w*h of batching box =(50cm*40cm) *h

  0.0470m3 = (0.2m2) * h (sand)

  h of sand = 23.50cm

  Use h of sand =(11.750cm) *2, sand batching box is = 40cm*50cm*11.75cm

- Coarse Aggregate: Volume of coarse aggregate = l*w*h of batching box40cm*50cm*h of coarse aggregate =0.0756m^3= (50cm*40cm) *h of CA = 0.0756m^3= (0.2m^2) * h of Coarse Aggregate

h of Coarse Aggregate batching box = 37.8cm

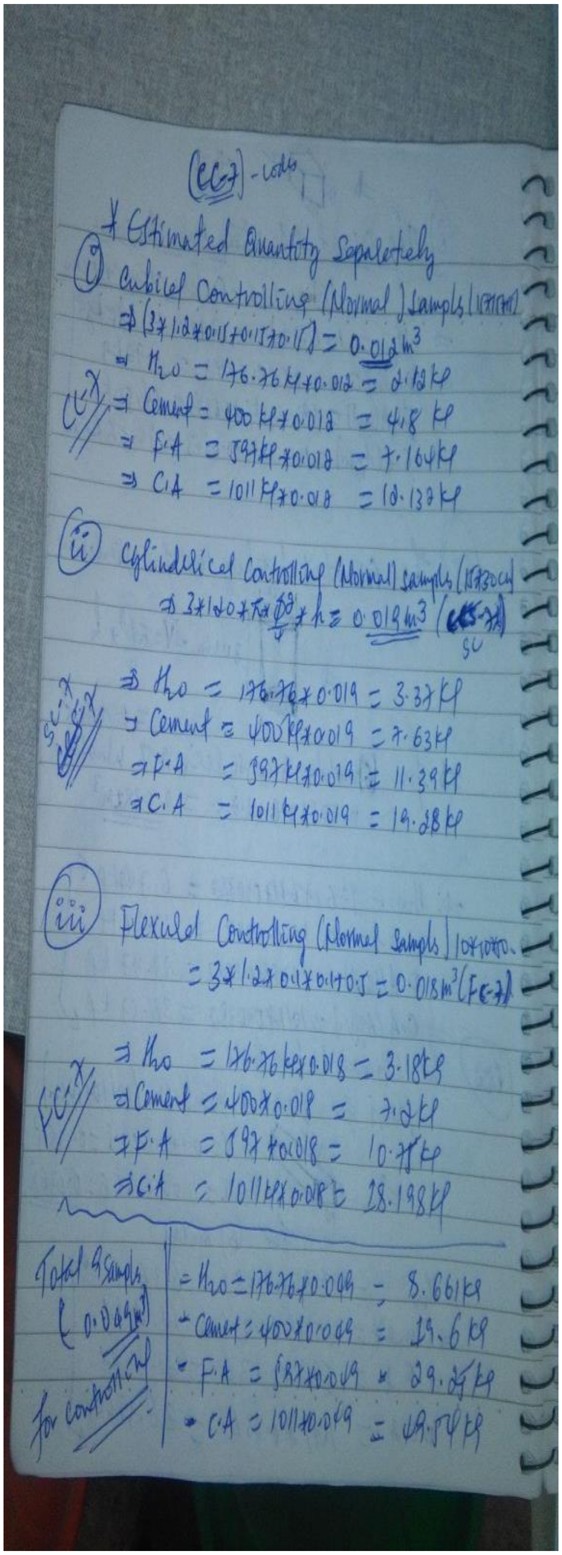
Use h of Coarse Aggregate = (18.90cm) *2

Therefore, the batching box for coarse aggregate is = 40cm*50cm*18.9cm

Therefore, the **mix ratio** was as follows: **Cement: Sand: Aggregate**, **1:2:2** or

1bag of cement: 2 (40*50*11.75) Sand: 2(40*50*18.9) C.A with Slump of =35mm

5.7 Rough hand calculations to prepare the mix



(CC-7) - cubic

* Estimated Quantity Separately

(i) Cubical Controlling (Normal) Samples (15*15*15)

⇒ (3*1.2*0.15*0.15*0.15) = 0.012 m³

⇒ H₂O = 176.76 kg*0.012 = 2.12 kg

⇒ Cement = 400 kg*0.012 = 4.8 kg

⇒ F.A = 597 kg*0.012 = 7.164 kg

⇒ C.A = 1011 kg*0.012 = 12.132 kg

(CC-7)

(ii) Cylindrical Controlling (Normal) samples (15*30 cm)

⇒ 3*1.20*π*ϕ²/4*h = 0.019 m³ (SC-7)

⇒ H₂O = 176.76*0.019 = 3.37 kg

⇒ Cement = 400 kg*0.019 = 7.63 kg

⇒ F.A = 597 kg*0.019 = 11.39 kg

⇒ C.A = 1011 kg*0.019 = 19.28 kg

(SC-7)

(iii) Flexural Controlling (Normal samples) 10*10*50

= 3*1.2*0.1*0.1*0.5 = 0.018 m³ (FC-7)

⇒ H₂O = 176.76 kg*0.018 = 3.18 kg

⇒ Cement = 400*0.018 = 7.2 kg

⇒ F.A = 597*0.018 = 10.75 kg

⇒ C.A = 1011 kg*0.018 = 18.198 kg

(FC-7)

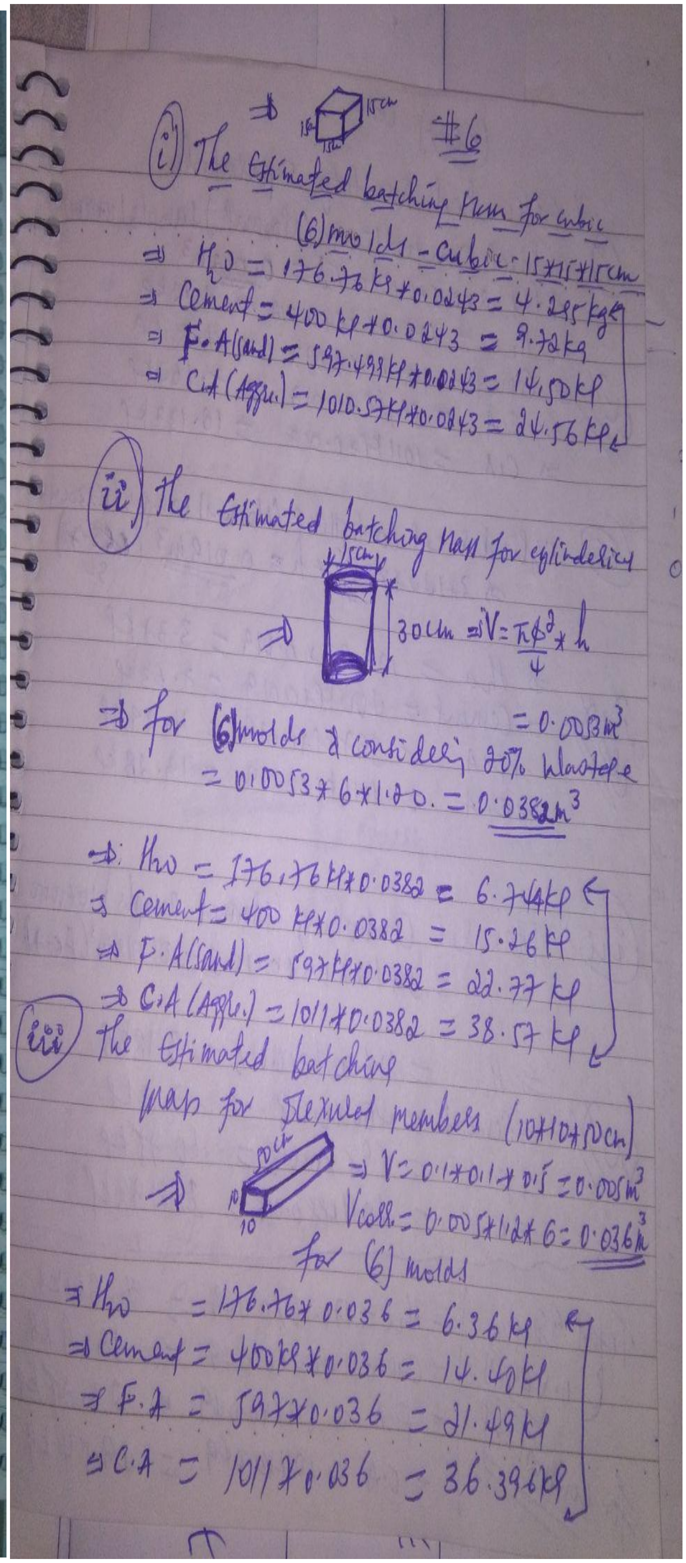
Total 3 samples (0.049 m³) for controlling

= H₂O = 176.76*0.049 = 8.661 kg

= Cement = 400*0.049 = 19.6 kg

= F.A = 597*0.049 = 29.25 kg

= C.A = 1011*0.049 = 49.54 kg



#6

(i) The Estimated batching mass for cubic (6) molds - cubic - 15*15*15 cm

⇒ H₂O = 176.76 kg*0.0243 = 4.295 kg

⇒ Cement = 400 kg*0.0243 = 9.72 kg

⇒ F.A (sand) = 597.493 kg*0.0243 = 14.50 kg

⇒ C.A (Aggre.) = 1010.57 kg*0.0243 = 24.56 kg

(ii) The Estimated batching mass for cylindrical

15 cm, 30 cm ⇒ V = π ϕ²/4 * h = 0.0053 m³

⇒ for (6) molds & considering 20% wastage

= 0.0053*6*1.20 = 0.0382 m³

⇒ H₂O = 176.76 kg*0.0382 = 6.754 kg

⇒ Cement = 400 kg*0.0382 = 15.26 kg

⇒ F.A (sand) = 597 kg*0.0382 = 22.77 kg

⇒ C.A (Aggre.) = 1011*0.0382 = 38.57 kg

(iii) The Estimated batching mass for flexural members (10*10*50 cm)

⇒ V = 0.1*0.1*0.5 = 0.005 m³

Vcoll. = 0.005*1.2*6 = 0.036 m³ for (6) molds

⇒ H₂O = 176.76*0.036 = 6.36 kg

⇒ Cement = 400 kg*0.036 = 14.40 kg

⇒ F.A = 597*0.036 = 21.49 kg

⇒ C.A = 1011*0.036 = 36.396 kg

Table5. 3: Laboratory Result Collection format.

S/N	Test Age (days)	Cross-Sectional type			Dimensions (mm)			Replace ment Amount	Weigth (gm)	Area (m2)	Failure Load(KN)	Comp/Spl/Flex. Strength(Mpa)	Comment 'a' in Cm
		Cubic	Cylindrical	Flexural	L	W	H						
1		X											
2		X											
3		X											
Mean Value													
1			X										
2			X										
3			X										
Mean Value													
1				X									
2				X									
3				X									
Mean Value													
1		X											
2		X											
3		X											
Mean Value													
1			X										
2			X										
3			X										
Mean Value													
1				X									
2				X									
3				X									
Mean Value													

Figure 5.2: prevailing Research Ingredients / of Thesis


a) Building in situ cast **b) Building pre-cast**


c) Road in situ cast/ rigid pavement **d) Road drainage Structures/ pre-cast**

Figure5. 3: In situ cast and Pre-cast of Structures

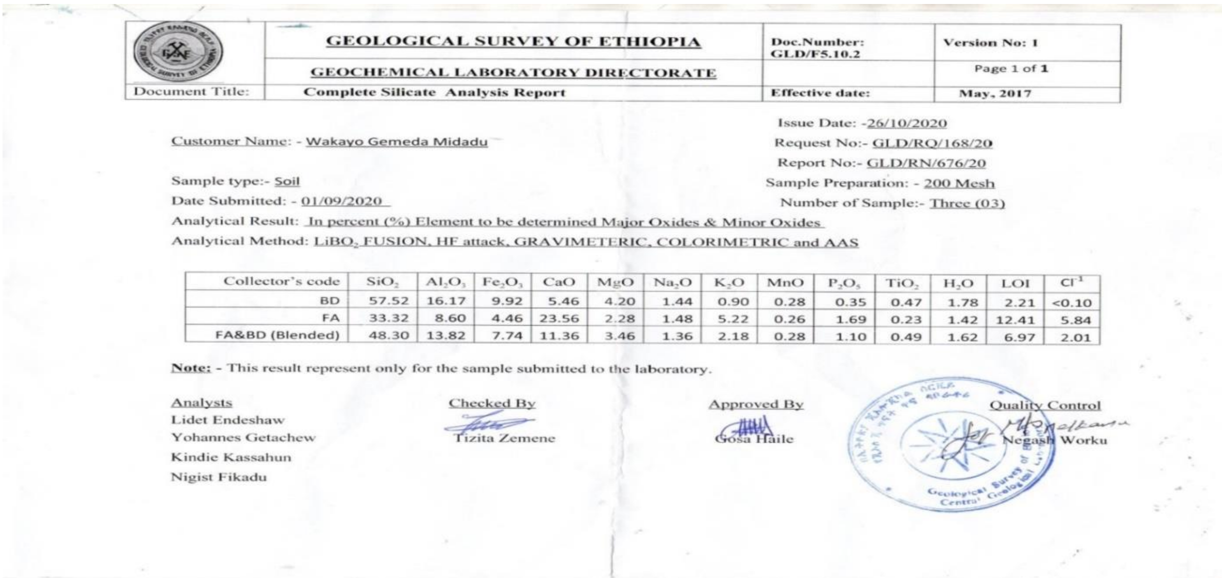
5.8 Accelerated Construction Techniques and Pours at Connections (Pre-cast)

a) Bailey Bridge

b) Bridge Connections pours with high early strength concrete

Figure5. 4: Accelerated Construction Techniques on Bridge

5.9 Silicate Analysis Result of Prevailing Fly Ash and Basaltic Dust



GEOLOGICAL SURVEY OF ETHIOPIA	Doc.Number: GLD/F5.10.2	Version No: 1
GEOCHEMICAL LABORATORY DIRECTORATE		Page 1 of 1
Document Title: Complete Silicate Analysis Report	Effective date:	May, 2017

Issue Date: -26/10/2020

Customer Name: - Wakayo Gemeda Midadu

Request No:- GLD/RQ/168/20

Report No:- GLD/RN/676/20

Sample type:- Soil

Sample Preparation: - 200 Mesh

Date Submitted: - 01/09/2020

Number of Sample:- Three (03)

Analytical Result: In percent (%) Element to be determined Major Oxides & Minor Oxides

Analytical Method: $LiBO_2$ FUSION, HF attack, GRAVIMETERIC, COLORIMETRIC and AAS

Collector's code	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI	Cl^{-1}
BD	57.52	16.17	9.92	5.46	4.20	1.44	0.90	0.28	0.35	0.47	1.78	2.21	<0.10
FA	33.32	8.60	4.46	23.56	2.28	1.48	5.22	0.26	1.69	0.23	1.42	12.41	5.84
FA&BD (Blended)	48.30	13.82	7.74	11.36	3.46	1.36	2.18	0.28	1.10	0.49	1.62	6.97	2.01

Note: - This result represent only for the sample submitted to the laboratory.

Analysts
Lidet Endeshaw
Yohannes Getachew
Kindie Kassahun
Nigist Fikadu

Checked By
Tizita Zemene

Approved By
Gosa Haile

Quality Control
Negash Worku

General steps followed to accomplish the prevailing task

Chart 5.1

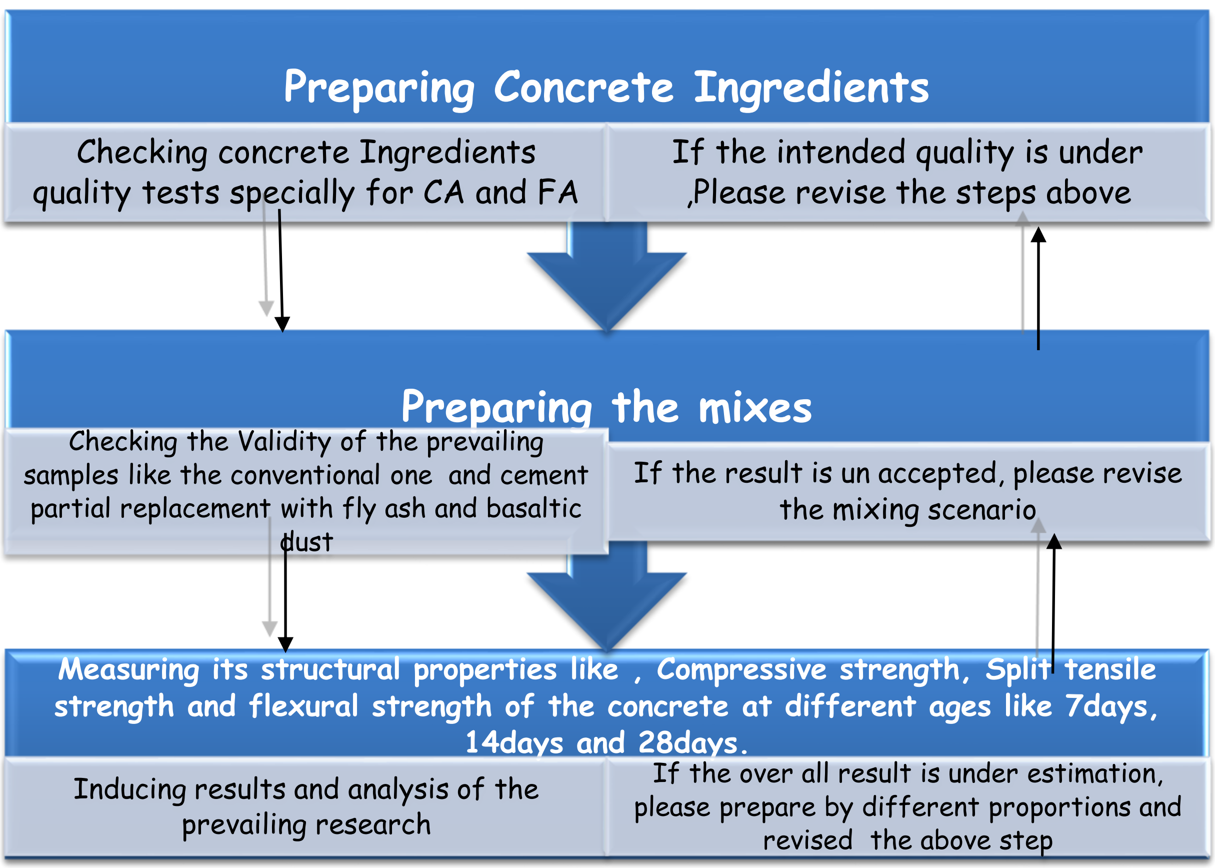


Figure 5.5: Prevailing Cubic, Flexural and Split Tensile Strength Samples after crushed/smashed

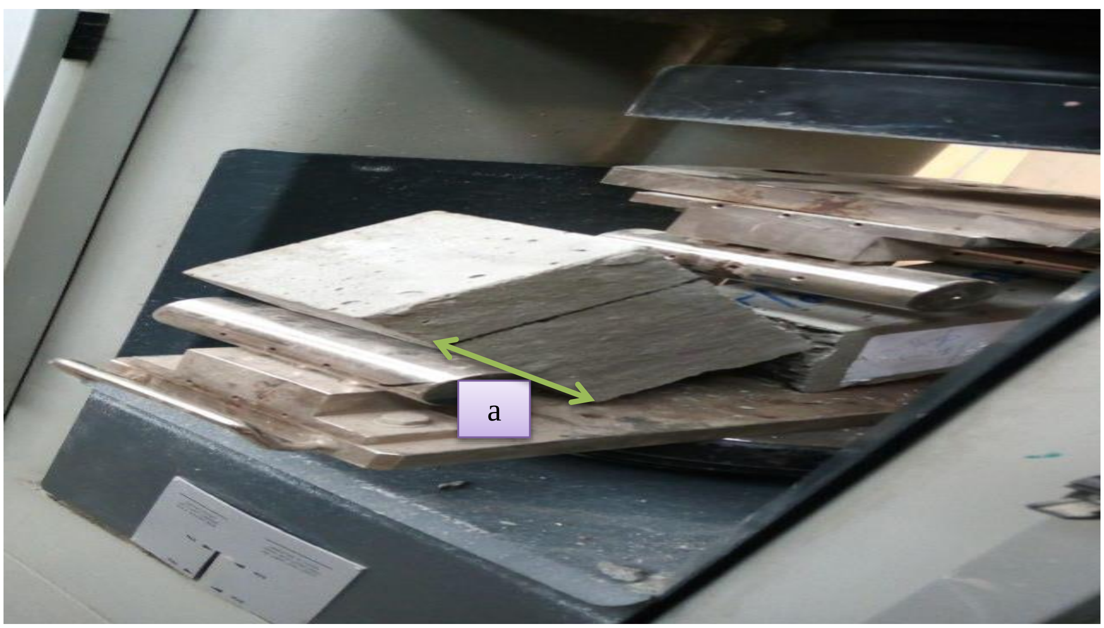


Figure 5.6 Flexural Sample beam during testing in laboratory