Investigation on the Partial Replacement of Cement by the Mixture of Ethiopian Marble Dust and Fly Ash in Concrete Production

Garomsa Wakuma Jifara

A Thesis Submitted to the Department of Civil Engineering

School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Civil Engineering (specialization of Construction Engineering and Management)

Office of Graduate Studies

Adama Science and Technology University

June, 2022 G.C

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DECLARATION

I declare that this thesis entitled **'Investigation on the Partial Replacement of Cement by the Mixture of Ethiopian Marble Dust and Fly Ash in Concrete Production''** is my own work and has not been submitted to any university for similar purpose. The references used in this thesis are duly recognized by proper citations.

Garomsa Wakuma Jifara ______________________ ____________________

Signature Date

RECOMMENDATION OF ADVISORS/ SUPERVISORS

I, the major advisor/supervisor of this research Thesis, hereby certify that I have closely advised/supervised the student while developing this Thesis and read the draft thesis entitled **'Investigation on the Partial Replacement of Cement by the Mixture of Ethiopian Marble Dust and Fly Ash in Concrete Production''** prepared under my guidance by **Garomsa Wakuma Jifara**. Therefore, I recommend the submission of the Thesis to the department for further review and evaluation.

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I/we hereby certify that the recommendation and suggestion given by the Thesis review committee are appropriately incorporated into the final thesis entitled "**Investigation on the Partial Replacement of Cement by the Mixture of Ethiopian Marble Dust and Fly Ash in Concrete Production" By Garomsa Wakuma Jifara**

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APPROVAL OF BOARD OF REVIEWERS

We, the undersigned, members of the Board of Reviewers of the thesis open defense by **Garomsa Wakuma Jifara** have read and evaluated the thesis entitled "**Investigation on the Partial Replacement of Cement by the Mixture of Ethiopian Marble Dust and Fly Ash in Concrete Production"** and assessed the understanding of the candidate about the research. This is, therefore, to certify that the thesis is accepted and we recommend the implementation of the thesis.

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Finally approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ACRONYMS

ACI	-	American Concrete Institute
ASTM	-	American Standard for Testing Material
ANOVA	-	Analysis Of
CCN	-	Chemist Cement Notation
EDAS	-	Evaluation based on Distance from Average
MD	-	Marble dust
FA	-	Fly Ash
MCFT	-	Marsh Cone Flow Time
MCDM	-	Multi-Criteria Decision Making
OPC	-	Ordinary Portland cement
SEM	-	Scanning electron microscope

ABSTRACT

Concrete is a mixture of cement, sand, coarse aggregate and water in the proper proportions. The cement which is one of the components of concrete plays a great role, but is the most expensive and environmentally unfriendly material. The main objective of the research work is to investigate the possibility of utilizing flay ash and marble dust available in Ethiopia as partial replacement of cement. Also to reduce such type of waste in environment or to reduce the amount of the CO_2 release during the manufacture of cement and to analyze the cost of the concrete construction and investigation of fresh and hardened properties of concrete. The setting behavior, soundness and consistency characteristics of cement pastes made by partially replaced cement with fly ash and marble powder are studied. The mechanical properties of the concretes are investigated along with compressive strength test and flexural strength test. Along this, strength development and micro-structural properties of cement modified with fly ash and marble dust are investigated by performing SEM analysis on the mixes specimen pieces. The results of the study indicates that the mixture up to 5% of fly ash and 10% of marble dust can be used as replacement of cement with no compromise on the technical characteristics of the mix. So, the 15% replacement of mix specimen Compressive strength shown us increments by 18.7% and flexural strength also increased by 8.56% at 28 days. The utilization of fly ash and marble dust in the construction industry can improve for environmental, technical and economic issues caused by cement production and cement cost.

Key Words: Cement, Marble dust, Fly Ash, Compressive strength, concrete.

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the study

Concrete is one of the most used building materials globally in developed and developing countries. It is also the second most demandable item, just behind water usage per capita. Cement, sand, aggregate, and water are the materials used in the production of concrete. All of these materials are derived from natural resources. As the demand for concrete rises, so does the need for these materials increases. Natural resource depletion grows as demand rises (Bibekananda Naik et al. 2019). And this rise in demand poses a significant danger to both the environment and society. Now a day, Construction works are taking place on a huge scale all over the world and the need for construction materials are increasing day by day. Production and utilization of concrete has rapidly increased, which results in increased consumption of cement. Similarly in Ethiopia the construction industry is one of the fastest-growing industries due to the fast growth of urbanization and infrastructure development; as a result, there is a high demand for concrete, this in turn results in increased cement demand. Cement is one of the components of concrete plays a great role in concrete production, but is the most expensive and environmentally unfriend material. Different types of industrial waste have been deliberated used by researchers to prevent environmental pollution and also to reduce construction cost (Tewodros G and Miskir G. 2020).

Many researches proved that mineral admixtures can be successfully and economically utilized to improve some fresh and hardened concrete properties. Therefore, requirements of economical and more environmental-friendly cementing materials have extended interest in other cementing materials that can be used as partial replacement of Portland cement. The search for alternative binder or cement replacement materials led to the discovery of the potentials of using industrial by-product cementitious materials. If these fillers have pozzolonic properties, they impart advantages to the resulting concrete and also enable larger quantities of cement replacement to be achieved.

The incorporation of pozzolonic waste ash in concrete can significantly enhance its basic properties in both the fresh and hardened states. The utilization of byproducts as the partial replacement of cement has important economic, environmental and technical benefits such as the reduced amount of waste materials, a cleaner environment, reduced energy requirement, durable service performance during service life and cost-effective structures (Madhavi et al. 2016)

1.2. Statement of the problem

Concrete is one of the suitable building materials used in the current construction industry in the developing countries including Ethiopia to meet the construction demand, where Cement is one of the components in concrete production, the cost of cement is increasing rapidly and becomes one of the challenges of the construction industry. The production of cement requires high consumption of natural raw resource, such as calcium oxide (lime) is being exploited in huge amount. Furthermore, the production process and extraction of raw materials is one of the most environmentally unfriendly due to the release of CO_2 gas to the atmosphere and high energy consuming. Fly ash is a by-product from burning pulverized coal in electric power generating plants .About 20% of quarried marble is resulted as waste and reached as high millions of tons. Marble waste is damped in pit near the construction site or factory. This practice will not consider safety as per environmental concerns since disposal of Marble dust and fly ash up on open places as in dry season marble powder flies in air and get deposited on vegetation which contaminate the ground water as well as surface water.

1.3. Research Questions

The research questions which are proposed for the research study will try to seek out the answers for follows:

1. What is effect of partially replaced cement concrete by the mixture of fly ash and marble dust on the fresh properties and mechanical properties?
2. How the chemical composition of mixture of Marble dust and fly ash affect concrete strength?
3. What is the cost benefit of partially replaced cement concrete than conventional concrete?
4. What is the environmental advantage of partially replaced cement concrete than conventional concrete?

1.4. Objectives of the study

1.4.1. General Objective of the study

The general objectives of the study is to investigate the effect of Partial Replacement of Cement concrete by the waste materials Mixture of Fly Ash and Marble Dust Concrete Production.

1.4.2. Specific Objectives of the study

The specific objectives of this research is:

- To investigate the fresh properties of cement concrete that partially replaced by the mixture of fly ash and marble dust.
- To investigate the Hardened properties of cement concrete that partially replaced by the mixture of fly ash and marble dust.
- To analyze the chemical composition of supplementary materials and comparison of replaced cement concrete with conventional concrete.
- To analyze the concrete cost and environmental pollution by discovering the effect of replacing materials on cement concrete in Ethiopia.

1.5. Significance of the Study

In this study the mixture of Ethiopia marble dust and fly ash was used as a supplementary cementitious material in concrete production; to study the suitability, the fresh and hardened properties of concrete with and without the mixture of marble dust and fly ash. The research studying the effect of microstructure of marble dust and fly ash chemical composition, physical properties of materials used for the study. The samples hydrated at different time intervals ranging from one hour to 4 weeks. Concrete cubes was prepared in the different series of concrete mixes based on the conventional mix techniques these tests were carried out to evaluate the strength properties for 7, 14 and 28 days. Fly-ash and Marble dust are among the solid wastes are generated by the industries. Thus they are considered as a pollutant or the wastes that they are very cheap and easily available and we can use them as a partial replacement. The partial replacement of cement with Fly Ash and Marble dust can be economically alternative. Fly Ash and Marble dust replaces the cement. The water cement ratio was maintained at 0.5 for all mixes.

1.6. Scope of the study

For this work M25 concrete was considered. The mixture of flay ash and Marble dust is used as replacement of cement by weight indifferent mix ratio. Workability, compressive strength and flexural strength of the partially replaced concrete, Analyzation of the cost and chemical composition of partially replaced concrete with conventional concrete. The procedure of Procuring Unprocessed mixture of fly ash and Marble Powder from Addis Ababa repi power generation for Fly ash and Sabata Tsegaye marble processing site and disposal. Blending up to 90µm size then Development of mix design as per IS 10262:2009.Preparing concrete cubes with the mixture of fly ash and Marble dust replacing cement with 0%, 10%, 15% and 20%, by weight.

1.7. Structure of the thesis

The research is organized into five chapters and each chapter contains a number of sections and further subsections. A general introduction provided along with the research objective and significance in the first chapter. In Chapter two, a comprehensive review of concrete replaced by different supplementary materials including marble dust and fly ash are presented. Chapter three used entirely to describe methodology and materials used in the research. It explains properties of materials, mix proportions, mixing, casting, and curing procedures used in the attempt to find out in a systematical and scientific study. Chapter four covers the experimental program of the study, results, and discussions of the tests carried out during this study. Conclusions are in chapter five together with recommendations for further research work. This followed by an extensive list of references. The Appendix's give the results of the individual tests, other relevant data and representative photos taken during the research work.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

Concrete is basically a mixture of two components: aggregates and paste. The paste, comprised of Portland cement and water, binds the aggregates (usually sand and gravel or crushed stone) into a rocklike mass as the paste hardens because of the chemical reaction of the cement and water. Supplementary cementitious materials and chemical admixtures may also be included in the paste.

Concrete manufacturing is one of the technique related to building and construction industry have been developed after the invention of cement, Cement is the widely used material in the world for various construction purposes but during manufacturing of cement lot of dangerous gases are released such as carbon monoxide and carbon dioxide in the same way the hazardous waste such as highly alkalized materials and volatile organic compounds. Due to these hazardous waste the different cause of problem in eco-system which leads to environmental imbalance formed. But by using supplementary cementitious material we can reduce the environmental imbalance and maintain the eco-system in the good way different types of industrial waste have been deliberated used by researchers to prevent environmental pollution and also to reduce construction cost. (Madhavi et al. 2016).

Waste material was found to have either reactive or filler effect in cement and concrete production. Reactive materials are named pozzolanas and have been used widely worldwide where available. The use of inert fillers is also a common practice in European countries, especially in France. The addition of inactive materials or fillers, principally limestone, is increasingly accepted in European Countries since the European Standard for common cement is first published in 1992 as pre-standard ENV 197-1. (Berhanu Negesse 2018) There has been an increasing trend in the use of limestone as a mineral additive in cement not only in the European countries but also in other parts of the world.

Many researches proved that mineral admixtures can be successfully and economically utilized to improve some fresh and hardened concrete properties. Reducing natural resources by using mineral admixtures and re-using waste materials have gained importance from the environmental perspective. The extraction of natural resources for concrete production is inevitable. Nevertheless, the use of natural local resources within limited territory does not meet the changing needs of the world; thus, it cannot be sustained in the future. The construction sector should promote the use of waste materials in concrete construction. Sector should also provide alternative sustainable approaches to reduce the need for natural materials on both national and international basis.(Sevket Can Bostanci 2018).

2.2. Basic Composition of concrete

Concrete is a composite material composed of cement, water, and aggregate (fine and coarse) in suitable proportions and allowing the resulting mixture to set and harden over time. The aggregates, Supplementary cementing materials, chemical admixtures, and fibers are added to the concrete based on the intended use of concrete. Each of the constituents of concrete has its own role in concrete. The reaction of Cement and water is a cementing medium or paste holds the aggregate together in concrete whereas the fine and coarse aggregate serves as filler in concrete production. (Dr. Edward G. Nawy 2008).

2.2.1. Cement

Cement is an intimate mixture of limestone ($CaCO_3$) and clay or silt (iron bearing alumino silicates), to which a small amount of iron oxide (Fe_2O_3) and sometimes quartz (SiO_2) is added, is heated in a kiln to a temperature of between 1400 and 1600°C; in this temperature range, the materials react chemically to form calcium silicates, calcium aluminates, and calcium alumino ferrites.

The raw materials, which are ground to a fineness of less than about 95 µm, are introduced at the top end of an inclined rotary kiln. The kiln is heated by fuel (natural gas, oil, or pulverized coal) that is injected and burned at the lower end of the kiln, with the hot gases passing up through the kiln. Thus, in a period ranging from about 20 minutes to 2.5 hours, depending on the kiln design, the raw ingredients are subjected to increasingly higher temperatures as they pass through the kiln, and a complex series of chemical reactions takes place.(Dr. Edward G. Nawy 2008).

2.2.1.1. Chemical composition of cement

The raw materials used for the manufacture of cement consist mainly of lime, silica, alumina and iron oxide. These oxides interact with one another in the kiln at high temperature to form more complex compounds. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement.

The European Standard EN 197-1 uses the following definition: Portland cement clinker is a hydraulic material which shall consist of at least two-thirds by mass of calcium silicates, (3 CaO SiO_2, and $2CaO \cdot SiO_2$), the remainder consisting of aluminium- and iron-containing clinker phases and other compounds. The ratio of CaO to SiO_2 shall not be less than 2.0. The magnesium oxide content (MgO) shall not exceed 5.0% by mass (Wikipedia 2021).

Table 2:1 typical constituents of Portland cement clinker (Abrar Awol 2011)

Clinker	**CCN**	**Mass**
Tricalcium silicate $(CaO)_3 \cdot SiO_2$	C_3S	25–50%
Dicalcium silicate $(CaO)_2 \cdot SiO_2$	C_2S	20–45%
Tricalcium aluminate $(CaO)_3 \cdot Al_2O_3$	C_3A	5–12%
Tetracalcium aluminoferrite $(CaO)_4 \cdot Al_2O_3 \cdot Fe_2O_3$	C_4AF	6–12%
Gypsum $CaSO_4 \cdot 2\ H_2O$	CSH_2	2–10%

Where, CCN is chemist cement notation, as the range in Table 2:1 shows to achieve the desired setting qualities in the finished product, a quantity (2–8%, but 5%) of calcium sulfate (usually gypsum or anhydrite) is added to the clinker, and the mixture is finely ground to form the finished cement powder. So the cement used in investigation conform ASTM 150-07 standard specification of Portland cement.

2.2.1.2. Properties of cement

Chemical composition and the physical parameters of the cement as cement grade with 42.5 compressive strength are presented below respectively.

Table 2:2 Chemical composition of cement (Alyousef et al. 2018).

Component	CaO	SiO_2	LOI	K_2O	MgO	Fe_2O_3	Al_2O_3	RI	SO_3
Percentage	63.53	20.19	3.21	0.46	1.07	3.75	4.92	0.61	1.57

Table 2:3 Physical and mechanical properties of cement (Alyousef et al. 2018).

Properties Absolute	density (g/cm3)	Bulk density (g/cm3)	BSS (cm2/g)	True class of strength (MPa)
Value	3.08	1.03	3100	44.5

2.2.2. Aggregate

Aggregate is granular material such as sand, gravel, crushed stone and lightweight aggregates that usually occupies approximately 60 to 75% of the volume of concrete. Aggregate properties significantly affect the workability of plastic concrete and also the durability, strength, thermal properties, and density of hardened concrete. The quality of aggregate is considerably important because at least three-quarters of the volume of concrete is occupied by it. (Bitew and Biruk N. 2014).

2.2.2.1. Properties of Aggregates

Crushed basaltic rock of Table 2:4 confirming the ASTM C136 with the nominal size of 0/2 and 4/8 with the Absolute density of 2.42 and 2.55 of fine and course aggregates respectively and the fineness modulus of 1.85 and 4.8 will be the proper specification of aggregate. Sieve analysis was performed to observe particle size distribution. 10 mm and 20 mm aggregates were used in equal proportion.

Table 2:4 Physical characteristics of aggregates(Ahiwale and Khartode 2020).

Aggregates	Absolute density (g/cm3)	Bulk density (g/cm3)	Finesse module	Equivalent of sand (%)	Los Angeles (%)	MDE (%)	Absorption (%)
Sand 0/2	2.42	1.47	1.85	91	-	-	-
Crushed sand 2/4	2.55	1.32	4.8	100	17	13	0.32
Gravel 4/8	2.55	1.42	-	-	17	13	0.32
Gravel 8/12	2.55	1.40	-	-	17	13	0.32

2.2.3. Water

Water acts as lubricates for the fine and coarse aggregate and acts chemical with cement to form the binding paste for the aggregate water is used for curing the concrete after it has cast in to the forms. Water used for both mixing and curing should be free from injurious amount of deleterious materials. Potable water is generally considered satisfactory for mixing and curing of concrete (Dumpati Mamatha and Kiran H P 2018). If water contains any sugar or an excess of acid or salt, it should not be used. Ordinary tap water from our college was used for preparation of concrete.

2.3. Supplementary materials

2.3.1. Fly Ash

Fly ash is the finely divided mineral residue resulting from the combustion of powdered coal or solid waste in electric power generating thermal plant. Fly ash is a beneficial mineral for pozzolonic Portland cement preparation. It influences many properties of cement. Utilization of waste materials in cement and concrete industry reduces the environmental problems of power plants and decreases electricity generation costs.

Fly ash is composed of the non-combustible mineral portion of coal. Particles are glassy, spherical ‘ball bearings’ finer than cement particles. Sizes of particle are 0.1µm-150 µm. it is a pozzolonic material which reacts with free lime in the presence of water, converted into calcium silicate hydrate (C-S-H) which is the strongest and durable portion of the paste in concrete. (Pitroda, Zala, and Umrigar 2012)

2.3.2. Marble Dust

Marble is a metamorphic rock which results from the transformation of pure limestone. Chemically, calcite, dolomite, or serpentine materials are the major components of marble as crystalline rocks. Marble powder was obtained by crushing marble sludge, which is a waste product from the marble cutting industry, was collected from locally situated marble cutting industries.

Marble is a very important material for construction, particularly for decoration reasons. %25 percent of marble turns to powder and dust due to shaping, polishing, and sawing. The wastes of the marble industry have become a major environmental problem since the beginning of the 2000s. This issue is not just a local problem, and it is of direct concern to dozens of countries. While many countries, such as Turkey, Iran, Italy, China, India, Spain, Brazil, South Africa, Portugal, Pakistan, USA, Egypt and Finland, export the marble products, many other countries, such as Japan, Germany, Taiwan and South Korea, import them. Turkey owns 40% of the world's marble reserves, and storing the waste released during production is of utmost importance. Turkey has nearly 3.872 * 106 m^3 of marble reserves, of which close to 125 * 103 t/year are generated in Afyon City alone. Five thousand processing factories are used for marble production in Turkey. It is clear that these waste products reach millions of tons; so it is too difficult to store this amount of wastes. (Çınar, Karpuzcu, and Çanakcı 2019).

Marble waste can be recycled as a useful material. The most suitable inactivating method nowadays is recycling waste by producing new products or by addition as admixtures so that the environment is protected from waste deposits. The characterization of the Marble dust was carried out using international experimental tests (Alyousef et al. 2018).

The results showed that the use of waste materials provided similar fresh properties as control mix. The 28th day compressive cube strength decreased by 19% for marble dust added mixes. Studies assessing other engineering properties, including sound permeability, thermal conductivity and water permeability showed enhanced performances for waste incorporated mixes. Regarding sustainability performance, marble dust and recycled glass sand mixes had a lower environmental footprint and higher cost compared to conventional concrete. Considering overall performance analysis, marble dust showed 17% improvement, revealing a promising solution for sustainable concrete production (Sevket Can Bostanci 2018).

2.3.2.1. Marble in Ethiopia

Marble is a rock composed of granular limestone or dolomite, which is recrystallized by the influence of heat, pressure and aqueous solutions. This Metamorphic rock can be found in nature with different attractive colors and varieties as well as quality.

Marbles can be processed in industries to produce various kinds of marble stones. The products of marble processing industries can be used for monuments, interiors decoration, statuary, table tops and novelties. In Ethiopia, marble occurs within the Precambrian basement rocks in all geologic ages; namely, calcite and dolomite marble in the Awata group of Archaean Complex, marble in the Birbir group, Tulu Dimtu group and Mormora group of Late Proterozoic rock of the volcano sedimentary succession of Pan African age and the most interesting deposits of marble are found in the western part of Wellega (Daleti) and Gojam (Mora, Bulen, Mankush and Baruda). The area is quite remote, and transport distances to Addis Ababa vary between 550 and 800 km, for the most part along non-paved roads. However, at the present time, transport costs are still low enough for the marble-producing companies to find the production profitable.(Walle and Zewde 2000).

Currently, there are more than fourteen marble processing plants in Ethiopia located in different towns. In Ethiopia, 3,365,615.00 metric square of marble commodities were produced from the year 2009 to 2013 which implies that 30% of this mineral was lost as waste. Currently the amount of loss as waste is increasing as more other companies joined the industry than before. Thus, checking the feasibility of the marble byproduct powder or dust which is left as a waste in marble factories for using it as a partial cement replacement material in concrete production (Berhanu Negesse 2018).

2.4. Conventional Cement Concrete

Conventional Concrete is prepared from a mixture of coarse and fine aggregates, Portland cement (PC), and water. Other additives such as fly ash and different types of admixtures such as air-entraining agents, accelerators, retarders, and plasticizers also may be used to improve the concrete's capabilities for workability and strength. Conventional concrete is a conglomerate of hydraulic (Portland) cement, sand, stone, and water. It was developed approximately 150 years ago to imitate natural stone while providing less labor-intensive methods of shaping the material (i.e., casting rather than hewing and carving). As such, it was initially expected to resist only compressive loads. (Syed Shahabuddin Ahmed 2015).

In conventional concrete Tests performed on hardened concrete cured under clean and fresh water, and compressive and flexure strength were observed at curing ages of 7, 14 and 28 days. The rate of gain in compressive strength, and flexural strength of concrete is very fast at 14 days curing period and the rate gets increases with age. (Dumpati Mamatha and Kiran H P 2018).

2.5. Partially Replaced cement Concrete

The partial replacement of cement concrete is one of the study area that many researchers investigates on to find the solutions of problems raise with cement. For example high cost of cement, used as binder, in the production of mortar, sand-Crete blocks, concrete has led to a search for alternative. In addition to cost, high energy demand and emission of CO_2, which is responsible for global warming, the depletion of lime stone deposits are disadvantages associated with cement production. About 7% CO_2 is released into the atmosphere during cement production, which has a negative influence on ecology and future of human being arising from global warming. (Joel 2010).

So many papers shows the results of an experimental study conducted to research the impact of waste marble powder (WMP) and fly ash (FA) on the fluidity (marsh cone flow time (MCFT), mini-slump diameter and plate cohesion meter (PCM) of concrete mixtures. The experiments were applied with the concrete mix including 1.00 water-binder (w/b) ratios and combined use of WMP (5-25%), FA (5-25%) and WMP+FA (10-30% + constant 25%). Test results illustrated that FA and WMP+FA to grout mix at w/b=1 ratio, strongly shear thickening behavior was got from the concrete mixtures the all WMP, FA and WMP+FA content. The increase in the percentage of WMP (5-25%) amount reduced the mini-slump flow diameter. Moreover, the increment in the percentage of FA (5-25%) amount increments the mini slum flow. According to the control sample, the increment in the percentage of marble dust (10- 25%) amount increased the mini-slump flow diameter for constant fly ash (25%) content. Also, the increase in marble dust amount in the concrete mix, there is no effect on MCFT. Also, MCFT decreased with the increase of FA amount. Especially, FA increased the fluidity of concrete, when the WMP showed negative effect in increase the MCFT in WMP+FA content.(Çınar et al. 2019).

2.5.1. The Effect of marble dust and fly ash on strength properties

The cement 42.5R grade was used complying with ASTM C150 Type-I cement. Class F FA was used an additive in Concrete according to ASTM C 618. Also, WMP was used as an additive. Waste marble sludge (WMS) was provided in the form of a wet slurry from marble factory in Gaziantep-Turkey. The WMS was dried in an oven at 100 ± 10 ° C for 24 hours and then sieved with 150 µm sieve.

Figure 2:1 Cement, Fly ash and waste Marble powder (Çınar et al. 2019).

Water-binder (w/b) ratio is one of the important factors that has a prominent impact on the fresh and hardened characteristics of concrete mixes. So, in this experimental work w/b= 1.00 rate were chosen to research the effect of WMP, FA and WMP+FA on the concrete. 16 injection mixtures with various WMP, FA and WMP+FA amount were prepared to the impact of WMP, FA on the characteristics of concrete mixtures. WMP, FA and WMP+FA was replace with cement substitutions of 5-25%, 5-25% and 10-30% + constant 25% by volume. The control mix was prepared with only Cement and water at w/b=1.00 rate. WMP and FA weren't added to the control mix. The mixture proportions are illustrated.

In this study the Method used for partial replacement of Cement with Marble Powder and Fly Ash is done in different proportion. After preparing the samples according to the orthogonal array, the mechanical characterizations are performed. Hardened concrete tests such as compressive strength, split tensile strength and flexural strength test have been conducted to appraise the mechanical properties of concrete. Multi-response optimization has been carried out by the application of a recent multi-criteria decision making (MCDM) method, i.e. (EDAS) In order to define relative significance of considered criteria a pairwise comparison matrix was used. Finally, the confirmation test was carried out to validate the obtained results and the models are validated using analysis of variance (ANOVA). The results of all tests were analyzed, comparison has done among concrete mixes and the conclusion is drawn.(Bibekananda Naik et al. 2019).

In preparation for the concrete mixtures, five-liter laboratory mixer was used. The mixing step was applied in the experiment as following; WMP, FA, cement and water were mixed at slow speed (120 rpm) for 1 min. The mixer was paused and the remaining concrete mixture on the sides of the container was stripped. Also, concrete mixes was blended by hand for one minute. Lastly, the mixer was restarted at high speed (240 rpm) and the concrete mixture mixed for three minutes. Temperature and humidity of the laboratory for all tests were checked and measured as 50-60% and 20±3 respectively. All concrete mixtures were obtained by using the same mixing procedures.

Figure 2:2 Laboratory Mixer (Bibekananda Naik et al. 2019)

Other researcher explores the development of concrete by replacing of cement with marble powder and fly ash. Compressive, split tensile and flexural strengths were evaluated for different replacement of marble powder and fly ash based concrete. The results of all tests were optimized using Evaluation based on Distance from Average Solution (EDAS) method and the conclusions were drawn. After the experimental study conclusions made from this study is From the 56 days compressive, split tensile and flexural strength results, it is found that with 5% replacement of marble powder with cement getting high strength as comparing to the control specimen. The predictive values determined using recently developed optimization technique i.e. EDAS and Taguchi coupled EDAS method is almost similar to each other. Optimal factor setting for fabrication of concrete specimen by replacing of cement with marble powder and fly ash using two optimization approach. The optimal values will be useful for the industry selection of combination of Cement, marble powder and fly ash for construction. More reliable prediction of unit process will enable industry to develop more optimized concrete which can be used in many areas.(Bibekananda Naik et al. 2019).

(Parth.D.Joshi1 2018) The workability of marble powder has found to increase than normal concrete. It appeared that the addition of marble powder improves the workability. Marble powder was added range of 5%, 10% by weight of cementations materials for maintaining the slump and Compressive strength of marble powder (Cube) for 0%, 5% & 10% replacement with OPC cement at 7 , 14 and 28 days is marginally decreased as follows.

Table 2:5 Experimental results of compressive strength of cube at 7 , 14 & 28 days of age.(Parth.D.Joshi1 2018)

Marble Powder %	Compressive Strength (MPa) (7days)	Compressive Strength (MPa)(14 days)	Compressive Strength (MPa) (28 days)
0%	14.21	19.68	31.93
5%	20.5	28.14	37.25
10%	21.97	29.56	38.96

Deepankar Experimental investigation concluded that the investigations shows increase in compressive strength on 15% replacement of sand by marble powder and it decreases on replacement of 15% cement also the Maximum split tensile strength was achieved on 10% sand replacement but on replacement of 15% sand and 15% cement in combined form shows decrease in split tensile strength and in comparison to the control concrete, flexural strength shows improved results for 10% replacement of sand and cement individually by marble powder. The ultrasonic pulse velocity shows improved results up to 15% replacement of sand with marble powder and The water absorption of concrete mix was slightly increased up to 15% replacement of cement and sand individually by marble powder.(Ashish, Deepankar K. et al. 2016) Ahiwale and Khartode investigated the partial replacement of cement concrete by adding rice husk ash on the mixture of fly ash and Marble dust they generalize Compressive strength increased when cement is replaced by 10% of fly ash, rice husk ash and marble powder as compare to control mix concrete, other flexural strength is slightly less as compare to control mix concrete. Compressive and flexural strength increases when percentage of fly ash increases as compare to rice husk ash and marble powder. The rice husk ash and marble powder is cost effective as compare to silica fumes. The maximum replacement of cement is 20% of fly ash, rice husk ash and marble powder when compared with minimum strength required. The use of supplementary cementing material as fly ash, rice husk ash and marble powder in concrete pavement roads of less traffic load is economical and eco-friendly.(Ahiwale and Khartode 2020) At 5.0% replacement of the marble powder, it is observed that the change in the flexural strength is very less, i.e. 2.04% increased, at the 10% replacement of the marble powder the strength is increased by 11.22%. In the same way with continuous replacement of the marble powder the strength got increased by 6.12% and 8.77% as compared to normal mix. But these are less when compared with the strength at 10% replacement. At the 10% replacement of the marble powder the strength is maximum at 7 days of curing. At 28 days the strength got increased comparatively at 5% replacement of the marble powder by 6.6%, at 10% replacement of the marble powder, there is increased in strength by 20% which is very high. In the same way with continuous replacement of the marble powder the strength got increased by 8.0% and 9.2% as compared to normal mix. But these are less when compared with the strength at 10% replacement got optimum result at the 10% replacement of the marble powder. At 56 days of curing, with the 5% replacement of the marble powder and without replacement of the marble powder, the change in strength is observed i.e. 3.7% increase. The strength is maximum at the 10% replacement of the marble powder which is 14.8% increased. In the same way with continuous replacement of the marble powder the strength got increased by 0.37 % and 1.85% as compared to normal mix. (Dr. B. Krishna Rao 2016).

The effect on strength and mechanical properties of cement concrete by using Fly ash (FA), Marble dust (MD) & Stone dust (SD). Concrete has become an indispensable construction material and it is now used in greater quantities than any other material. In the present context durability, strength, economy and stainable development are key issues for development. 25% and 35% of fly ash is used as replacement of cement and 30% and 40% natural sand is replaced by MD and SD in different proportion in concrete. Properties of fresh concrete and hardened concrete are investigated. Concrete prepared by replacing 25% of cement by Fly ash and 30% of sand by marble dust and stone dust showed good results. The 7day & 28 days compressive strength was only about 3 to 4 % lesser than the control concrete. (Kumar and Bhadoriya 2015).

2.5.2. Partially replaced cement concrete effect on Work ability of concrete

The ease of placing, consolidating, and finishing freshly mixed concrete and the degree to which it resists segregation is called workability. Factors that influence the workability of concrete are the method and duration of transportation, quantity and characteristics of cementitious materials, concrete consistency (slump), grading, shape, and surface texture of fine and coarse aggregates, Water content ambient air temperature and the use of Admixtures.

The Author concluded that the Use of marble powder and fly ash by substitution to cement has no negative effect of workability of concrete. In Fresh property such as Filling ability and Passing ability is increase by Use of 10% Marble Powder and 25% Fly Ash by Substitution of cement in binder material, Increase of Marble powder in concrete increase slump flow the increase of Marble powder in concrete decreases both T50 test time and V –funnel time, Increase of Marble Powder in concrete increase passing ability. In Hardened property such as Compressive strength, Flexural strength and Split tensile strength would be taken into account, Marble powder can be used up to 10% and Fly ash 25%. the positive effect of marble powder 10% and Fly ash 25% by substitute cement in binder material in self-compacting concrete.(Pala, Dhandha, and Nimodiya 2015)

2.5.3. Partially replaced cement concrete effect on Durability of concrete

All the mixes containing the waste marble powder absorbs less water as compare to control mix. So there is a slightly increase in the durability of concrete. MX1 absorbs 13% less water as compared to control mix (MX0). Similarly MX2, MX3, MX4, MX5 and MX6 absorbs 12.5%, 15%, 11%, 5.7% and 2% less water as compared to MX0. Low water absorption was noticed in blended cement concrete with the use of marble powder as it is micro fine filler, due to which low porosity can also be observed. (Ashish, Deepankar K. et al. 2016)

Varun and Harish B From the study titled as "Effect of Addition of Fly-ash and Ground Granulated blast Furness slag on Cement Concrete in Fresh and Hardened State" concluded that

- Incorporation of Fly ash and GGBS as a partial replacement of cement in concrete gives good results in both fresh and hardened state.
- In low volume replacement Mix M2 (20%Fly ash +20%GGBS+60%OPC) gives good workability and strength.
- In high volume replacement Mix M7 (40%Fly ash+20%GGBS+40%OPC) gives good workability and strength.
- The study reveals that low volume replacement mix M2 (20% Flyash+20% GGBS+60% OPC) is giving good result than high volume replacement Mix M7 (40%Flyash+20% GGBS+40% OPC) at all ages of curing.

Making concrete with the combination of Fly ash and GGBS and cement with different percentages gives good results compared to control concrete. So the best way to use these materials is in combination. (B K Varun, Harish B A 2018).

2.5.4. The effect of Fly Ash and marble dust chemical composition on Concrete

These decreases in strength mainly occur due to replacement of Portland cement with powder addition causing dilution of C_3S and C_2S which is responsible for strength; and also due to less filler effect of the powder as the fineness of the waste powder being not much greater than that of the cement which probably hinders the $CaCO_3$ to be nucleation site.(Abrar Awol 2011) One of the efforts to produce more environmentally friendly concrete is to reduce the use of OPC by partially replacing the amount of cement in concrete with by-products materials such as fly ash. As a cement replacement, fly ash plays the role of an artificial pozzolonic, where its silicon dioxide content reacts with the calcium hydroxide from the cement hydration process to form the calcium silicate hydrate (CS-H) gel. The spherical shape of fly ash often helps to improve the workability of the fresh concrete, while its small particle size also plays as filler of voids in the concrete, hence to produce dense and durable concrete.(Syed Shahabuddin Ahmed 2015).

Table 2:6 Chemical composition of marble powder.(Syed Shahabuddin Ahmed 2015).

Component	SiO2	Fe2O3	Al2O3	CaO	MgO	LOI
Percentage	3.00	0.39	0.14	52.28	0.50	42.60

Table 2:7 Physical parameter of Marble Dust

Properties	Particle size (mm)	Absolute density (g/cm3)	Bulk density (g/cm3)	Blaine specific surface (BSS) (cm2/g)
Value	0/0.063	2.69	0.61	9459

Fly ash material solidifies while suspended in the exhaust gases and is collected by electrostatic precipitators or filter bags. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5µm to 300 µm. The major consequence of the rapid cooling is that only few minerals will have time to crystallize and that mainly amorphous, quenched glass remains. Nevertheless, some refractory phases in the pulverized coal will not melt (entirely) and remain crystalline. In consequence, fly ash is a heterogeneous material. SiO_2, Al_2O_3, Fe_2O_3 and occasionally CaO are the main chemical components present in fly ashes. The mineralogy of fly ashes is very diverse. The main phases encountered are a glass phase, together with quartz, mullite and the iron oxides hematite, magnetite. (Jatale 2013).

Table 2.8 Chemical composition of fly ash(Jatale 2013).

Component	**Bituminous**	**Sub bituminous**	**Lignite**
SiO_2 (%)	20-60	40-60	15-45
Al_2O_3 (%)	5-35	20-30	20-25
Fe_2O_3 (%)	10-40	4-10	4-15
CaO (%)	1-12	5-30	15-40
LOI (%)	0-15	0-3	0-5

The above concentrations of trace elements vary according to the kind of coal combusted to form it. In fact, in the case of bituminous coal, with the notable exception of boron, the chemical properties of the fly ash are largely influenced by the chemical content of the coal burned.

2.5.5. Environmental Impact of using supplementary cementing material's

It is estimated that The Ethiopian Marble Processing Enterprise produces 1800m3 (4500 tons) marble waste annually, which implies that using marble waste of The Ethiopian Marble Processing Enterprise as cement replacing material can indirectly reduce CO_2 emission to the atmosphere by 4500 tons annually.(Abrar Awol 2011).

In addition to the loss, disposal of this waste material will cause different environmental problems like - If the waste is disposed on soils, the porosity and permeability of topsoil will be reduced, the fine marble dust reduces the fertility of the soil by increasing its alkalinity. When the waste is dumped and dried out, the fine marble dust suspends in the air and slowly spread out through wind to the nearby area. When dumped along a catchment area of natural rainwater, it results in contamination of over groundwater reservoir and causes drainage problem. (Berhanu Negesse 2018).

Environmental impact comparison of normal concrete with marble dust incorporated concretes shows positive signs of reduced impact of concrete because of large savings in environmental impact of cement reduction and sand extraction and also Disposal of concrete affects fossil depletion, ozone depletion and agricultural land use (Singh et al. 2017).

Due to environmental issues in the production of cement, industrial by products like fly ash and GGBS are used as supplementary materials in concrete and it saves cost of production of concrete, and makes it eco-friendly.

In Above, literature review suggests that fly ash and marble dust waste can be utilized as cement partial replacement up to a certain level. The existing literature mostly deals with the fresh and hardened properties of waste incorporated concretes, compressive strength, water absorption, drying shrinkage, and moisture content, a sampling of concrete to test criteria, chemical and physical property of marble dust, fly ash and other supplementary cementing material investigated and discussed based on the fact collected from the experiment, some previous studies of using those materials as a filler in concrete. Pozzolonic materials like fly ash, GGBS and rice husk ash are better substitutes for cement replacement. Various industrial wastes or recycled materials were introduced as a replacement for either Cement or aggregates to encourage sustainability.

2.6. Research Gap

From the literature survey, it has been observed that the studies have been performed on conventional concrete comprising the mixture of fly ash, Marble Powder and other supplementary material as a cement replacement. These concretes cannot be classified as a sustainable product unless they practically satisfy economic, environmental and social principles.

- There is no collective frame work conclusion on the environmental and economic (cost) analysis by sustainability of waste incorporated mixes in practice.
- The chemical composition of the materials are not concerned as the consequences on decreasing or increasing of concrete quality during investigation.

This study was suggested an optimum percentage of the mixture of fly ash and Marble powder as a cement concrete partial replacement and analyze the needed chemical composition in replacing materials. This will not only help the construction industry in producing cheaper concrete but also reduce the waste produced from the industry and thermal power plants. This will also reduce the CO_2 emissions from the cement manufacturing industry this study aimed to investigate the feasibility of partially waste incorporated mixes through engineering tests and sustainability analysis more even in Ethiopia by considering economic, social and environmental aspects. One control mix along with three replacement mix was prepared to carry out the study.

CHAPTER THREE

3. MATERIALS AND METHOD

3.1. Introduction

The materials used for the investigation are described with respect to their sources and relevant physical and chemical properties. All laboratory investigations on the materials used in studying the properties of marble dust and fly ash also blended cements are carried out in East cement factory quality control assurance department; whereas the properties of concrete made by incorporation of marble waste powder and fly ash ingredients is studied in Addis Ababa Science and Technology University, Civil Engineering Department, construction materials lab.

3.2. Research Design

The strategy was followed as first start with problem identification, which was done through literature review and book. Then data and information from lab test and experimental studies are determined. The formulated research procedure was analysis and the study was conduct.

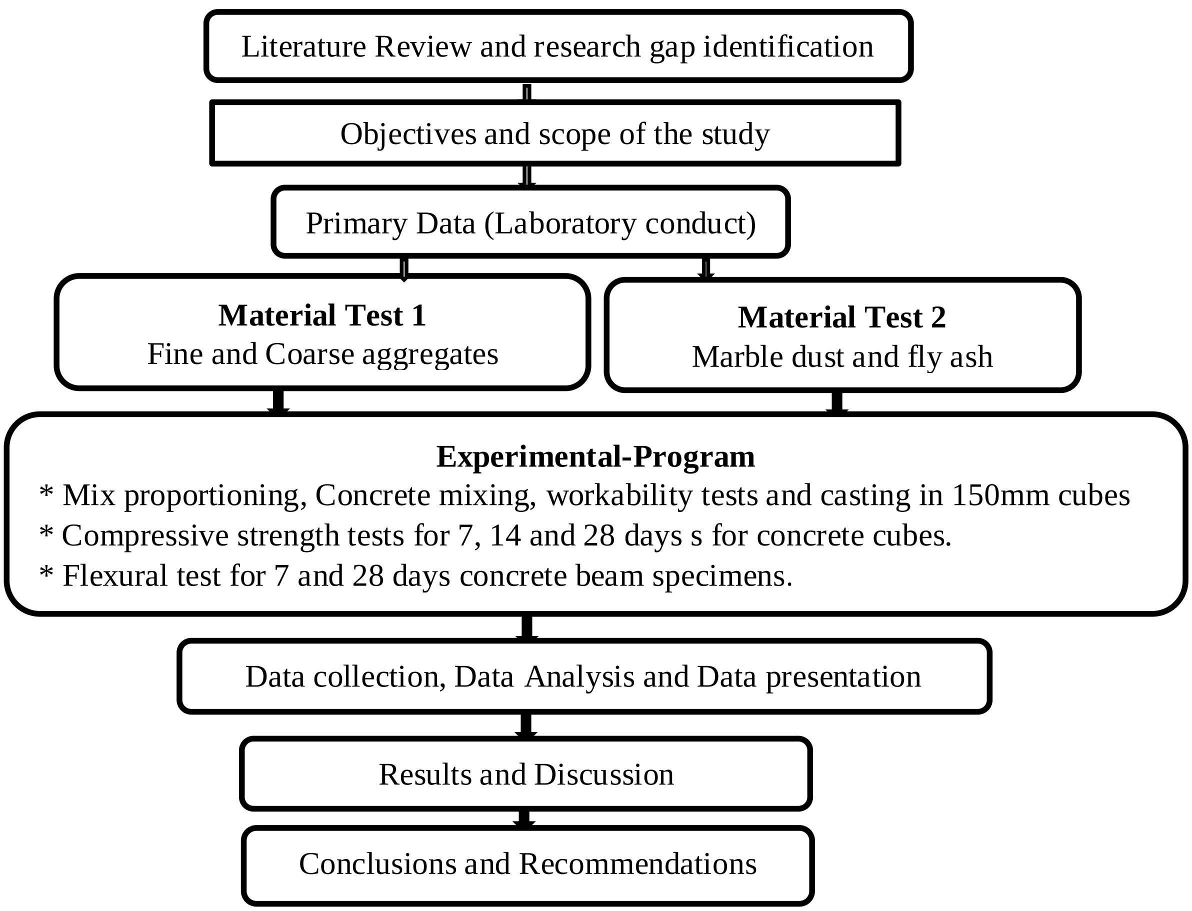

Figure 3:1 Research Design

3.3. Materials

3.3.1. Cement

Cement is a fine grey powder and the most versatile and widely used construction material which when reacted with water hardens to form a rigid chemical mineral structure which holds the aggregates together acting like glue and gives the concrete its strengths. It is the mixture of compounds made by burning calcareous (calcium carbonate bearing) material, such as limestone and an argillaceous (silica and alumina) material such as clay, shale, fly ash.

In this present work CEM I 42.5N grade East ordinary Portland cement (OPC) was used for casting cubes and cylinders for all concrete mixes. The tests conducted on cement are soundness, normal consistency, initial and final setting time. Testing on cement is completed as per IS codes.

3.3.2. Fine Aggregate

The fine aggregate used for this research is natural river sand from matahara, Ethiopia. The fine aggregate used in the investigation is clean river sand and conforming to zone II. The sand was first sieved through 4.75mm sieve to remove any particles greater than 4.75mm. Fine aggregates shall conform to the required standard.

3.3.3. Coarse Aggregate

The Coarse aggregate are obtained from a local quarry, conforming to ASTM C136 is used. Fractions from 37.5 mm to 4.75 mm are used as coarse aggregate.

3.3.4. Water

Water conforming to Standards should be used in concrete mixes. The water itself is often not considered when dealing with materials that go into the production of concrete, it is an important ingredient. The old rule of thumb for water quality is “If you can drink it, you can use it in concrete,” although good-quality concrete can be made with water that is not really potable.

For this research Addis Ababa tap water confirming the standard of IS: 3025-1986 with 7.5 PH value that satisfy the PH value of water above 6 we can use for construction purpose.

Indeed, more bad concrete is made by using too much drinkable water than by using the right amount of undrinkable water. Where recycled water, recovered from processes in the concrete industry, is used but should conform the specifications.(Dr. Edward G. Nawy 2008).

3.3.5. Fly Ash

Fly ash was collected from Ethiopian 'Reppie Waste Electric Power Plant'. Fly ash is a supplementary cementitious material in concrete and a byproduct of the combustion of pulverized coal/ solid waste in electric power generating plants. It compared with the ASTM C618 standard specification and AASHTO M 295 with raw or calcined natural pozolan for use in concrete.

The major constituents of most of the fly ashes are silica (SO_2), alumina (Al_2O_3), ferric oxide (Fe_2O_3) and calcium oxide (CaO). The other minor constituent of the fly ash are MgO, Na_2O, K_2O, SO_3, MnO, TiO_2 and unburnt carbon. There is wide range of variation in the principal constituents - silica (25 – 60%), Alumina (10 – 30%) and ferric oxide (5 – 25%). When the sum of these three principal constituents is 70% or more and reactive calcium oxide is less than 10% technically the fly ash is considered as siliceous fly ash or class F fly ash. Such type of fly ash is produced by burning of anthracite or bituminous coal and possess pozzolonic properties. If the sum of these three constituent is equal or more than 50% and reactive calcium oxide is not less than 10%, fly ash was considered as calcareous fly ash also called as class C fly ash. This type of fly ash commonly produced by burning of lignite or sub – bituminous coal and possess both pozzolonic and hydraulic properties.

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%.(Wakayo G 2021).

3.3.6. Marble Dust

Marble used was obtained from Tsegaye Marble processing industry out of sawing and polishing of marble blocks. Sources of marble dust was obtained from Ethiopia, Benishangul Gumuz Region with its physical properties of Specific gravity 2.64 and water absorption is 0.92%. It was sieved by IS-90 micron sieve before mixing in concrete.

The marble waste originally was discharged from the factory in slurry form and was very wet during collection. This required drying the slurry to get it in powder form. Therefore, the marble Using Marble Waste Powder in Cement and Concrete Production slurry collected from the factory was dried by sun light for more than 15 days (due to the winter season) until its water content is nil. The interest of the researcher was to use the marble waste powder with its original (natural) fineness. However as the powder comes out in slurry form from the factory, drying turns it to large conglomerate grain form than to powder form; this required a certain manual grinding to get its natural (original) fineness.

Figure 3:2 Cement, Fly ash and Marble dust used in research

3.4. Methods

3.4.1. Cement Tests

3.4.1.1. Normal Consistency of Cement Paste

The normal consistency of cement paste with the mixture of cement paste were conducted in accordance with the ASTM C-187 standard. Here, ASTM C-595 recommends the normal consistency test of blended cement to be done by the ASTM C-187 method. The objectives of this test is to determine the amount of water required to prepare the standard cement paste.

The Procedure: first preparing 500g of cement sample mix with measure quantity of water for three minutes then quickly form cement paste in shape of ball with glove hand by tossing 6 times and fill the mold and level then lower the plunger gently then bring it in the contact with the surface of the paste, thirty second after releasing the plunger record the penetration. The paste is said to be of normal consistency when the rod settles 10 + or – 1 below the original surface within thirty second.

Then, the amount of water required for normal consistence is then expressed as a percentage by weight of dry cement.

$$\% \text{ water} = \frac{\text{Weight of water in gram}}{\text{Weight of cement in gram}} \; x \; 100 \qquad \text{……………………..Eq.3:1}$$

3.4.1.2. Soundness of cement

The soundness test for cement was done based on the ASTM C-151 standard. For this study, the 'Le Chatelier' apparatus was used to test the soundness of paste. To measure the expansion of cement.

Procedure, preparing cement of normal consistency, filling cylinder mold, covering he mold with glass plate, submerging into water at temperature of 20+1 ^{O}C for 24 hours then measure the distance b/n the indicator needles taking the mold out and submerge it again into the water then heat the water up to its boiling point in 30 minutes and continue boiling for one hour then remove out and measure the needle difference again. As Ethiopian standards the expansions for Portland cement shall not exceed 10mm.

3.4.1.3. Initial and Final setting time of cement

EN 196- 3.No.6.2, 1994: Standard Test Method for Determination of Initial Setting Time of Cement by Vicat Needle, the initial setting time of cement paste shall not be less than 45 minute and the final setting time not to exceed 10hrs.

The procedure to find setting time of cement first insert the paste into larger end of the conical ring then allow the specimen to remain in the moist cabinet for 30minutes without disturbing. Tighten the screw and set the indicator at the upper end of the scale or take initial reading. Release the road quickly and allow the needle to settle for 30 second. Determine the penetration of the1mm diameter needle at this time and every 10min thereafter until a penetration of 25mm or less is obtained and record the result of all penetration tests. Then interpolate between the results obtained to determine the time when penetration of 25mm is obtained. This is the initial setting time. The final setting time is when the needle does not sink visibly in to the paste.

3.4.1.4. Density of cement

The density of the material is defined as mass or weight per unit volume or it is a quantitative representation of the amount of mass contained per unit volume. The density standard unit is the kilogram per meter cubed.

Procedure, preparing the kerosene and dry flask and fill the flask and record the first reading. Then introduce the weight of cement up to 64g and weight to the nearest 0.05g in small increments at the same, place stopper in the flask and roll the flask in an inclined position. If proper amount of cement has been added the level of liquid will be in its final position at the same point of upper series gradation. Then take the final reading after the flask has been immersed in the water bath. So, Density is mass per volume, it represented in grams per cubic centimeter (gm/cm^3). Weight of cement is 64g, volume of cement (21 – 0.5) is 20.5ml.

$$\textbf{Density} = \frac{\text{weight of cement}}{\text{Volume of cement}} \quad \text{……….........……………Eq. 3:2}$$

3.4.2. Fine Aggregate

3.4.2.1. Silt content of sand

The sand was washed before the silt content test. However, it may contain other materials such as dust, loam, and clay that are finer than sand. The presence of such materials in the sand used to make concrete decreases the bond between the materials to be bound together and the strength of the mixture.

Procedure, take graduated cylinder having capacity of greater than 100ml, pour 30ml of sand, fill approximately ¾ of cylinder with water, shake the cylinder vigorously for about a minute, leave the cylinder for about an hour to allow the silt to settle on the layer of the sand and measure the amount of fines forming a separate layer on the top of the washed sand Then:

$$Silt\ content\ (\%) = \frac{\mathrm{A}}{\mathrm{B}}\ x\ 100 \quad \text{………………..….Eq. 3:3}$$

Where A is amount of silt deposited above the sand and B is amount of clean sand.

3.4.2.2. Gradation of fine aggregate

A sample of fine aggregate for sieve analysis is first surface dried and then sieved through the series of sieves, starting with 4.75mm. The material retained on each sieve after shaking represents the fraction of fine aggregate coarser than the sieve in question and finer than the sieve above. The summation of the material retained on the sieves divided by 100 is called the fineness modulus. It is used as an index to the fineness or coarseness and uniformity of aggregate supplied. Then calculate the fineness modules of sand by:

$$\text{Fineness Modulus of Sand} = \frac{\text{Summation of cumulative \%ge weight retained}}{100} \quad \text{..........Eq.3:4}$$

3.4.2.3. Unit weight of fine aggregate

The bulk density or unit weight of fine aggregate is the mass of a given volume of graded aggregate. It is measured by weighing a container of known volume filled with aggregate. The mass of the container is subtracted to give the mass of the fine aggregate, and the bulk density is the fine aggregate mass divided by the volume of the container.

The unit weight of fine aggregate was done based on ASTM-C 29 standard and the sample result was found to be 1,874kg/m3.here the result was satisfying the ASTM minimum and maximum limit of 1280 and 1920 kg/m3 respectively. Hence, the sample is in this range and acceptable for use.

3.4.2.4. Specific gravity and absorption capacity of fine aggregate

The specific gravity and absorption capacity affect the type and quality of concrete and as such parameters are input for mix designing, these parameters were determined for both fine and coarse aggregate.

The Specific Gravity and absorption of fine aggregate were done based on ASTM-C 128 Then:

Bulk specific gravity for (saturated surface dry) is, $$\frac{\mathbf{500}}{\boldsymbol{B}+\mathbf{500}-\boldsymbol{C}} \quad \text{....................Eq. 3:5}$$

And for the absorption capacity (%), $$\frac{\mathbf{500-A}}{\boldsymbol{A}} * 100 \text{.......................Eq. 3:6}$$

Where, A is weight of oven dry sample in air in gram, B is weight of pycnometer filled with water in gram and C is weight of pycnometer with sample and water to calibration mark.

3.4.3. Coarse Aggregate

3.4.3.1. Gradation of coarse aggregates

The gradation of coarse aggregate is determined by sieve analysis. Sieve Analysis is a procedure for the determination of the particle size distribution of aggregates using a series of sieves. It is used to determine the fineness modulus of the course aggregate which tells the fineness and coarseness of aggregate. The gradation of the aggregate was done based on ASTM-C 136 standard and the grain size distribution of the coarse aggregate.

$$\text{Fin. Mod. of Course aggregate} = \frac{\text{Summation of cumulative \%ge weight retained}}{100} \quad \text{…....Eq.3:7}$$

3.4.3.2. Unit weight of coarse aggregate

The unit weight of coarse aggregate was done based on ASTM-C 29 standard and the sample result was found to be 2,350 kg/m3. Here the result was satisfying the ASTM minimum and maximum limit of 2275 and 2425 kg/m3 respectively. Hence, the sample was in this range and acceptable for use.

3.4.3.3. Specific gravity and absorption capacity of coarse aggregate

The Specific Gravity and absorption capacity of Coarse Aggregate was done based on the ASTM C-127 standard and the result was found to be 2.88 and 0.71% respectively.

3.4.3.4. Moisture content

The moisture content of coarse aggregate was calculated in the same way as fine aggregate; done based on ASTM-C 566.

The oven dried sample (B) is 4975g and weight of original sample (A) is 5000g then,

Moisture content (W) is:

$$\frac{A-B}{B} * 100 \text{………………………………………….Eq. 3:8}$$

Where moisture is content, A is weight of original sample and B is oven dried sample.

3.4.4. Mix Design

The main target of this study is to produce concrete made with partial replacement of cement by marble dust and fly ash mixture then to characterize its properties, especially the mechanical properties in the hardened state. To succeed that ACI Concrete mix design were used According to ASTM C33.The American Concrete Institute (ACI) mix design method is but one of many basic concrete mix design methods available today. Concrete mix design is the process of finding right proportions of cement, sand and aggregates for concrete to achieve target strength in structures. So, concrete mix design can be stated as Concrete Mix Cement Sand and Aggregates. The concrete mix design involves various steps, calculations and laboratory testing to find right mix proportions.

Using the ACI mix design methods, to design a concrete mix for an application requiring a characteristic strength of 25MPa at 28 days and a slump of 10-30 mm. The materials available for uncrushed fine and coarse aggregate.

3.4.4.1. Batching of concrete

The process of measuring ingredients or materials to prepare concrete mix is known as batching of concrete, The ASTM C685 /C685M and ASTM C94 for Volumetric batching and batching by weight is available respectively. For this research batching by Weight is used According to ASTM C94. Procedure For this research work first, the marble dust and fly ash was collected from locally available marble processing industry Tsegaye marble industry Sebata area and fly ash from Repi solid waste power generating industry for investigation. Then the grinding and blending of collected materials was performed to get the proper dust. Locally available coarse aggregates and matahara sand was selected and collected based on the quality requirement confirmation as in standards (ASTM and ACI), Portland cement (CEM I-42.5N) was used complying with ASTM C150 Type-I cement. Course aggregate the weight stated taken and damped, then the weight of sand by depending on its mix ratio finally the amount of cement and supplementary material was added.

Figure 3:3 Proportion of materials for concrete specimens of concrete (laboratory materials).

3.4.4.2. Mixing of concrete

Mixing was done by mechanically operating concrete mixer by confirming the AASHTO T162 standard. During the process of mixing, the mixer wetted with ordinary potable water, then mixing was started by adding aggregate to mixing drum, after that adding 25% of total water to the mixer to prevent cement sticking to blades or at the bottom of the drum. Then sand is added, with 25% of water. After through mixing of aggregates, cement is added and remaining 50% of water is added and then the mixture of fly ash and marble dust are added to the wet mix.

3.4.5. Fresh properties of concrete

Measuring the properties of fresh concrete is an essential process that should be carried out in the site before placing the concrete. The main reason for carrying out these tests is to ensure whether the desired properties are associated in the fresh concrete which influencing the strength and durability of the structures.

3.4.5.1. Workability of concrete

The concrete slump test measures the consistency of fresh concrete before it sets. It is performed to check the workability of freshly made concrete, and therefore the ease with which concrete flows. It can also be used as an indicator of an improperly mixed batch. After mixing, the standard slump test performed according to the ASTM C143 standard. As it shown in Figure 3:4 the Procedure is first the standard slamp cone 300mm high with a bottom diameter of 200mm and top diameter of 100mm and steel tamping road of 16mm diameter, 600mm long, with one end rounded, measuring tape or ruler, steel float and water proof base plate about 450 x 450mm square plate prepared then after fixing the slump cone the concrete mix poured in three round by rodding 25 times each layers. After the top surface of cone is rodded, strike off the surface then remove excess concrete and clean area of the concrete. Immediately remove the mold from the concrete by a steady upward pull. Rest the tamping rod across the top of the empty invert the cone so that it reaches over the slumped concrete. Using the ruler from the underside of the road to the highest point of the concrete to the nearest 5mm that will be the slump.

Figure 3:4 slump test of concrete (laboratoty photo)

3.4.5.2. Molding, Casting and Compacting

The Mold was prepared for cube and beam specimen is prepared for casting the concrete according to ASTM C31. The molds used for casting concrete cubes and other specimens have to be lubricated so that the concrete does not adhere to the molds due to the cement paste. The dimension of the mold for cube specimen is 150mm x 150mm x 150mm and for beam specimen dimensioned by 100mm x 100mm x 500mm. After casting concrete is filled into molds and compacted on vibration table.

3.4.6. Hardened Properties of the Concrete

Hardened concrete has a lot of properties those by what we know the durability, creep, deformation and acid attack on the concrete. But the main important properties is strength of concrete. To measure the Strength of Concrete tests like Compressive Strength test and Flexural Strength test was conducted.

3.4.6.1. Remolding and Curing

Remolding was done after 24 hours of casting according to ASTM C124. Specimens was cured in curing tank. Water immersion method of curing is adopted. After casting, primarily all concrete specimen were placed in a shelf with relative humidity of above 65% and room temperature of between 20-22^{0}c to enable the concrete achieve enough strength for water curing by ensuring that moisture is retained and not lost rapidly. Then all the concrete specimen were immersed in a water curing pond until testing period. Each of the specimen were marked using permanent ink marker in each case to clearly show the percentage cement content, date and time of production and an identification number. Then after the stated age of curing every proportion cubes and beams were dry the surface of concrete by sun, for the minimum of two hours and tested for compressive and flexural strength in the compressive testing and flexural testing machine.

3.4.6.2. Sample size and Sampling Technique

A purposive sampling to be used in this study is the materials required for producing Concrete was purchased and supply to the laboratory, then the laboratory was produce specimen in cubes, cylinder and beams for experiments see figure 3:5. So this cubes for compressive test and beams specimen for flexural test different number of casted concrete specimen was used for compressive strength to take the average. 5 specimen was tested alone for compressive strength for 7, 14 and 28days age of concrete, 5 specimen for flexural strength test for 7, 14, and 28 day's age of casted concrete. The same material with required for producing conventional concrete with the same properties will be purchased and then supply to the laboratory. Then the result of each and every specimen was recorded properly and the average of different specimen of the same mix and its age was recorded and after the proper analysis the conclusion was drawn.

Figure 3:5 Samples of concrete specimen (laboratory photo)

3.4.6.3. Compressive strength of concrete

In this study the compressive test worked as ASTM C109standard. As we understood the process of fresh properties and sampling technique is preparing the casted specimen to the test like compressive strength, the Testing machine of 3000 KN load was used and first we place the cube concrete specimen inside the Impact or loading machine. Then the load should start applying till the specimen break the satisfactory and unsatisfactory failure identified. When the machine stop counting we record the failure load. The stresses at failure dividing the failure loads by the respective contact areas with the load.

The cubes specimen are generally 150 mm x 150mm 150 mm dimension and the specimen is casted, cured and tested as per standards prescribed for such tests. Then the result is calculated as in the table 4:12.

Figure 3:6 Compressive Strength of the Concrete (Laboratory photo).

3.4.6.3.1. Correlation and Regression of the Compressive strength Method

Correlation is an analysis of the co-variation between two or more variables. Numerically Two variables are said to be correlated, if the change in one variable relates in a corresponding change in the other one. Here we measured the compressive strength at control concrete and at different dosage. The procedure is selecting the value of two variables by X and Y then damp the data of both variable in Excel. Then by using correlation button on scale calculate the correlation coefficient and Regression equation.

$$Rxy = \frac{=\sum_{1}^{n}(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum_{1}^{n}(xi - \bar{x})2 \ \sum_{1}^{n}(yi - \bar{y})2}} \quad \text{……………………………………Eq. 3:9}$$

And by Y equation for Regression analysis.

Regression line equation: y = α + βx…………………………………………...Eq. 3:10

3.4.6.4. Flexural Strength of the Concrete

The flexural strength of concrete determined by the use of a simple beam with third-point loading according to ASTM C78. The test was applied by 100 KN load applying machine. Results are reported as the modulus of rupture (MOR) as shown in figure 3:7, which is the flexural strength of the concrete sample just before it yields the determination of flexural tensile strength is essential to estimate the load at which the concrete members may crack. Also here the spacemen placed in the loading machine, applying the load until the specimen breaks then record the maximum applied load. As it is difficult to determine the tensile strength of concrete by conducting a direct tension test, it is computed by flexure testing.

Figure 3:7 Flexural Strength test (laboratory photo).

Since the pure flexural stress is $\sigma = \frac{MY}{I}$ ………………………………………Eq. 3:11

3.4.6.4.1.Correlation and Regression of the Flexural strength results.

Correlation and regression are statistical measurements that are used to quantify the strength of the linear relationship between two variables. Correlation determines if two variables have a linear relationship while regression describes the cause and effect between the two variables.

To find the correlation coefficient we will Use the following formula: the procedure is the same with the correlation regression procedure in under compressive strength.

$$Rxy = \frac{=\sum_{1}^{n}(\mathrm{xi} - \bar{\mathrm{x}})(\mathrm{yi} - \bar{\mathrm{y}})}{\sqrt{\sum_{1}^{n}(\mathrm{xi} - \bar{\mathrm{x}})2}\ \sum_{1}^{n}(\mathrm{yi} - \bar{\mathrm{y}})2} \text{……………………………………Eq. 3:12}$$

And by Y equation for Regression analysis.

Regression line equation: $y = \alpha + \beta x$…………………………………………...Eq. 3:13

3.4.7. Water Permeability

According to IS 516 (Part 2/Sec 1): 2018 three specimens shall be tested and the maximum depth expressed to the nearest millimeter of penetration, shall be indicated for each specimen. The final depth of penetration shall be taken as the average of the three results.as it shown in figure 3:8 By this experiment concrete permeability was calculated 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).

Figure 3:8 permeability test (Laboratory photo)

3.4.8. Micro structure Analysis

The chemical analysis of the concrete depends on the silicate test of material chemical composition and the image and shape gathered from micrograph of electron microscope scanning. Scanning electron microscope (SEM) is an electron microscope that focuses across the specimen by scanning it through interaction with a beam of electrons. Broken piece of concrete cubes after compression test were used to study microstructure of different concrete mixes. Then the prepared specimen was inserted in the scanning machine. Then depending on the micrograph image we discuss the chemicals.

3.4.9. Environmental and Economic Analysis of concrete

In this research work, detail Environmental cost break down and economic analysis of all concrete was not worked out as the cost of cement depends on its user point location; but to find some amount of its effect, the carbon amount emission was estimated and its price the effect of using supplementary materials are shown. For cost benefit the market current price for material and power consumption was studied, the amount of replacement identified and total cost for both control concrete and partially replaced concrete was calculated also the cost reduce from the production of cement was calculated..

3.5. Method of Data Analysis

The method to be followed to achieve the objectives of the research determines the required data, which intern is a ground to decide on type and method of data collection and their analysis. Different alternative data collection methods such as experiments, observations and archival records was used. Data was collected on materials Test and concrete specimen (concrete compressive strength, flexural strength, permeability test) from Laboratory test time to time the result was recorded carefully.

The data was analyzed using Tools (excel, Tableau and origin pro.) and present by (charts, graphs, tables, diagram) to answer the study objectives By using correlation and regression methods the value gathered, the percentage of material replacement and their effect was discussed.

Scanning electron microscope (SEM) test was conducted to investigate and analyze the morphological structure and chemical reaction of concrete structure.

To analysis the cost benefit of partially replaced concrete with control, different literature reviews, and experimental studies with current cost of materials and service was carried out.

The gathered data was analyzed using the appropriate statistical analysis tools and both quantitative and qualitative methods. Finally, conclusions and recommendations are forward from the analysis of the results and brief discussions

CHAPTER FOUR

4. EXPERIMENTAL RESULTS AND DISCUSSION

4.1. Introduction

In this chapter laboratory test results for cement, sand, coarse aggregate, fly ash and marble dust are briefly discussed. Revision on the physical properties also summarized to make the comparison between partially replaced and control concrete samples. From the result comparison are outlined for the partially replaced cement concrete and control concrete the tests includes slump test, permeability test, compressive and flexural test was conducted.

4.2. Cement

4.2.1. Normal Consistency of Cement Paste

The normal consistency of cement paste with the mixture of fly ash and marble dust blended cement paste were conducted in accordance with the ASTM C-187 standard. Here, ASTM C-595 recommends the normal consistency test of blended cement to be done by the ASTM C-187 method.

As it described above the result of normal consistency of cement and blended cement with supplementary materials are calculated by Eq.3:1 formula and listed as follows:

Table 4:1 consistency of Cement and mixture of marble dust and fly ash.

S.No	Designation code	Consistency %
1	(F.A + M.D) 0%	29
2	(5F.A + 5M.D) 10%	28
3	(5F.A + 10M.D) 15%	26
4	(5F.A + 15M.D) 20%	26

Figure 4:1 Normal Consistency of Paste (Lab photo)

As we are see from Table 4:1 normal consistency of the paste was measured by the Vicat apparatus. Since the standard usual range of water cement ratio for normal consistency is between 26 – 33 percent the experiment result was incremental and is valid up to 33%. The reason why the nature of marble dust is filler and water adsorbent to hydration and it delay chemical reaction of particles.

4.2.2. Soundness of cement

The soundness test for cement was done based on the ASTM C-151 standard. For this study, the 'Le Chatelier' apparatus was used to test the soundness of paste and the result in Table 4:2.

Table 4:2 Soundness of Cement and mixture of marble dust and fly ash.

S.No	Designation code	Expansion (mm)
1	(F.A + M.D) 0%	1.8
2	(5F.A + 5M.D) 10%	2.0
3	(5F.A + 10M.D) 15%	2.1
4	(5F.A + 15M.D) 20%	2.1

According to the Ethiopian standard, the expansion of Portland cement shall not exceed 10mm. In this experiment listed in table 4:2, the change of expansion of the paste was less than 10mm and therefore it is acceptable to use in concrete production.

Figure 4:2 'Le Chatelier' apparatus (Lab photo)

4.2.3. Initial and final setting time of cement

The setting time of cement paste and mixture of marble dust and fly ash blended cement paste was conducted in accordance with the ASTM C-191 method. The result of setting time of cement paste and mixture of marble dust and fly ash blended cement paste are as shown below in the table.

Table 4:3 Initial and final setting time

S.No	Designation code	Setting time(minute) (ASTM C- 191)	
		Initial setting time	final setting time
1	(F.A + M.D) 0%	60	330
2	(5F.A + 5M.D) 10%	75	300
3	(5F.A + 10M.D) 15%	75	270
4	(5F.A + 15M.D) 20%	85	270

From the result shown in the table 4:3, the setting time was within the specified limit so, it is acceptable to use. The setting time increase as the mixture of marble dust and fly ash replacement level increase; this is due to the effect of lower cement content. To support this argument, as the marble dust and fly ash replacement level increase the setting time of supplementary material mixture blended paste. It increases due to the water adsorption of marble dust and fly ash on its surface and the lower cement content in the paste.

4.2.4. Density of cement

From the prepared kerosene or free of water the chatelier flask was filled around 0.5ml. Then the result was recorded carefully, then 64g Weight of cement was added gradually and roll the flask to free the cement from air bubble. Then the volume of cement plus kerosene is 21ml.

So, by the Eq. 3:1 the Density is mass per volume, it represented in grams per cubic centimeter (gm/cm^3). Weight of cement is 64g, volume of cement (21 – 0.5) is 20.5ml.

$$\textbf{Density} = \frac{\text{weight of cement}}{\text{Volume of cement}} = \frac{64}{20.5} = 3.12 \text{ g/cm}^3$$

As ASTM C 188 – 17 the value of density 3.12 fulfill the Validity standard of 3.15.

4.3. Fine Aggregate

4.3.1. Silt Content

The finer particle do not only decrease the strength but also the quality of the mixture produced resulting in fast deterioration. Therefore it is necessary that one make a test on the silt content.

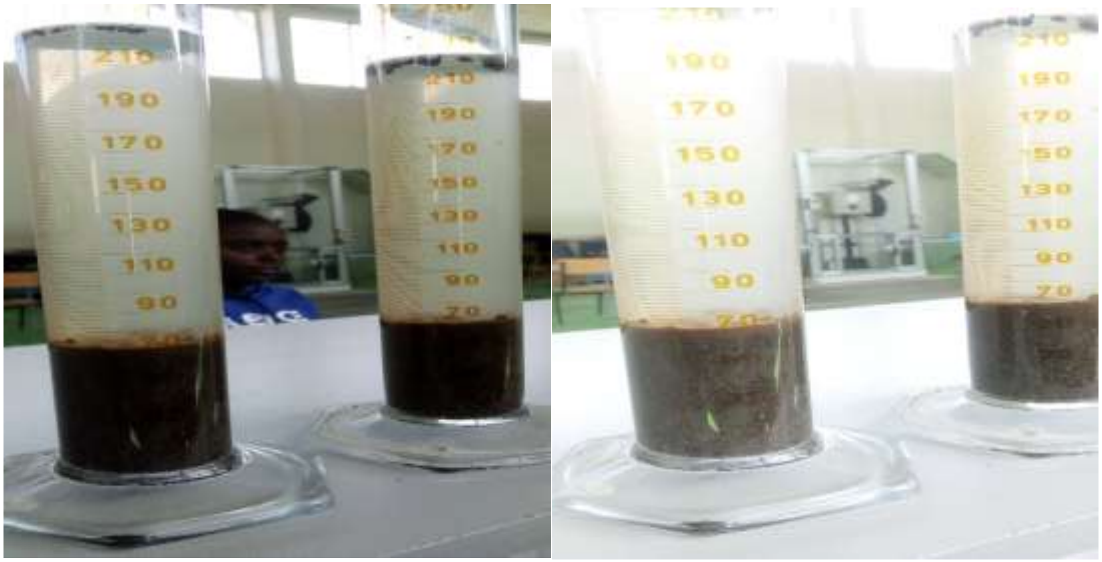

Figure 4:3 silt content of sand

The finer particles do not only decrease the strength but also the quality of the mixture produced resulting in fast deterioration. Therefore, from Figure 4:3 the silt content obtained from the test result is 3.66% which is below the Ethiopian Standard of 6%.

4.3.2. Gradation of fine aggregate

The grading requirement for fine aggregate according to ASTM C-33 and the grain size distribution of the fine aggregate.

Table 4:4 Grain size distribution of fine aggregate

Sieve size (mm)	Weight of sieve (gm)	Wt. of sieve & retained weight	Weight retained (gm)	Perc. retained (%)	Cum. coarser (%)	Cum. passing (%)	ASTM Limit		Remarks
							Min. %	Max. %	
9.5	525	525	0	0	0	100	100	100	Ok!
4.47	575	585	15	3	3	97	95	100	"
2.36	525	555	40	8	11	88	80	100	"
1.18	495	560	80	16	27	72	55	85	"
0.6	455	610	105	21	48	51	25	60	"
0.3	430	610	165	33	81	18	5	30	"
0.15	400	445	55	11	92	7	0	10	"
pan	330	335	35	7	-	0			"
Total					262				

$$\text{Fineness Modulus of Sand} = \frac{\text{Summation of cumulative \%ge weight retained}}{100}$$

Fineness Modulus of sand is $= \frac{262}{100}$ = **2.62**

The graph for the sieve analysis of the sand and the ASTM limit is as follows;

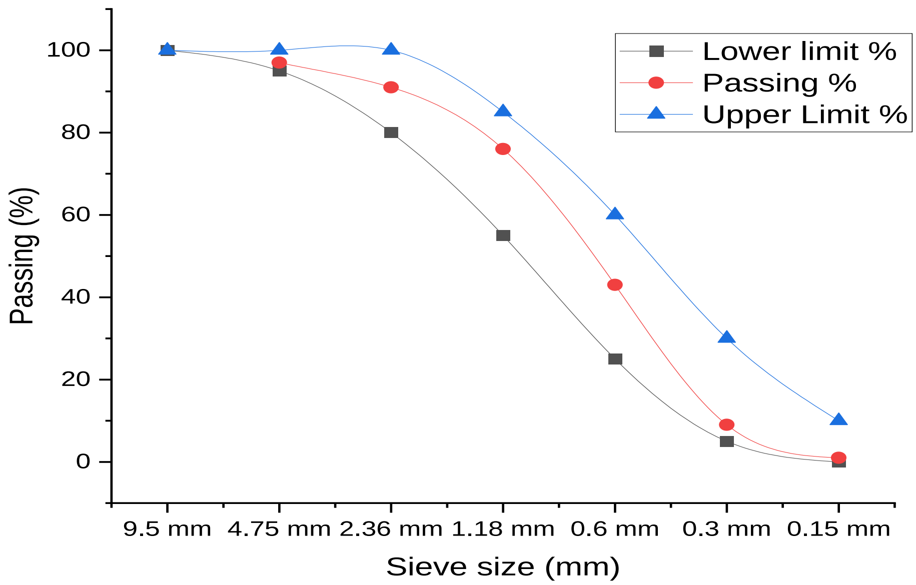

Figure 4:4 Grain size distribution of fine aggregate

The grading or particle size distribution of fine aggregate shall be in the limits specified standard the Ethiopian standard that 2.6 to 2.9 for medium sand. In Table 4:4 and figure 4:4 the fineness modulus 2.62 satisfy the standard.

4.3.3. Specific gravity and absorption capacity of Fine aggregate

From the data gathered from sand samples the weight of oven dry (A) is 486.5g, the weight of water and Pycnometer (B) is 1557.4g and weight of pycnometer plus sand plus water (C) is 1872.6g depending on the equation in Eq. 3:5 and Eq. 3:6

The Bulk specific gravity for (saturated surface dry) is: $= \frac{\mathbf{500}}{\boldsymbol{B} + \mathbf{500} - \boldsymbol{C}}$

$$= \frac{\mathbf{500}}{\mathbf{1557.4} + \mathbf{500} - \mathbf{1872.6}}$$

= **2.7**

And for the absorption capacity (%), $= \frac{\mathbf{500-A}}{\boldsymbol{A}} * 100$

$$= \frac{\mathbf{500-486.3}}{\mathbf{486.3}} * 100$$

= 2.82 %

The Specific Gravity and absorption of fine aggregate were done based on ASTM-C 128 standard and the sample results were found to be 2.7 and 2.82 respectively. Here the result of the specific gravity of fine aggregate was satisfying the ASTM minimum and maximum limit of 2.6 and 2.83. Hence, the sample is in this range and acceptable for use. The result of the absorption capacity of fine aggregate was found to be within the maximum limit of 4%.

4.4. Coarse aggregate

4.4.1. Gradation of coarse aggregate

Aggregate grain size distribution or gradation is one of the properties of aggregates, which influence the quality of concrete.

Table 4:5 Grain size distribution of coarse aggregate

Sieve size (mm)	Weight of sieve (gm)	Wt. of sieve & retained weight	Weight retained (gm)	Perc. retained (%)	Cum. coarser (%)	Cum. passing (%)	ASTM Limit		Remarks
							Min. %	Max. %	
37.5	1145	1145	0	0	0	100	100	100	Ok!
25	1190	1270	80	4	4	96	95	100	"
19	1115	1795	720	36	40	60	40	85	"
12.5	1220	2180	620	31	71	29	25	60	"
9.5	1230	1450	460	23	94	6	0	15	"
4.75	1125	1185	120	6	100	0	0	10	"
pan	895	895	0	0	-	0	0	0	"
Total					309				

As the formula stated above in Eq. 3:7

$$\text{Fin. Mod. Of Course aggregate} = \frac{\text{Summation of cumulative \%ge weight retained}}{100}$$

$$\frac{\mathbf{309}}{100} = \mathbf{3.09}$$

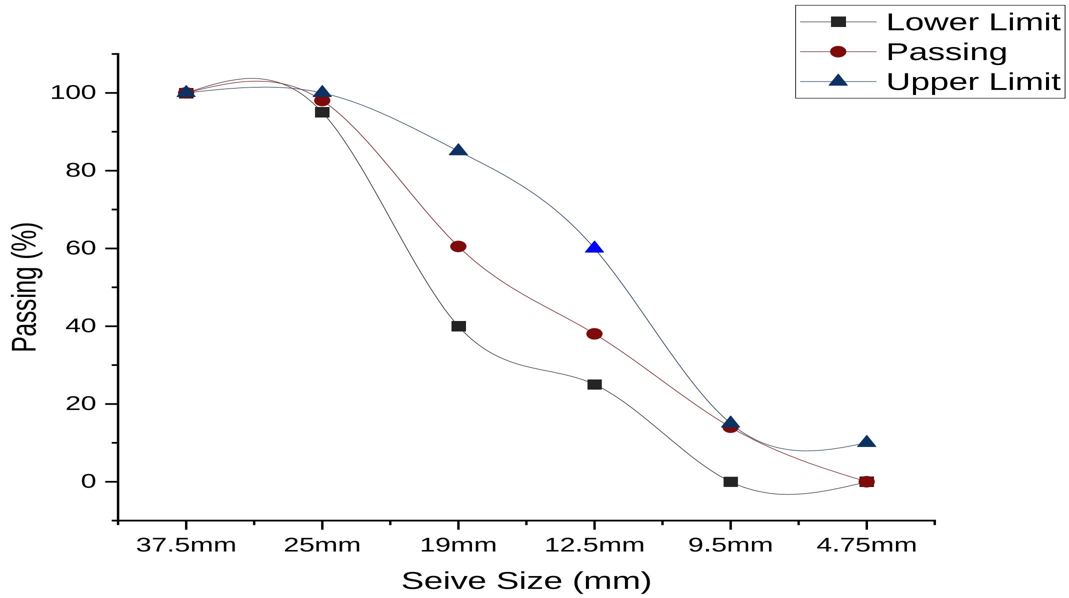

Figure 4:5 Grain size distribution of Coarse aggregate

According to ASTM C 33 standard the fineness modulus of coarse aggregate should be between the ranges of 2.3 to 3.1. So from the above calculation the value of grain size distribution fineness modulus of coarse aggregate is 3.09 is acceptable, the detail gradation of coarse aggregate is shown in the appendix.

4.4.2. Moisture content

The oven dried sample (B) is 4975g and weight of original sample (A) is 5000g then,

Moisture content (W) as Eq. 3:8:

$$= \frac{\text{A}-\text{B}}{B} * 100$$

$$= \frac{5000-4975}{4975} * 100$$

$$= 0.5\%$$

The moisture content satisfy the maximum moisture content. 2% is maximum percentage that limit the aggregate for construction of structure.

4.5. Fly Ash Chemical composition

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 4:6 Fly ash chemical composition percentage by weight (source from silicate test)

Chemical	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TiO_2	H_2O	LOI
Fly ash	33.6	8.40	5.54	23.7	3.54	4.28	7.92	0.24	3.42	0.41	0.47	7.6

As it described in Table 4:6 FA is a divided siliceous tailing from the burning up of municipal solid waste. FA has the same fineness like Port land cement. It can also react easily chemically with cement, fly ash is also recognized as an environmentally friendly material because it is a byproduct and has low embodied energy, the measure of how much energy is consumed in producing and shipping a material.

4.6. Marble dust Chemical Composition

Silicate analysis of Marble dust has been done and the following result was obtained

Table 4:7 Marble dust chemical composition percentage by weight (Silicate Test data)

Chemical Composition	**Marble Dust chemical composition**	**Standard by East cement factory**
SiO_2	6.48	≤5.0
Al_2O_3	<0.01	≤1.50
Fe_2O_3	0.42	≤0.80
CaO	50.96	≥50.0
MgO	1.66	≤0.80
Na_2O	0.22	≤0.30
K_2O	0.50	≤0.80
MnO	0.01	≤0.30
P_2O_5	0.01	≤0.30
TiO_2	0.01	≤0.30
H_2O	0.14	-
LOI	40.01	≥40.0

Comparing the test results shown in Table 4:7 with EN 197-1 standard, and with past investigators report, the marble dust raw material quarried from cement factory source is suitable for utilization as addition to cement in the production of concrete under controlled and specified cement quality standards.

4.6.1. Fineness of Marble Dust

After grinding, the fineness of the marble dust samples was tested for fineness by Blaine air permeability apparatus and it was found that one sample had a fineness of 3571cm^2/g whereas the other sample had Blaine fineness of 4843 cm2/g. according to the Ethiopian standard the specific surface area of cementitious material should not be less than 2250cm^2/g.

Table 4:8 Marble dust Physical properties test result

No.	Properties for Marble Dust	Result
1	Specific gravity	2.64
2	Moisture content	0.58
3	Water absorption	0.92
4	Size	0.90

4.7. Mix design

Based on the calculation explained in the appendix, the mix ratio of concrete ingredient is as follows.

Table 4:9 Concrete M ix ratio

Ingridient	Course aggregate	Fine aggregate	Cement (Kg)
Quantities	1111.54/366.6	478.22/366.6	366.6/366.6
Ratio	3.03	1.3	1

The mix Ratio is 1:1.3:3.03, where 1 is for cement, 1.3 is for sand and 3.05 is course aggregate The concrete designed for this investigation is medium strength concrete (C-25) ordinary concrete, it was prepared by replacing cement of constant 0-5% fly ash replacement with marble dust from 0-20% replacement ranges with 5% increment to study the effects on performance of concrete

Table 4:10 Proportion of materials for concrete specimens of concrete, C-25

S.No	% Repl	Cement (kg)	Marble powder (kg)	Fly ash (Kg)	Coarse aggregate (kg)	Fine aggregate (kg)	Water (kg)	w/(cm)
1	0%	20.28	0	0	65.4	26.92	13	8.65
2	10%	18.26	1.014	1.014	65.4	26.92	13	9.04
3	15%	17.24	2.028	1.014	65.4	26.92	13	8.34
4	20%	16.23	3.043	1.014	65.4	26.92	13	8.33

4.8. Fresh properties of concrete

4.8.1. Workability of concrete

The workability of concrete prepared by the partial replacement of fly ash and marble powder mixture has found to increase than normal concrete. It appeared that the addition of common 5% fly ash and 5%, 10% and 15% range of Marble dust by the percentage weight of cement designed in mix ratio.

Table 4:11 Slump values of C-25 OPC, FA & MD blended concrete

Mix Notation	Slump (cm)	Requirement
0% F.A and 0% M.D	5.35	
5% F.A and 5% M.D	6.40	
5% F.A and 10% M.D	7.60	
5% F.A and 15% M.D	8.00	

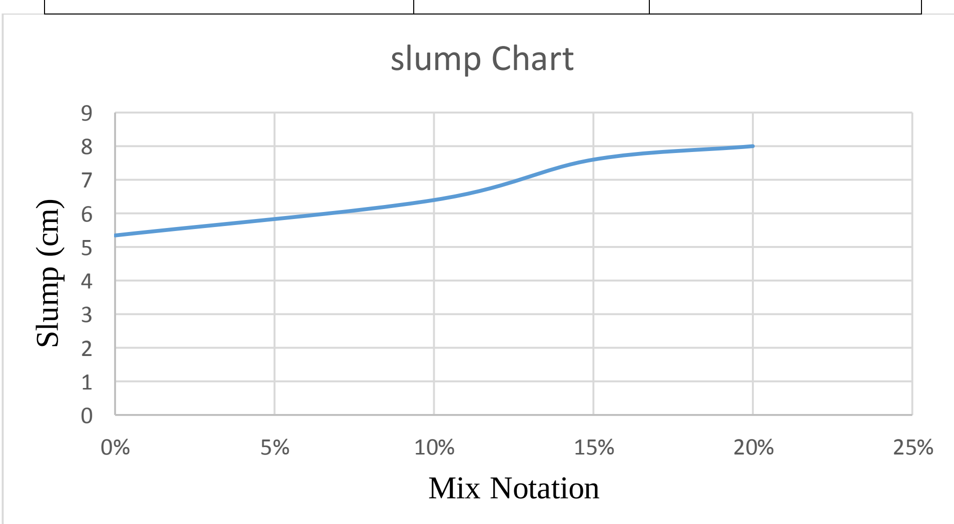

Figure 4:6 slump test value in chart

The workability of the concrete in Figure 4:3 was checked by the slump test just before casting freshly made concretes into the mold. The main point noted in this experiment is, the results indicate as the replacement percentage of fly ash and marble dust increase the workability of the mixes increased as observed in Table 4:11 this may due to the absorption capacity and rough surface texture of marble dust since the amount of fly ash is constant in the partially replaced mix. Partial replacement of Portland cement by fly ash and marble dust in concrete reduces the water required to obtain a given consistency or increases the workability and slump for a given water content compared to that of concrete without fly ash and marble dust. This phenomenon is generally attributed to the spherical particle shape of fly ash and texture of marble dust assists in improving workability.

4.9. Hardened Properties of the Concrete

For observing the performance changes due to the substitution of part of cement by marble waste powder in concrete production, C-25 classes of concrete, were prepared and tested for compressive strength and flexural strength at 7, 14 and 28 days.

The test results for all samples are presented on the Appendices. But for the purpose of discussion the summarized test results are presented in Tables 4:12 and 4:13 below according to the type of the specimens.

4.9.1. Compressive Strength of the Concrete

The determination of compressive strength has received a large amount of attention because the concrete is primarily meant to withstand compressive stresses. It may be defined as the maximum compressive load that can be taken by concrete per unit area. It has been prepared that with special care and control, concrete can be made to bear as high loads as it was designed for or even more.

Table 4.12 Compressive Strength of the concretes on 7th ,14th and 28th days

S.n	sample Quantity	%ge replacement	Compressive strength of the prevailing (C-25) sample Mpa.			
			Concrete sample age in day			
			7d (69-70)%	14d (89 – 90)%	28d (100)%	Durability
			17.50	22.50	25	permeability
1.	5	0%FA+0%MD	17.58	22.52	27.17	Impermeable
2.	5	5%FA+5%MD	16.35	22.96	27.88	"
3.	5	5%FA+10%MD	20.43	25.21	32.26	"
4.	5	5%FA+15%MD	17.55	23.78	28.05	"

The strength of concrete is very much dependent up on the hydration reaction. The type and amount of cement used in concrete determines the hydration reaction. The reactivity of supplementary material that from marble dust calcium carbonate (limestone) has been debated while most researchers have previously believed that limestone serve as an inert filler, research shows that limestone does react to a limited extent.

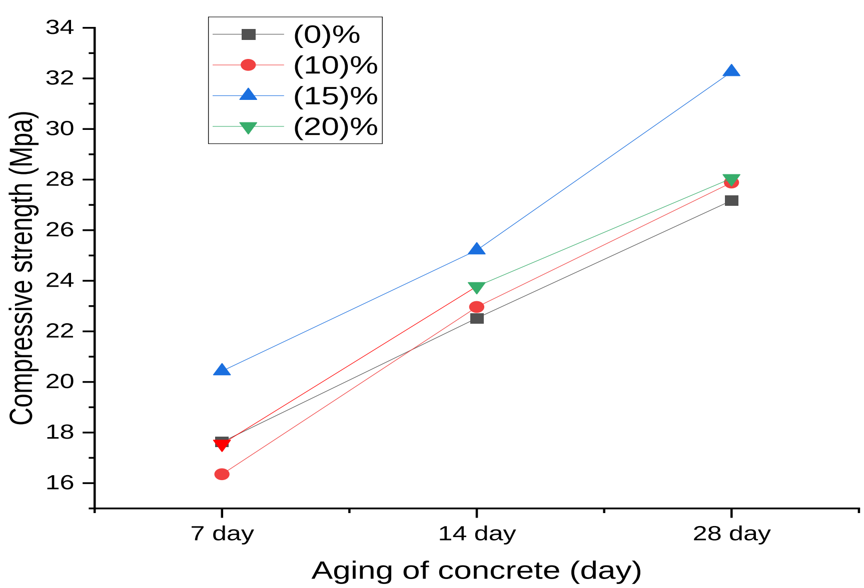

Figure 4:7 Mean Value of Compressive concrete Strength samples

From the angle of strength comparisons with control concrete in Table 4:12, At 7 days, initially with 10% replacement of the fly ash and marble dust mixture the compressive strength decreased by 6.9%, at 15% the compressive strength increased by 16.2% and at 20% replacement remains similar with control concrete. At 14 days, initially with 10% replacement of the fly ash and marble dust mixture the compressive strength increased by 1.96%, at 15% the compressive strength increased by 11.9% and at 20% replacement increased by 5.6% and finally on 28 days, with 10% replacement of the fly ash and marble dust mixture the compressive strength increased by 2.6%, at 15% the compressive strength increased by 18.7% and at 20% replacement 3.24% when we compare with the control concrete. Replacement of the Fly ash and marble dust mixture, we observed increased in strength more in 15% replacement amount.

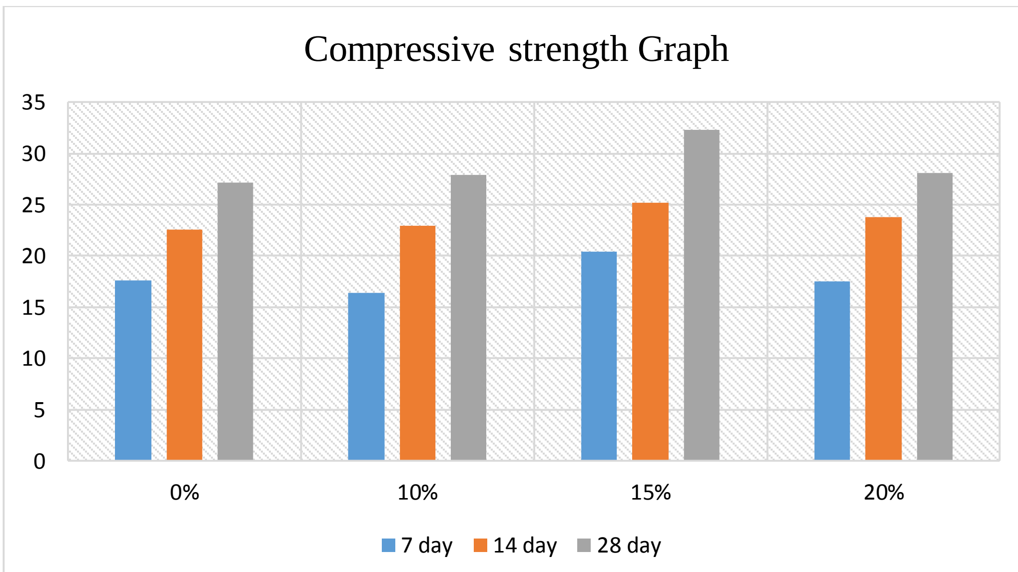

Figure 4:8 Mean Value of Compressive Strength concrete samples

According to IS 516 - 1959 the measured compressive strength of the specimen shall be calculated by dividing the maximum load applied to the specimen during the test by the cross-sectional area. The results in Table 4:12 on Figure 4:7 and 4:8 shows that, with the increase of fly ash and marble content, the compressive strength of Concrete mixed with water-binder ratio of 0.5 shows a trend of decrease after 15% replacement ratio of Fly ash and marble dust at later age. In early age, the compressive strength shows increments before 15% of replacement ratio.

It has been concluded that the maximum compressive strength value of concrete with partial replacement of cement by fly ash and marble dust was obtained at 15% replacement.

4.9.1.1. Correlation on the Compressive strength of control and 10% replacement

The statistical measurements that used to quantify the strength of the linear relationship between the change of structural strength and partial replacement of supplementary materials was expressed as follows:

The equation and correlation coefficient for control concrete and 15% replacement of fly ash and marble dust mixture and its effect on concrete strength numerically. From Eq. 3:10

$$R^2 = 0.9879$$

$$R = 0.994$$

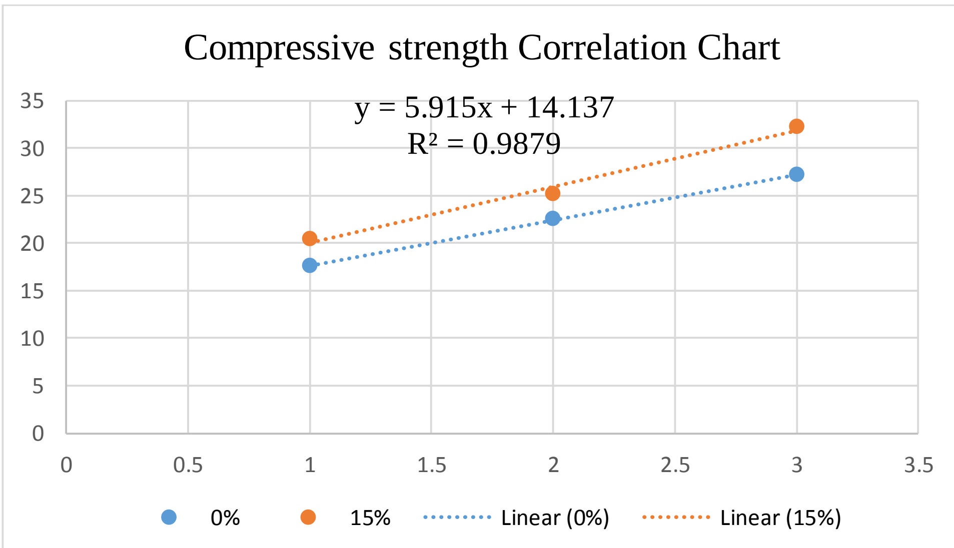

Figure 4:9 the correlation of control concrete and 15% replacement

Based on the results obtained from (figure 4:9 and 4:10) the investigation of correlation between the addition of supplementary material and Compressive strength of concrete is the high degree of correlation (R value of 0.99) for both equation. The replacement up to 15% shows the positive incremental relationship, but at the 20% partial replacement it changed to constant. It can be implied that the possibility of characterizing the mix proportion of the concrete is depended.

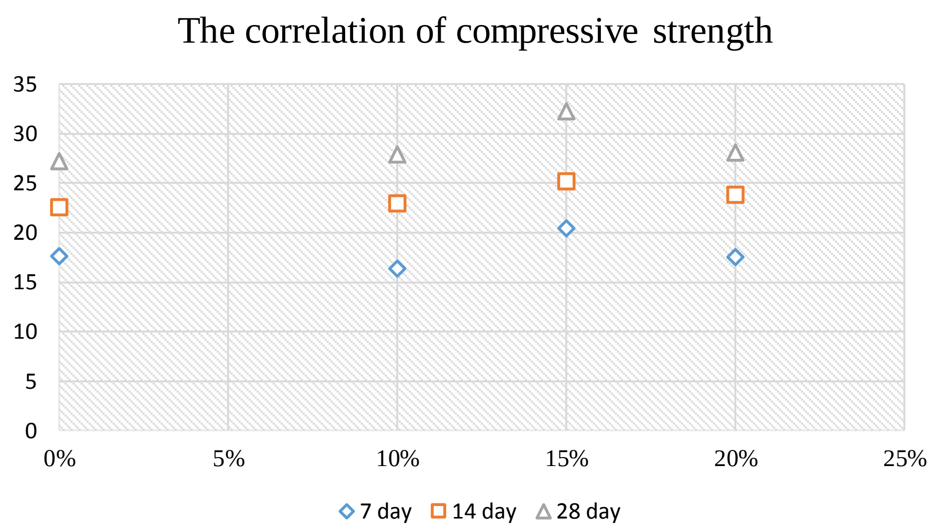

Figure 4:10 the correlation of compressive strength of concrete and material replacement

4.9.1.2. Compressive Validity of 15% partially replaced concrete with standard

Since the expected conventional concrete compressive strength at 7th days is 70% of the cubic compressive strength of C-25 and hence 0.7*25 = 17.5Mpa. But the mean result obtained from the prevailing partially replaced (15%) mix is 20.43 MPa which is much greater than the estimated concrete result. The result shows that partially replaced concrete induces higher result than the conventional increase and also it shows validity of trial mix as well.

4.9.2. Flexural Strength of the Concrete

The determination of flexural tensile strength is essential to estimate the load at which the concrete members may crack. As it is difficult to determine the tensile strength of concrete by conducting a direct tension test, it is computed by flexure testing.

The modulus of rupture is determined by testing standard test specimens of 100mm X 100mm X 500mm under symmetrical two-point loading.

Table 4:13 Flexural Strength of the concretes on 7th ,14th and 28th days

S.n	sample Quantity	%ge replacement	Flexural strength of the prevailing (C-25) sample Mpa.			
			Concrete sample age in day			
			7 days	14 days	28 days	Durability
			17.50	22.50	25	permeability
1.	5	0%FA+0%MD	3.41	4.51	5.72	impermeable
2.	5	5%FA+5%MD	3.41	4.70	5.18	"
3.	5	5%FA+10%MD	4.23	5.28	6.21	"
4.	5	5%FA+15%MD	4.53	5.32	5.98	"

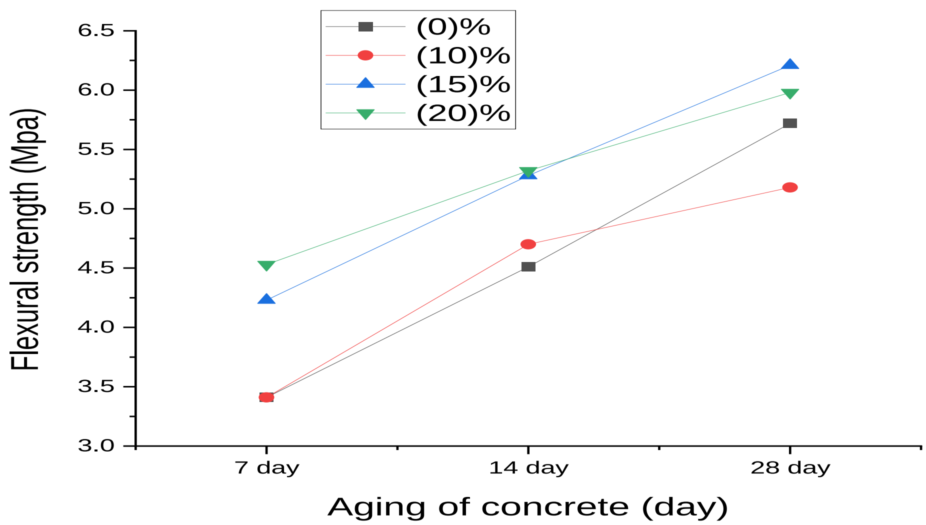

Figure 4:11 Mean Value of Flexural Strength concrete samples

It is seen that from the figure 4:7 that the concrete replaced with Fly ash and Marble dust at 5% FA + 10%MD has given maximum compressive strength which is 32.26Mpa. It is also seen that from the figure 4:11 of flexural strength that the concrete replaced with Fly ash and Marble dust 5% FA + 10%MP has given maximum strength which is 6.21Mpa

The Flexural strength comparisons with control concrete is crucial, at 7 days, initially replacement of the fly ash and marble dust mixture with 10%, The Flexural strength remains similar with control concrete, at 15% the Flexural strength increased by 24.04% and at 20%

replacement the Flexural strength increased by 32.8% with control concrete. At 14 days, with 10% replacement of the fly ash and marble dust mixture the Flexural strength increased by 4.21%, at 15% the Flexural strength increased by 17.1% and at 20% replacement increased by 17% and finally At 28 days, with 10% replacement of the fly ash and marble dust mixture the flexural strength decreased by 9.4%, at 15% the Flexural strength increased by 8.56% and at 20% replacement the Flexural strength increased by 4.5% when we compare with the control concrete. Replacement of the Fly ash and marble dust mixture we observed increased in strength more in 15% replacement amount.

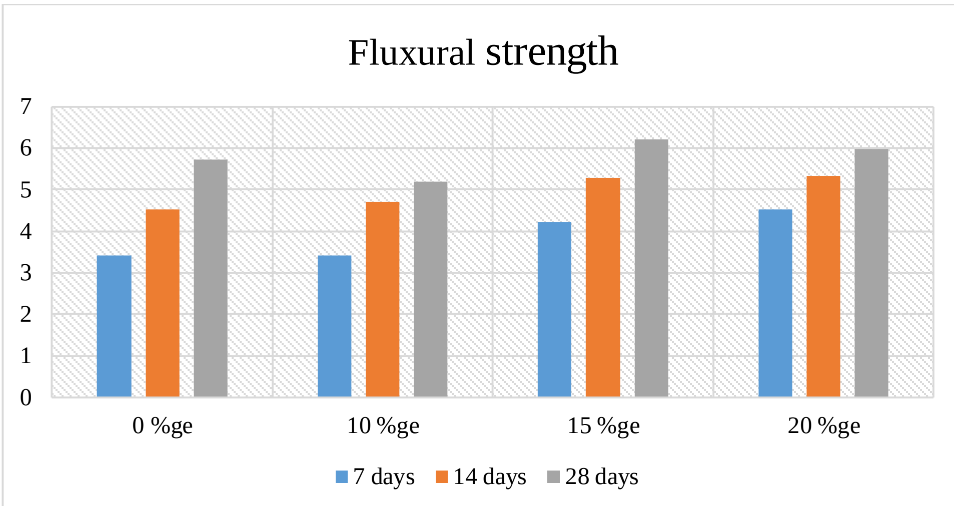

Figure 4:12 Mean Value of Flexural Strength concrete samples by chart

It can be summarized as the maximum flexural strength value of concrete with partial replacement of cement by mixture of marble dust and fly ash was obtained at 15% replacement.

4.9.2.1. Correlation of the concrete specimen strength of 0% replacement and 10% replacement

Correlation describe the strength of association between variables, from the graph axis of view x and y are independent and dependent variables respectively. From the equation, When “Y” indicates the equation trade line and “R” indicates linear association of correlation coefficient that scaled between +1 through 0 to -1.

Using the formula of correlation:

$$Rxy = \frac{=\sum_{1}^{n}(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum_{1}^{n}(xi - \bar{x})2 \ \sum_{1}^{n}(yi - \bar{y})2}}$$

Here, "$\bar{x}$ " is the mean, where each data point is represented by "xi". Similarly, " $\bar{y}$ "is the mean, and each data point is represented by "yi". "n" is the number of data points in the datasets. From the data in Table 4:13 of Flexural Strength the linear association correlation coefficient (R) When $R^2 = 0.9347$, $R = 0.9667$. There is a Very strong positive correlation between the two variables

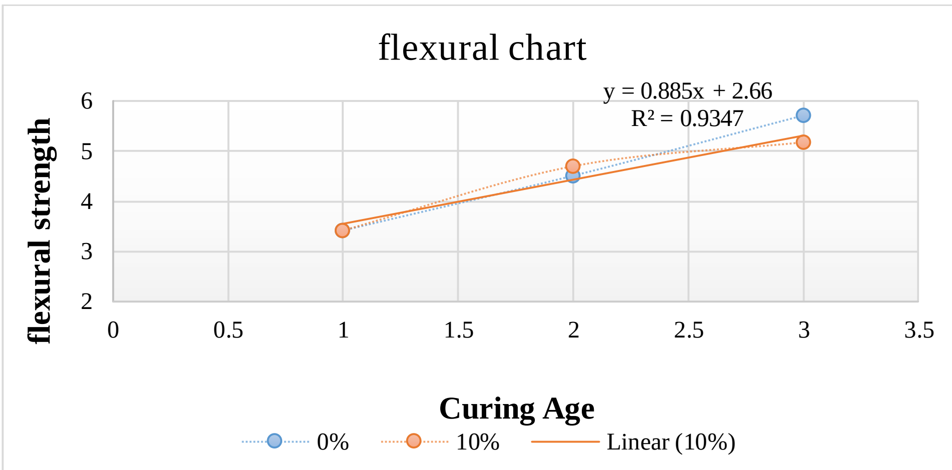

Figure 4:13 Correlation of 0% and 10% replacement

The relation in variable of control concrete and 10% supplementary material replacement are positive and Very strong relationship that both variable increases. to label the strength of the association, for absolute values of R, 0-0.19 is regarded as very weak, 0.2-0.39 as weak, 0.40-0.59 as moderate, 0.6-0.79 as strong and 0.8-1 as very strong correlation, but these are rather arbitrary limits, and the context of the results should be considered.

So, the incremental strength value of control concrete and 10% replacement of fly ash and marble dust mixture on cement concrete is very strong similar as around 0.9667 coefficient of correlation or around 96 % correlate.

❖ **Regression of the concrete specimen strength of 0% replacement and 10% replacement**

The regression equation representing how much y changes with any given change of x can be used to construct a regression line on a scatter diagram, and in the simplest case this is assumed to be a straight line. As it mentioned above in Eq. 3:12 and Eq.3:13, Regression line equation: $y = \alpha + \beta x$

$$\text{Where, } \beta = \frac{= \sum_{1}^{n}(xi - \bar{x})(yi - \bar{y})}{\sqrt{\sum_{1}^{n}(xi - \bar{x})2}}$$

$$\beta = R_{xy} \frac{\sigma x}{\sigma y}$$

$$\alpha = \bar{y} - \beta\bar{x}$$

$$y = 0.885x + 2.66$$

Here, also " $\bar{x}$ " is the mean, and "σx" is the standard deviation of the first data set where each data point is represented by xi. Similarly, " $\bar{y}$ " is the mean, and "σy" is the standard deviation of the second data set. "n" is the number of data points in the data sets.

4.9.2.2. Flexural Validity of 15% partially replaced concrete with standard

The validity of flexural strength of simply supported beam at different ages of concrete is as Abebe Dinku Construction material manual calculated as follows: consider the simply supported beam of 15% partial replacement of cement, and point load of 7.13 KN applied at mid span of the beam with span length of 0.5m. By using the Eq. 3:8.

Since the pure flexural stress is:

$\sigma = \frac{MY}{I}$. Where M = 0.89KNm, Y = d/2, 0.1/2 = 0.05 and $I = 8.33*10^{-6}\ m^4$,

$\sigma = \frac{0.89KNm*0.05m}{8.33*10-6\ m4}$ = 5.43Mpa is the expected maximum flexural strength of prevailing beam after 28 days. So from the trial, the 15% replacement of cement concrete is 6.21Mpa is the maximum and valid.

4.9.3. Water Permeability

For assessment of performance changes related with durability due to the addition of fly ash and marble dust in cement concrete production, water permeability test, of non-steady, was conducted, the durability of concrete structures depends on the permeability of reinforcement cover by concrete. It is this thin layer of concrete over reinforcement on which life of a structure depends. The permeability tester for concrete cover is a non-destructive instrument for the determination of air permeability of cover concrete. The permeability of concrete cover depends on the condition of concreting at site such as segregation and bleeding, finishing and curing, the formulation of micro-cracks, etc. The composition and properties of the cover concrete may differ very considerably from those of the good quality of cover concrete. In addition, the concrete test specimens used for quality controls can never represent the quality and properties of the cover concrete since they are produced and stored in a completely different manner. This layer is intended to protect the reinforcement from corrosion which may occur as a result of carbonation or due to ingress of chlorides or other chemical effects.

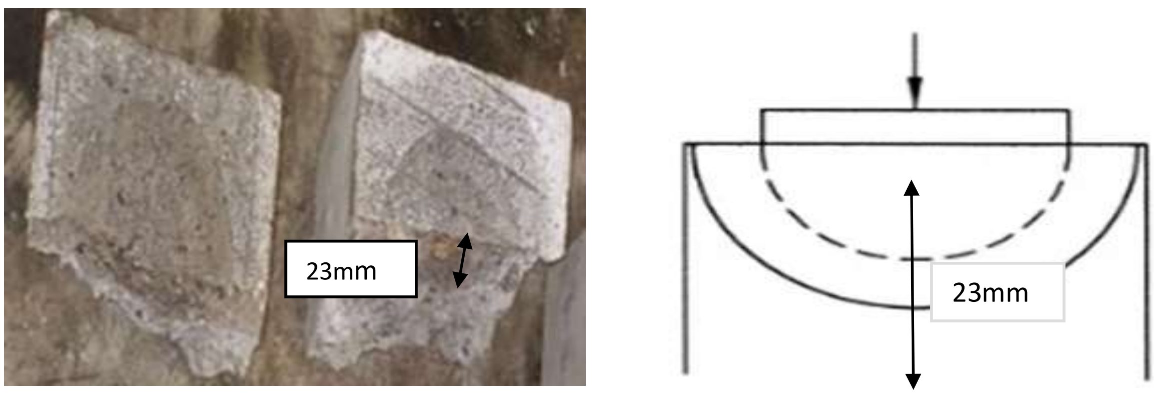

Figure 4:15 Permeability measurement of concrete

Table 4:14 Water Penetration test depth (h)

Sample no	Mix Notation	Concrete class	Penetrated depth(mm)	
			Average(h)	maximum
1	0% F.A and 0% M.D	C-25	21.67	25
2	5% F.A and 5% M.D	C-25	22.34	27
3	5% F.A and 10% M.D	C-25	23	26
4	5% F.A and 15% M.D	C-25	24	24

From the experiment the average value of permeability depth is shown in the table 4:14. Likewise the standard 'h' should be less than 25mm. so the value is acceptable.

Water penetration depth increments are recorded with substitution of the cement with fly ash and marble dust except for 20% replacement mix. This is due to the reduction of cement amount that reduces the CHS(calcium hydro silicate) part which was responsible for reducing gel pores

.The exception for the 20% replacement mix is may be due to the filling effects of certain micro size particles of the marble dust and fly ash which makes the paste more compact.

Generally, from the nature of material we used in concreting the laboratory concrete, the amount depth of water penetration on the concrete specimens are low and the durability of concrete is good regarding to standard, more the depth of water penetration, the less is the durability of concrete. This can be used for comparing the potential durability of various types of concrete. Unfortunately, in this study its long-term performance or durability was not been checked owning to lack of specialized equipment in laboratory.

4.10. Microstructural Analysis of the study

Complete silicate analysis of fly ashes and marble dust was conducted in the Geological Survey center of Ethiopia and the results of which are given in Table 4:6 and 4:7 respectively. The full Chemical analysis of the fly ashes and marble dust as reported by the Geological Survey of Ethiopia is attached in the appendix section of this study.

Scanning electron microscopy (SEM) micrographs images of specimens at 28 days are shown in figure below, the micrograph shows that the paste is composed of amorphous particles of calcium silicate hydrate(C-S-H), calcium hydroxide (C-H) crystals and the ettringites (E) needles of calcium sulfo-aluminate hydrate are located.

The SEM investigations indicated that $Ca\ (OH)_2$ morphology in specimens with and without Marble Dust are different from each other. While the crystals of the series without any replacement of the very fine sand aggregate with marble Dust have formed in a large and euhedral manner, in the series where a particular weight proportion of fine sand material have been replaced with marble dust, the CH crystals are small and have been dispersed through the matrix.

The composition of C–A–S–H is best estimated from microanalyses of characteristic X-rays in a scanning electron microscope (SEM) or microprobe of polished sections of cement concrete paste from the figure 4:16 (a) the paste without cement replacement the crystalline of calcium silicate hydrate (CSH) that formed from the hydration of tri-calcium silicate ($2C_3S$) or alite is visible as short networked fiber structure.

The reactive alumino silicate and calcium alumino-silicate components of fly ash are routinely represented in their oxide nomenclatures such as silicon dioxide, aluminum oxide and calcium oxide. The alumino silicate 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.

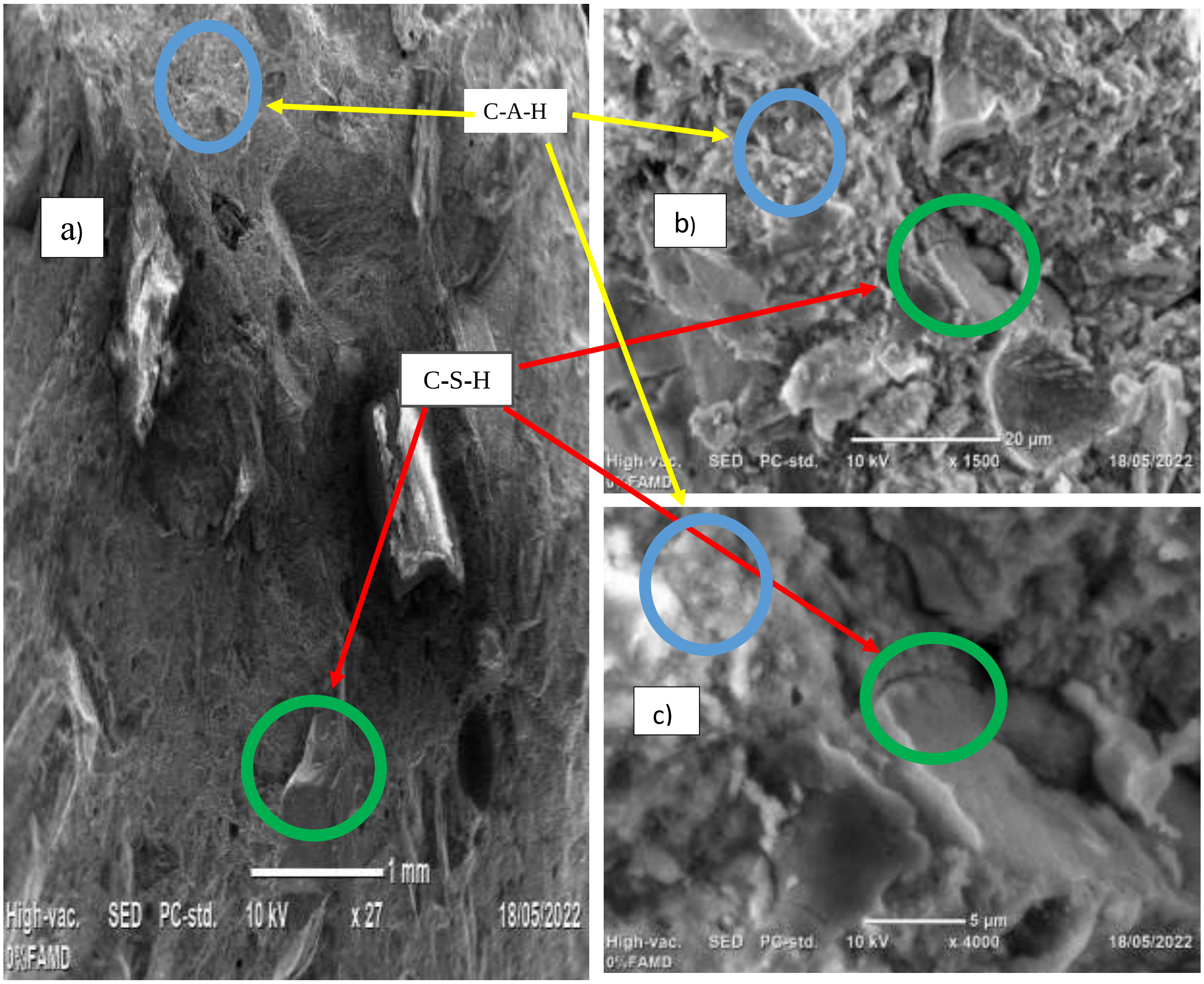

Figure 4:16 SEM Micrograph of control concrete

Here from the above SEM Image of figure 4:16 (a) control concrete also the tri calcium aluminate react with water to produce C-A-H, from figure 4:16 (b) concrete produced by blended cement with fly ash and marble dust mixture is an alumino silicate based cement substitute, in the reaction of calcium silicate hydrate (C-S-H) it increases alumina and silica. From the chemical composition of 10% replacement the high amount of calcium (CaO) in marble dust and Silicate (SiO_2) compound in water Calcium Hydrate (CH) that the white rim around aggregate, is secondary hydration products.

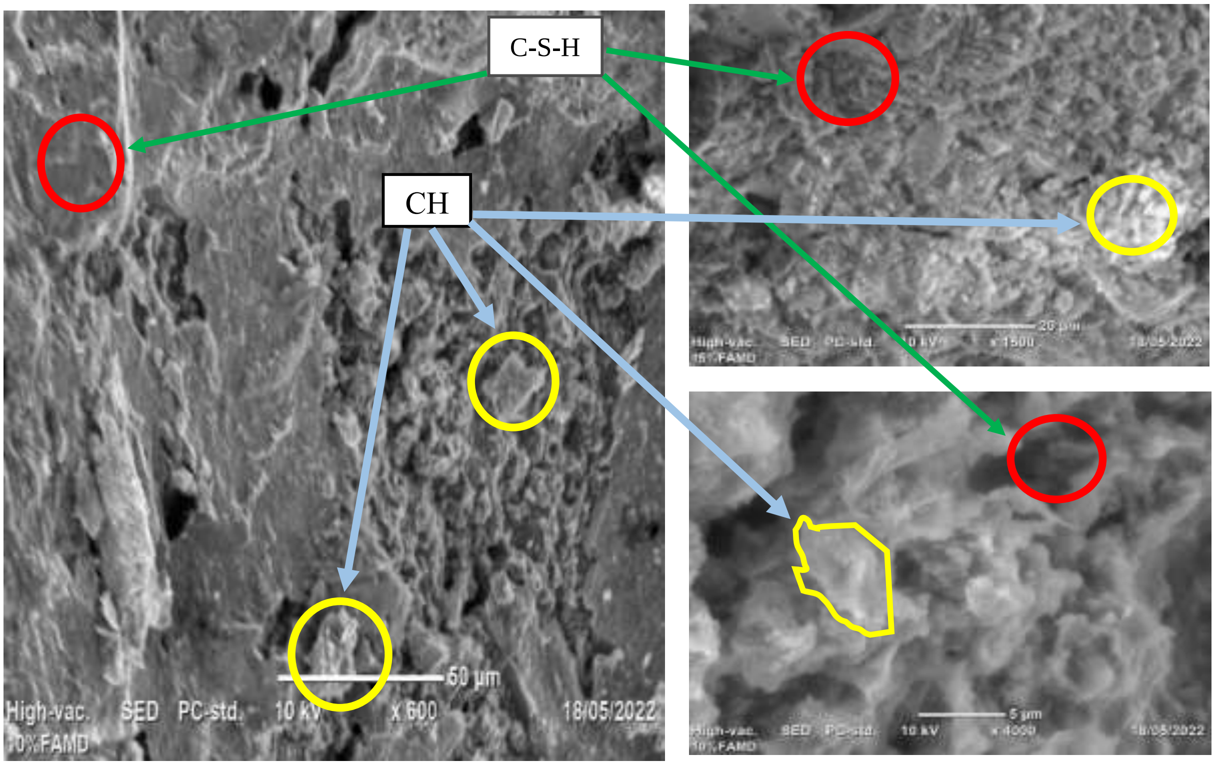

Figure 4:17 SEM micrographs image of 10% and 15% replacement

In Figure 4:17 SEM images, the particle diameters are in the range of 1.5 to 200 µm. The largest volume is calcium Ca 50.96% in marble dust and 23.66% in fly ash when blended with cement it increase, is occupied by particles of calcium hydrate that is the light grey product (CH) Chemical composition is typical for fly ash Silica and alumina oxide dominate, which is. The large bright grains are unreacted alite, and the dark regions indicate porous regions or low-density products. The brightest spots are typically iron from the ferrite phase.

Generally from morphological characteristics test results this paper has got as Ordinary Portland cement type produced in different cement factory have significant effects like on variation of bonding of particles, surface depression on morphological characteristics of concrete, which is mainly influenced by chemical composition. Also the partially replaced cementing material mixture modified the chemical reaction up to proportions of amount that meet the chemical composition requirement.

4.11. Environmental and Cost Analysis partially replaced cement concrete

Recycling of industrial wastes has actually environmental, economic and technical benefits. These benefits can be seen from two different angles, one from the point of the waste producer and the other from the user part. About 7% CO_2 is released into the atmosphere during cement production, which has a negative influence on ecology and future of human being arising from global warming.

4.11.1. Environmental Analysis of partially replaced cement Concrete

One of the greatest environmental concerns in the construction industry is the production of cement which emits a large amount of CO_2 gas to the atmosphere, that 1 tons of cement production emit the same 1 tons of CO_2 (Virendra and Kamble 2018).

On average, to produce one ton of cement, 3.4 GJ of thermal energy (in dry process) and 110 kwh of electrical energy are needed. Furthermore, manufacturing a ton of cement releases 0.73–0.99 tons of CO_2 which primarily depends on the clinker-to-cement ratio and other factors Replacing the cement paste in concrete production Minimize the quantity of cement in the mix and that similarly decrease the needed of cement production and its impact CO_2 emission.

From the result strength of our laboratory test, suppose 15% replacement of fly ash and marble dust mixture improves the mechanical properties of our concrete The CO_2 produced for the manufacture of one ton of structural concrete is estimated at 410 kg/m^3 or 180kg/ton by density of 2.3g/cm^3 by pure cement and after we partially replaced the cement concrete by 15% the amount of CO_2 emission reduced to 350 kg/m^3.

The demand ability of a wastes will ensure environmental benefits as far as the wastes used as useful materials. It is also expected that it can get more economic benefits when there is more demand for the wastes. Therefore, the use of marble dust and fly ash in the construction industry undoubtedly will increase the demand for the waste and Recycling the west marble dust and fly ash in substitution of cement also indirectly can reduce environmental problem related to cement production and impact of disposal marble powder was reduced for cement replacement cases as the disposal of this waste has a negative effect on the environment.

4.11.2. Cost Analysis of partially replaced cement concrete

The costs that were incorporated in the cost analysis of this study were partial replacement of ordinary Portland cement concrete by the mixture of Ethiopian marble dust and fly ash percentage of substitutions were considered.

Ethiopia, September 2021: The price of electricity is 0.3185 birr per kilowatt hour (kwh) for households and 0.91 birr for businesses which includes all components of the electricity bill such as the cost of power, distribution and taxes. For comparison, the average price of electricity in the world for that period is 6.1425 birr per kwh for households and 5.733 birr for businesses. One of the interesting facts of life cycle analyses of concrete is that the energy used in the production of cement, which is 0.25 GJ/ton (Gigajoule per ton), is much higher than in the extraction of raw materials 0.13 GJ/ton. The energy required in cement production is as high as 70% which is around 1.18 GJ/ton. Therefore, even if 15% cement is replaced by the mixture of fly ash and marble dust it would account to almost 1.05% less energy consumption

Where 1 Giga Joule = 277.778 Kilowatt hour and in Ethiopia as mentioned above the price of electricity is 5.733 birr per kilo watt hour for business.

So cost of cement production is 1.18 * 277.778 * 5.733 = 1879.15 birr.

The cost of15% partial replacement blended cement is 1.003*277.778*5.733 =1597.28 birr.

So, the difference of cost from energy consumption of cement concrete and partially replaced cement concrete is visible around 281.87 birr per ton only by energy consumption. It energy consumption decrease when using partially replacing proportion increase. To give insight for cost benefits, the average cost of cement, and selling price of Fly ash and marble dust is presented below

Table 4:15 Market price of Material costs (source current market)

S.No	Type of Material	Average Price (Birr)
1	Cement	970 per quintal
2	Fly ash	85
3	Marble waste	155 per quintal

The calculated prices for cement, fly ash and marble per one meter cube of concrete is used to quantify materials. Hence, the comparisons is about the effect of using supplementary material with the partial replacement of cement in concrete, and FA indicates Fly ash and MD indicates marble dust.

Table 4: 16 Cost of cement, fly ash and marble dust per 1m^3 of concrete

Cost of cement, fly ash and marble dust per 1m^3 of concrete									
%ge repl. [%]	Cement (kg)	FA to repl. (kg)	MD to repl. (kg)	Cost of cement (birr)	Cost of FA (birr)	Cost of MD in (birr)	Total (birr)	Cumulative d/ce (birr)	Cumulative d/ce [%]
0%	315	-	-	2961	-	-	2961	0	
10%	283.5	15.75	15.75	2664	13.4	24.41	2701	260	8.78
15%	267.7	15.75	31.5	2516	13.4	48.82	2578	383	12.93
20%	252	15.75	47.25	2368	13.4	73.24	2388	573	19.35

The table 4:16 describes that, concrete production without partial replacement of cement is expensive than concrete production with partially replaced cement concrete. Being a waste material, marble powder is freely available except for the transportation costs.

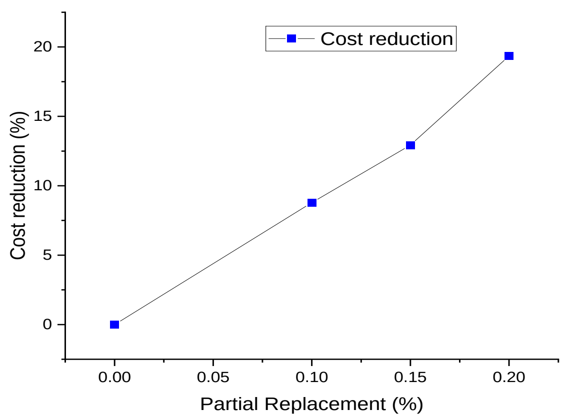

Figure 4:18 the graphical representation of concrete Cost analysis

The current unit costs of the materials for 1 meter cube of concrete in Ethiopia are indicated in Table 4:10 and in above figure for OPC concrete C25 grade. The rate for 1 m3 concrete with Marble dust 0% and fly ash 0% replacement of cement concrete is 2961.00, the rate of 10% cement replacement by 5% marble dust is 2701.00 birr, the rate of 15% replacement 5% fly ash and 10% marble dust is 2578.00 and for the 20% replacement of 5% fly ash and 15% marble dust the rate of material is 2388.00 birr. As the graph shown us along the replacement range increases the cost reduction increase by 8.78% for 10% replacement, by 12.93% for 15% replacement and by 19.35% for 20% replacement. Using of supplementary material that fly ash and marble dust in partial replacement of cement concrete in Ethiopia can play cost reduction.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The main target of this study is to produce Concrete made with partial replacement of marble dust and fly ash mixture and then to characterize the mechanical properties of concrete in fresh and hardened state

The main factors controlling the mechanical performance of the obtained concrete are the properties of the ingredient. For this reason, investigation of the properties of the constituent's material and preliminary characterization of their mechanical property was performed. The performance of marble dust and fly ash mixture blended concrete were evaluated in order to check the effect of waste marble dust and fly ash on produced concrete. Thereafter, the compressive strength in the hardened state at 7th, 14th, and 28th day and water permeability at 28th day were evaluated for each mix, varying the weight fraction of cement by mixture of fly ash and marble dust.

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

- Marble Dust and fly ash used for the study satisfies the chemical standard requirement for partial replacement of Ordinary Portland cement, and natural fineness of the marble and fly ash is comparable with that of the fineness of ordinary Portland cement to be used as a filler or reactive partial replacement on concrete
- Workability of concrete is also increasing due to increase in percentage of marble dust and fly ash mixture and the setting time of concrete is increasing.
- Use of 5% of fly ash and 10% of marble dust improves workability, without adversely affecting strength and with no effect on expansion and setting characteristics.
- Due to extra increase percentage of fly ash and marble dust mixture in concrete the strength of concrete is reducing.
- The maximum compressive strength of the concrete with partial replacement of cement by mixture of fly ash and marble dust is 32.26Mpa by 15% replacement, maximum value of flexural strength is 6.21Mpa also by 15% replacement.

- Marble dust and fly ash can be used as filler and reactive helps to reduce the total voids content in concrete. Through reaction with the concrete admixture improves pozzolonic reaction, micro void filling, and concrete durability.
- It decrease the material cost by using these waste as cementations materials. And the cost analysis indicates as the percent of cement decreases the construction cost decrease
- It keeps green environment by decreasing Co_2 emissions in to the prevailing environment during cement production and increase the demand ability of west from environment to decrease pollution.
- They can be innovate supplementary cementitious construction material but judicious decision taken by engineers.

Generally, those Wastes fly ash and marble dust can be used as cementitious construction materials and concrete for structures as per the engineering modifications are considered.

5.2. Recommendations

Based on the process and result of this research, the following recommendation were provided:

- In Ethiopia there are bulky of waste marble dust and fly ash. Its potential utilization should be realized by all level of society and Government. Its optimal management can benefit the nation.
- The construction sector and Construction industry main stakeholders like Contractors, Consultants and Clients should be informed, promote and work together about the use of prevailing wastes in concrete construction.
- Further study on details of micro structural and chemical composition of marble dust and fly ash long-term effects on concrete properties and structures durability should be perform.

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APPENDIX'S

APPENDIX A

Concrete Mix Design

Using the ACI mix design methods, to design a concrete mix for an application requiring a characteristic strength of 25MPa at 28 days and a slump of 10-30 mm. The materials available are:

- ✓ Uncrushed fine and coarse aggregate
- ✓ Specific Gravity of aggregate=2.68
- ✓ Max. Nominal size of C. aggregate =25mm
- ✓ Fine aggregate confirms to grading Zone II.
- ✓ Concrete is likely to be exposed to moderate climate.
- ✓ Appropriate assumption for any missing and applied charts is required

Step: 1. computing required average compressive strength from the given characteristic strength of 25MPa.

1. **Table 10: as per ACI-318 standard formula forcharacteristic average compressive strength**

Specified characteristic compressive strength (f'c, MPa)	Required average compressive strength in (f'cr, MPa)
<21	f'c + 7
21-35	f'c + 8.5
>35	1.1*f'c + 5

Where, the Specified characteristic compressive strength (f'c) value is 25Mpa is between 21 – 35 Mpa, to find the value of average compressive strength (F'cr), the formula is (f'c + 8.5).

So F'cr is:

= f'c + 8.5

= 25 + 8.5

<u>= 33.5 Mpa</u>

Step: 2. Specifying minimum cement content

From durability considerations cement content should not be reduced below 300Kg/m3 for RCC. IS 456 –2000 recommends higher cement contents for more severe conditions of exposure of weathering agents to the concrete.

Step: 3. Choice of slump

The slump size is (10 – 30) mm, from the given data

Step: 4. Selecting the maximum size of Aggregate

Thus the ACI method is based on the principle that the maximum size of aggregate should be the largest available so long it is consistent with the dimensions of the structure. In practice the dimensions of the forms or the spacing of the re-bars controls the maximum CA size.

When high strength concrete is desired, best results may be obtained with reduced maximum sizes of aggregate since these produce higher strengths at a given w/c ratio In our case the maximum size of Aggregate = 37.5mm

Step 5. Estimate mixing water, and air content from ACI mix design method table water content is 180liter/m3 and air content is 15%

Step: 6. Computing water cement ratio by interpolation we can get 33.5Mpa strength concrete, where 30Mpa = 0.54, 33.5Mpa = x and 35 Mpa = 0.47 x = 0.491.

As a thumb rule every 1% increase in quantity of water added, reduces the strength of concrete by 5%. Workability can be resolved with the use of plasticizers or super-plasticizers

Step: 7. determining the mix cement content

Once the water content and the w/c ratio is determined, the amount of cement per unit volume of concrete is found by dividing the estimated water content by the w/c ratio.

Cement content = water content/ water cement ratio

Cement content = 180 kg/m3/0.491

Cement content = 366.6 kg/m3

Step: 8. Estimating the bulk volume of dry rodded as per unit volume of concrete

Fineness Modulus (2.6-3.0) = 2.6, and

Dry rodded aggregate per unit volume of concrete becomes = 0.5

Step: 9. Calculating the weight of coarse aggregate (WCA) per m3 of concrete

WCA = bulk volume of dry rodded aggregate per unit volume of concrete * bulk density C.A

Where; volume of dry rodded aggregate. = 0.688

Assume bulk density C.A = 1624 kg/m3

WCA= bulk volume*bulk density

WCA = 0.688 m3 * 1624Kg/m3

WCA = 1117.312kg

Step: 10. Determining the solid volume of the coarse aggregate

Solid volume of C.A. = WCA / Specific gravity

Solid volume of C.A. = 1117.312 kg / 2.88, =387.95liter/m3

where; Specific gravity of C.A.: 2.88(given)

Step: 11. Calculating the solid volume of cement, water and volume of air.

Volume of cement = weight of cement / unit weight of cement

Volume of cement = 366.6 / 3.12 =117.5liter/m3

Volume of water = 180 liter/ m3

Volume of air = 15% or 150 liter/ m3

Step 12. Determining solid volume of sand (Solid volume of sand is then calculated by subtracting from the data volume of concrete).

	Volume (Lit)	Weight (Kg)
Air	150	-
Cement	117.5	366.6
Water	180	181.34
Course Aggregate	387.9	1117.31
Fine Aggregate	= 164.5	= 473.88 kg
Total	1000 liter	= 2139.13 kg

✓ Solid volume of sand =

1000 – (387.9(VCA) +117.5(VC) + 180(VW) + 150(VA))

Solid volume of sand = 164.5 liter or 0.1645 m3

Solid weight of sand = 0.27684* 2.88 * 1000

Weight of sand = 473.88 kg/ m3

Step: 13. Adjustment for moisture in the aggregate.

Since the moisture level of the fine aggregate in our storage vary, we will apply a simple rule to adjust the water required.

Let: assume

1.01% of moisture absorption by coarse aggregate.

0.5% of moisture adsorption by fine aggregate.

The amount of water absorbed by coarse aggregate 1117.3kg/m3 * 0.005 = 5.5865 kg/m3

The amount of water supplied by fine aggregate 473 kg/m3 * 0.0101 = 4.784kg/m3

So estimated amount of water needed for mix = (180 + 5.586) – 4.784 = 180.802

The estimated batch weight of cubic meter of concrete are:

Water (free water)	180.802 liter/m3
Cement	366.6 Kg/m3
Course aggregate (1117.3 – 5.76)	1111.54 kg/m3
Fine aggregate (473.8 + 4.42)	478.22 Kg/m3

From the above result the mix design

Ingridient	**Course aggregate**	**Fine aggregate**	**Cement (Kg)**
Quantities	1111.54/366.6	478.22/366.6	366.6/366.6
Ratio	3.03	1.3	1

The mix Ratio is 1:1.3:3.03, where 1 is for cement, 1.3 is for sand and 3.05 is course aggregate

Number of specimen and Quantity of Material for compressive (cube test) and flexural test

	For compressive strength				**For flexural strength**			
Age	0%	10%	15%	20	0%	10%	15%	20
7 days	5	5	5	5	5	5	5	5
14 days	5	5	5	5	5	5	5	5
28 days	5	5	5	5	5	5	5	5

- For compressive strength test the quantity of concrete is: 0.15x0.15x0.15 = 0.003375m3

Dry concrete = 0.003375 x 1.54 = 0.0051975

We have 100 specimen of cube (100 x 0.0051975) = 0.519m3

- For flexural strength test the quantity of concrete is: 0.10x0.10x0.5 = 0.005m3

Dry concrete = 0.005 x 1.54 = 0.0077m3

We have 100 beam specimen for flexural strength test (100 x 0.0077) = 0.77m3

The total quantity of concrete used is = Total concrete for cube + Total concrete for beam

0.519 + 0.77 = 1.289 m3

- For 0% replacement of cement concrete the quantity of cement. Sand and course aggregate:

The mix ratio is 1:1.3:3.05 the sum of this ratio is = 5.35

For, cement = 1/5.35 x 1.289m3 x 1400 Kg/m3 x 1.3 *1.05= 460.426kg/50kg = 9.2 bags

Fine aggregate = 1.3/5.35 x 1.289m3 x 1440Kg/m3 x 1.3 x 1.05 = 615.655kg

Course aggregate = 3.05/5.35 x 1.289 x 1480Kk/m3 x 1.3 x 1.05 =1484.545Kg

- So, 10% cement replacement for compressive cube and flexural beam is 460.426/4=115.101kg

When 115.101 is 100% of cement the 10% amount that should be replaced by the mixture of 5% fly ash and 5% marble dust is 11.51 kg that 5.75 kg fly ash and 5.75 kg marble dust.

- For, 15% cement replacement, When 115.101 is 100% of cement the 15% amount that should be replaced by the mixture of 5% fly ash and 10% marble dust is 17.26 kg that 5.75 kg fly ash and 11.51 kg marble dust.
- For, 20% cement replacement, When 115.101 is 100% of cement the 20% amount that should be replaced by the mixture of 5% fly ash and 5% marble dust is 23.02 kg that 5.75 kg fly ash and 17.27 kg marble dust.

Amount of water, 1m3 = 180 liter then for 1.289m3 of concrete = 232.02 liter is needed

Figure 5:1 Material testsPhoto

APPENDIX B

Grain size distribution of fine and coarse aggregates

Sieve size (mm)	Weight of sieve (gm)	Wt. of sieve & retained weight	Weight retained (gm)	Perc. retained (%)	Cum. coarser (%)	Cum. passing (%)	ASTM Limit		Remarks
							Min. %	Max. %	
9.5	525	525	0	0	0	100	100	100	Ok!
4.47	575	585	15	3	3	97	95	100	‘‘
2.36	525	555	40	8	11	88	80	100	‘‘
1.18	495	560	80	16	27	72	55	85	‘‘
0.6	455	610	105	21	48	51	25	60	‘‘
0.3	430	610	165	33	81	18	5	30	‘‘
0.15	400	445	55	11	92	7	0	10	‘‘
pan	330	335	35	7	-	0			‘‘
Total					262				

		% passing		
	Sieve size (mm)	Lower Limit %	Passing %	Upper Limit %
Sieve Size	9.5	100	100	100
	4.75	95	97	100
	2.36	80	88	100
	1.18	55	72	85
	0.6	25	51	60
	0.3	5	18	30
	0.15	0	7	10

Table 5:2 Grain size distribution of fine aggregate


Figure 5:2 different size of sieves and sand used

Sieve size (mm)	Weight of sieve (gm)	Wt. of sieve & retained weight	Weight retained (gm)	Perc. retained (%)	Cum. coarser (%)	Cum. passing (%)	ASTM Limit		Remarks
							Min. %	Max. %	
37.5	1145	1145	0	0	0	100	100	100	Ok!
25	1190	1270	80	4	4	96	95	100	"
19	1115	1795	720	36	40	60	40	85	"
12.5	1220	2180	620	31	71	29	25	60	"
9.5	1230	1450	460	23	94	6	0	15	"
4.75	1125	1185	120	6	100	0	0	10	"
pan	895	895	0	0	-	0	0	0	"
Total					309				

		% passing		
	Sieve size (mm)	Lower Limit %	Passing %	Upper Limit %
Sieve Size	37.5	100	100	100
	25	95	96	100
	19	40	60	85
	12.5	25	29	60
	9.5	0	6	15
	4.75	0	0	10

Table 5:2 Grain size distribution of coarse aggregate

Figure 5:3 Coarse aggregate

APPENDIX C

Unit weight of sand and coarse aggregate

- **Compacted weight determination of fine aggregate**

Volume of measuring cylindrical metal =0.005m^3

1^{st} = 10810g

2^{nd} =10810g

3^{rd} = 10795g

Average measure = 10805g it's equal to 10.805kg

Unit weight = Average weight measure/ volume of cylinder

10805/0.005 =10.805kg/0.005m^3 = 2161kg/m^3

- Lose weight determination of fine aggregate

Volume of measuring cylindrical metal =0.005m^3

1^{st} = 9595g

2^{nd} =9975g

3^{rd} = 9855g

Average measure = 9808.3g it's equal to 9.8083kg

Unit weight = Average weight measure/ volume of cylinder

= 9.8083kg/0.005m^3 = 1962kg/m^3

- Compacted weight determination of coarse aggregate

Volume of measuring cylindrical metal =$0.005m^3$

1^{st} = 12170g

2^{nd} =12165g

3^{rd} = 12045g

Average measure = 12127g it's equal to 12.127kg

Unit weight = Average weight measure/ volume of cylinder

= $12.127kg/0.005m^3 = 2425.4kg/m^3$

- Lose weight determination of coarse aggregate

Volume of measuring cylindrical metal =$0.005m^3$

1^{st} = 11530g

2^{nd} =111240g

3^{rd} = 11360g

Average measure = 11377g it's equal to 11.377kg

Unit weight = Average weight measure/ volume of cylinder

= $11.377kg/0.005m^3 = 2275kg/m^3$

APPENDIX D

Experimental result of slump test

Mix Notation	Average Slump (cm)
0% F.A and 0% M.D	5.35
5% F.A and 5% M.D	6.40
5% F.A and 10% M.D	7.60
5% F.A and 15% M.D	8.00

Mix Notation	Slump (cm)	Average slump(cm)
0% F.A and 0% M.D	4.62	5.35
	6.08	
5% F.A and 5% M.D	5.84	6.40
	6.96	
5% F.A and 10% M.D	8.43	7.60
	6.77	

5% F.A and 15% M.D	7.45	8.00
	8.55	

Figure 5:4 slump of concrete

APPENDIX E

Compressive Strength of the partial replacement of cement at 7, 14 and 28 days

%ge replacement	Test age [days]	Dimension			Weight [kg]	Failure Load [KN]	Compressive Strength[MPa]
		L	W	H			
0%	7	15	15	15	8.46	403.24	17.92
	7	15	15	15	8.85	447.79	19.90
	7	15	15	15	8.75	369.36	16.40
	7	15	15	15	8.90	346.50	15.40
	7	15	15	15	8.40	416.74	18.52
Mean value						= 396.73	= 17.63
0%	14	15	15	15	9.02	456.66	20.32
	14	15	15	15	8.91	493.25	21.92
	14	15	15	15	8.64	541.30	23.97
	14	15	15	15	8.87	515.31	22.90
	14	15	15	15	8.75	528.13	23.50
Mean value						= 506.92	= 22.52
	28	15	15	15	8.92	550.60	24.50
	28	15	15	15	7.93	568.58	25.30

0%	28	15	15	15	8.56	645.44	28.72
	20	15	15	15	8.34	627.01	27.90
	28	15	15	15	8.84	665.06	29.45
Mean value						= 611.34	= 27.17

%ge replacement	Test age [days]	Dimension			Weight	Failure	Compressive
		L	W	H	[kg]	Load [KN]	Strength[MPa]
10%	7	15	15	15	8.60	327.30	14.55
	7	15	15	15	9.47	301.97	13.42
	7	15	15	15	8.53	446.97	19.87
	7	15	15	15	8.46	416.60	18.52
	7	15	15	15	8.71	346.50	15.40
Mean value						= 367.87	= 16.35
10%	14	15	15	15	8.42	457.09	20.32
	14	15	15	15	8.42	527.51	23.45
	14	15	15	15	8.53	556.29	24.73
	14	15	15	15	9.55	507.93	22.58
	14	15	15	15	8.84	534.25	23.75
Mean value						= 516.61	= 22.96
10%	28	15	15	15	8.71	541.30	23.97
	28	15	15	15	8.61	661.40	29.36
	28	15	15	15	8.56	645.44	28.72
	28	15	15	15	8.84	665.06	29.45
	28	15	15	15	8.79	630.06	27.90
Mean value						= 628.65	= 27.88

%ge replacement	Test age [days]	Dimension			Weight	Failure	Compressive
		L	W	H	[kg]	Load [KN]	Strength[MPa]
	7	15	15	15	8.33	526.50	23.40
	7	15	15	15	8.35	514.10	22.85

15%	7	15	15	15	8.90	417.58	18.56
	7	15	15	15	8.40	392.83	17.46
	7	15	15	15	8.72	447.05	19.87
Mean value						=389.01	= 20.43
	14	15	15	15	9.02	555.07	24.67
	14	15	15	15	8.91	587.92	26.13
15%	14	15	15	15	8.64	571.94	25.42
	14	15	15	15	8.87	536.85	23.86
	14	15	15	15	9.21	584.10	25.96
Mean value						= 567.17	= 25.21
	28	15	15	15	8.39	749.70	33.32
	28	15	15	15	7.75	661.40	29.40
15%	28	15	15	15	8.56	741.71	32.97
	28	15	15	15	8.84	743.51	33.05
						732.60	32.56
Mean value						= 725.78	= 32.26

%ge replacement	Test age [days]	Dimension			Weight	Failure	Compressive
		L	W	H	[kg]	Load [KN]	Strength[MPa]
	7	15	15	15	8.22	363.70	16.20
	7	15	15	15	8.44	344.80	15.33
20%	7	15	15	15	8.90	419.15	18.67
	7	15	15	15	8.38	446.91	19.87
	7	15	15	15	8.40	396.92	17.68
Mean value						= 394.29	= 17.55
	14	15	15	15	9.02	505.70	22.48
	14	15	15	15	8.91	538.09	23.92
20%	14	15	15	15	8.48	576.78	25.64
	14	15	15	15	8.64	541.30	23.97
	14	15	15	15	8.87	515.14	22.90

Mean value						= 535.41	= 23.78
20%	28	15	15	15	8.74	628.20	27.92
	28	15	15	15	8.28	579.37	25.76
	28	15	15	15	8.96	643.44	28.63
	28	15	15	15	9.01	640.57	28.47
	28	15	15	15	8.89	662.62	29.45
Mean value						= 630.84	= 28.05

Figure 5:5 Compressive Test

Flexural Strength of the partial replacement of cement at 7, 14 and 28 days

%ge replacement	Test age [days]	Dimension			Failure Load [KN]	Flexural Strength[MPa]
		L	W	H		
0%	7	50	10	10	4.18	3.14
	7	50	10	10	4.32	3.24
	7	50	10	10	5.34	4.01
	7	50	10	10	4.47	3.36
	7	50	10	10	4.54	3.41
Mean Value					= 4.54	= 3.41
	14	50	10	10	5.50	4.12
	14	50	10	10	6.09	4.57

0%	14	50	10	10	6.30	4.72
	14	50	10	10	5.90	4.43
	14	50	10	10	6.26	4.69
MeanValue					= 6.01	= 4.51
0%	28	50	10	10	7.95	5.98
	28	50	10	10	8.25	6.21
	28	50	10	10	7.62	5.74
	28	50	10	10	7.21	5.43
	28	50	10	10	6.99	5.28
Mean Value					= 7.60	= 5.72

%ge replacement	Test age [days]	Dimension			Failure	Flexural
		L	W	H	Load [KN]	Strength[MPa]
10%	7	50	10	10	4.05	3.04
	7	50	10	10	5.09	3.82
	7	50	10	10	4.84	3.64
	7	50	10	10	4.46	3.35
	7	50	10	10	4.28	3.22
Mean Value					= 4.54	= 3.41
10%	14	50	10	10	5.75	4.32
	14	50	10	10	6.47	4.86
	14	50	10	10	6.21	4.67
	14	50	10	10	6.55	4.92
	14	50	10	10	6.24	4.69
Mean Value					= 6.24	= 4.70
10%	28	50	10	10	6.73	5.05
	28	50	10	10	7.13	5.35
	28	50	10	10	6.98	5.24
	28	50	10	10	6.81	5.11
	28	50	10	10	6.87	5.16

Mean Value					= 6.90	= 5.18

%ge replacement	Test age [days]	Dimension			Failure Load [KN]	Flexural Strength[MPa]
		L	W	H		
15%	7	50	10	10	5.50	4.12
	7	50	10	10	5.88	4.41
	7	50	10	10	5.09	3.82
	7	50	10	10	5.56	4.27
	7	50	10	10	6.02	4.52
Mean Value					= 5.61	= 4.23
15%	14	50	10	10	6.09	4.57
	14	50	10	10	7.22	5.42
	14	50	10	10	7.87	5.91
	14	50	10	10	7.53	5.65
	14	50	10	10	6.47	4.86
Mean Value					= 7.03	= 5.28
15%	28	50	10	10	8.19	6.14
	28	50	10	10	8.44	6.33
	28	50	10	10	7.97	5.98
	28	50	10	10	8.38	6.29
	28	50	10	10	8.41	6.31
Mean Value					= 8.27	= 6.21

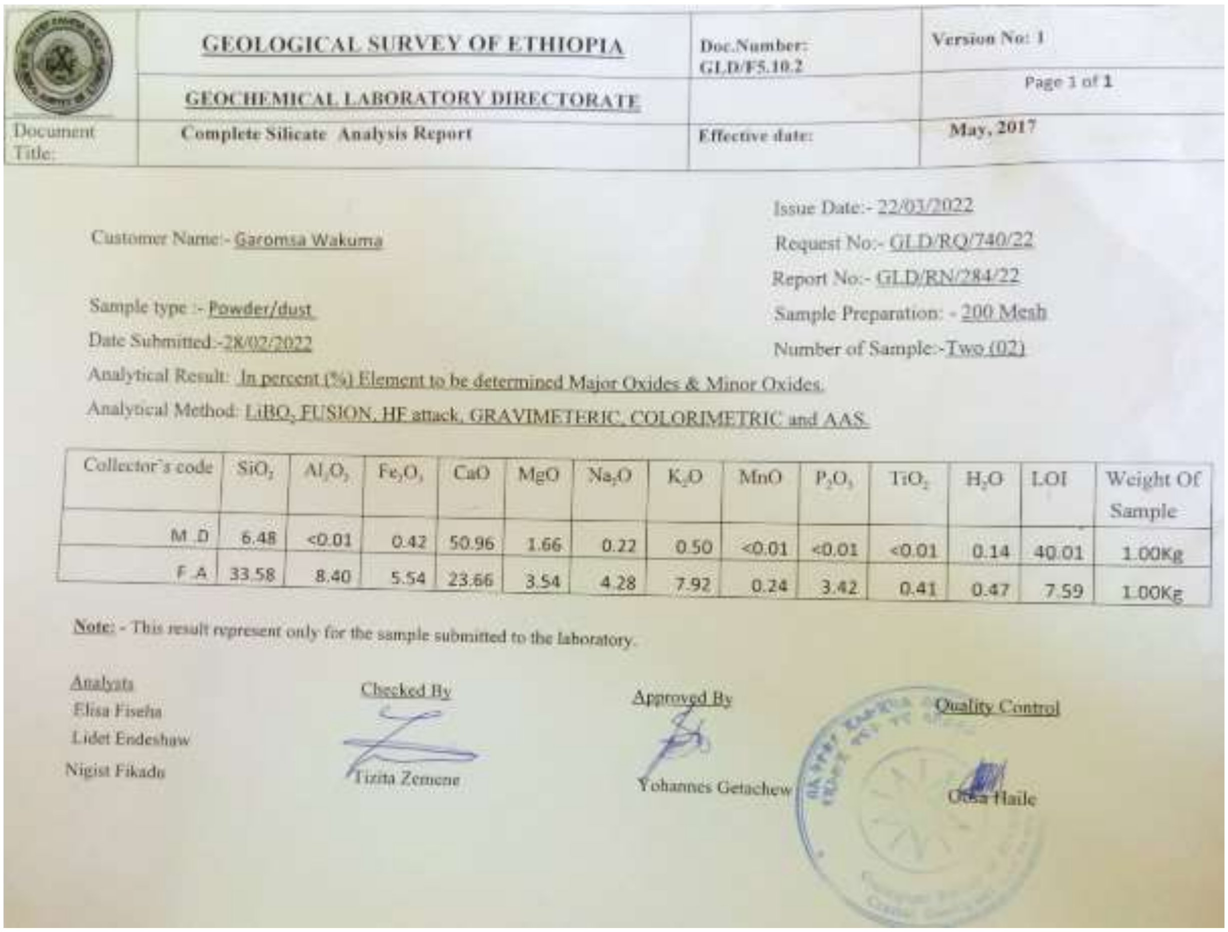
%ge replacement	Test age [days]	Dimension			Failure Load [KN]	Flexural Strength[MPa]
		L	W	H		
20%	7	50	10	10	5.36	4.02
	7	50	10	10	6.58	4.94
	7	50	10	10	5.79	4.35
	7	50	10	10	6.07	4.56
	7	50	10	10	6.36	4.77

Mean Value					= 6.03	= 4.53
20%	14	50	10	10	7.49	5.62
	14	50	10	10	6.95	5.21
	14	50	10	10	6.63	4.97
	14	50	10	10	7.09	5.32
	14	50	10	10	7.31	5.48
MeanValue					= 7.09	= 5.32
20%	28	50	10	10	7.92	5.94
	28	50	10	10	8.19	6.14
	28	50	10	10	7.71	5.78
	28	50	10	10	8.12	6.09
	28	50	10	10	7.97	5.98
Mean Value					= 7.98	= 5.98

Figure 5:6 Flexural test

APPENDIX F

Chemical composition of fly ash and marble dust from Geochemical laboratory



	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:- 22/03/2022

Customer Name:- Garomsa Wakuma

Request No:- GLD/RQ/740/22

Report No:- GLD/RN/284/22

Sample type :- Powder/dust

Sample Preparation: - 200 Mesh

Date Submitted.-28/02/2022

Number of Sample:-Two (02)

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	Weight Of Sample
M.D	6.48	<0.01	0.42	50.96	1.66	0.22	0.50	<0.01	<0.01	<0.01	0.14	40.01	1.00Kg
F.A	33.58	8.40	5.54	23.66	3.54	4.28	7.92	0.24	3.42	0.41	0.47	7.59	1.00Kg

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

Analysts	Checked By	Approved By	Quality Control
Elisa Fiseha			
Lidet Endeshaw			
Nigist Fikadu	Tizita Zemene	Yohannes Getachew	Obsa Haile

Figure 5:7 Fly ash and marble dust Silicate test result

APPENDIX G

Permeability of concrete

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'

% ge replacement	Penetration Depth (h)	Average depth
(F.A + M.D) 0%	21	21.67
	25	
	19	
(5F.A + 5M.D) 10%	27	22.34
	19	
	21	
(5F.A + 10M.D) 15%	23	23
	20	
	26	
(5F.A + 15M.D) 20%	17	20
	24	
	19	

Sample no	Mix Notation	Concrete class	Penetrated depth(mm)	
			Average(h)	maximum
1	0% F.A and 0% M.D	C-25	21.67	25
2	5% F.A and 5% M.D	C-25	22.34	27
3	5% F.A and 10% M.D	C-25	23	26
4	5% F.A and 15% M.D	C-25	20	24

APPENDIX H

Cost analyzation

Suppose we take $1m^3$ of concrete and analyze the cost benefit of using fly ash and marble dust by using 1:2:3 mix ration.

The total addition of mix ratio is: 1 + 2 + 3 = 6

Cement = $\frac{1}{6} * 1m^3 * 1400kg/m^3 * 1.35 = 315kg$

10% replacement of 315kg is 31.5k,

Fly ash = 15.75kg and

Marble dust = 15.75kg

For 15% replacement

Fly ash = 15.75kg and

Marble dust = 31.5kg

For 20% replacement

Fly ash = 15.75kg and

Marble dust = 47.25kg

Cost of cement, fly ash and marble dust per 1m³ of concrete									
%ge repl. [%]	Cement (kg)	FA to repl. (kg)	MD to repl. (kg)	Cost of cement (birr)	Cost of FA (birr)	Cost of MD in (birr)	Total (birr)	Cumulative d/ce (birr)	Cumulative d/ce [%]
0%	315	-	-	2961	-	-	2961	0	
10%	283.5	15.75	15.75	2664	13.4	24.41	2701	260	8.78
15%	267.7	15.75	31.5	2516	13.4	48.82	2578	383	12.93
20%	252	15.75	47.25	2368	13.4	73.24	2388	573	19.35