INVESTIGATING THE USE OF BASALT ROCK POWDER IN THE PARTIAL REPLACEMENT OF CEMENT IN PLAIN CONCRETE

KELLY WAYOMIRWOTH

S18B32/802

A FINAL YEAR RESEARCH AND DESIGN PROJECT REPORT SUBMITTED TO THE FACULTY OF ENGINEERING, DESIGN AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF A DEGREE OF BACHELOR OF SCIENCE IN CIVIL AND ENVIRONMENTAL ENGINEERING OF UGANDA CHRISTIAN UNIVERSITY

April 2024

ABSTRACT

This research study focused on investigating the optimum replacement of Basalt Rock powder (BRP) that can be used to partially replace cement as a cement supplementary material (SCM) while achieving the maximum suitable compressive strength. The Basalt rocks used in this study were collected and crushed from Mugarama site in Kibaale District to form powder. The physical and mechanical properties of concrete ingredient such as sand and coarse aggregates were determined and these included sieve analysis, ACV, AIV, moisture content, flakiness index, specific gravity and water absorption. The properties of the BRP were determined by carrying out different tests such as sieve analysis, x-ray fluorescence, water absorption with results provided in chapter 4 below. The control mix of a cement content 430Kg, fine aggregate, 675kg, water 206kg and coarse aggregate of 1007kg. The percentage replacement of cement with BRP varied from 0, 10,15,20,25 and 30%. Concrete cubes of sizes 150mmx150mmx150mm were casted and evaluated for 7 and 28 days.

Increase in percentage replacement of cement with BRP showed an increase in compressive strength from 0% to 15% attaining the highest value of 43.9Mpa and then gradually decreased with increasing percentage replacement of BRP. The setting time decreases while workability increases, with an increase in BRP percentage replacement. The compressive strength, setting time and workability were all lying in the acceptable ranges according to literature, 43.9Mpa, 7.7hrs and 87mm respectively. The 15% is the optimum percentage replacement since its strength is well above the control concrete of 40.5Mpa, and target strength of 35.1Mpa.

DECLARATION

I, Wayomirwoth Kelly hereby declare that this is my original work, is not plagiarized and has not been submitted to any other institution for any award

WAYOMIRWOTH KELLY

S18B32/802

Signature …………………………………… Date: ……………………………………

APPROVAL

This final year research project report has been submitted by WAYOMIRWOTH KELLY to the department of Engineering and Environment at Uganda Christian University for examination with my approval as the university supervisor

SIGNATURE ……………………………………… **DATE: ……………………………………**

MR NATHAN NATUKUNDA

(ACADEMIC SUPERVISOR)

ACKNOLEDGMENT

This far the Lord has brought us, we would really love to give the Almighty God all the thanks, for protecting and blessing us throughout this research period. If it wasn't for God, this research would have rather been more difficult but thank God the ends have come to meet.

I do extend my gratitude to my beloved Mum and Dad and siblings, for the constant reminders, prayers and provision, so much support to enable me have a successful research experience. They have been the major motivation towards this research success.

I give thanks to the department of Engineering and Environment, for this program that gives students the opportunity to apply the knowledge acquired in class

I sincerely appreciate my academic supervisor, **MR NATHAN NATUKUNDA** for all the guidance and insights he provided whenever we reached out to him

It has also been a major blessing to have such a committed project partner Kugonza Martin, it was really great working together. I also give thanks to other class mates (Ssebulime Rodney and Kyesigwa Raymond) and a friend (Manede Eric) who constantly were there to help whenever contacted;

I do appreciate the staff team and China lab, for their complete support, guidance and provision of facilities while carrying out the various laboratory tests as required to achieve the research's objectives.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACCRONYMS/ABBREVIATIONS

ACI	–	AMERICAN CONCRETE INSTITUTE
ACV	–	AGGREGATE IMPACT VALUE
AIV	–	AGGREGATE CRUSHING VALUE
ASTM	–	AMERICAN STANDARD FOR TESTING MATERIALS
BRP	-	BASALT ROCK POWDER
BS	–	BRITISH STANDARD
CSCEC	-	CHINA STATE CONSTRUCTION ENGINEERING CORPORATION
etc	-	et cetera (and many others)
FI	-	FLAKINESS INDEX
i.e.	-	That is to say
LTD	-	LIMITED
mm	-	millimeter
SCM	-	Supplementary Cementitious Materials
SD	-	Standard Deviation

CHAPTER ONE: INTRODUCTION

1.1 Background

Concrete is a man-made building substance that has been used for decades in the construction industry and is known to be the second most used substance on the planet, after water. Concrete is a mixture of majorly; coarse aggregates, sand, cement and water (Azad, 2019).

Production of concrete is associated with lots of environmental concerns due to the over consumption of raw materials, energy and labor. Cement as one of the key ingredients in concrete, consumes a lot of energy during its production while still releasing about 0.55-0.94 tons of carbon dioxide emissions per ton, possessing about 7% of the world's total carbon dioxide emissions (Li, 2022). Several researches have been carried out to find alternatives or supplements to cement in concrete, especially on natural pozzolans like fly ash, silica fume, blast furnace slag, volcanic pumice etc. Also, more research investigated agricultural waste like coconut, maize, rice, sugar cane and industrial by products like basalt rock powder, waste foundry sand etc as Supplementary Cementitious Materials (SCM) (Qiao, 2019). But with all these studies, there's limited knowledge regarding the potential use of Basalt rock powder in concrete production, given that little have been investigated towards achieving the appropriate particle size and optimum percentage for partial cement replacement.

Basalt rock is an igneous rock that covers about 30% of the Earth's surface making it the most rock, therefore its volume is abundant as it is available in most continents. This igneous rock is a dark colored, fine grained, rock that forms as a result of volcanic activity, when basaltic lava, the molten magma from the mantle, cools down. The dark color is due to the presence of the minerals such as plagioclase, pyroxene (augite), olivine with possible minor glass. Basalt rocks are largely found in various parts of Uganda including Mbale district, Kibaale district, Kisoro district etc, and can be identified by their black or grayish-black rock color, fine and even grain texture with no crystals or minerals discernible to the naked eye.

Basalt rock has been used in the construction industry for various applications but majorly as aggregates due to its availability, sustainability, durability and strength properties (Qiao, 2019). Basalt rock powder (BRP) has a large specific surface area and high SiO_2 and Al_2O_3 contents thus when used as a supplementary cementitious material, it can have a positive impact on the mechanical properties. This is because basalt rock powder forms a gel on hydration, when Calcium Oxide from Cement reacts with SiO_2, resulting into nucleation of the C-S-H and strengthening the bond between basalt and the matrix (Li, 2022). This research will investigate the optimum percentage of Basalt Rock Powder that can be used to partially replace cement in concrete, to produce a high-performance concrete which is economical and environmentally sustainable.

1.2 PROBLEM STATEMENT

Cement production contributed to the release of about 2.3 gigatons of carbon dioxide in 2019, possessing about 7% of the world's total carbon dioxide emissions. This is expected to reach 4.83 billion metric tons in 2030. A solution for decreasing the CO_2 emissions determined by the cement industry is its replacement by supplementary cementitious materials - SCMs, (Adrian, 2022).

As a result, cement is expensive both economically and environmentally, such that much research is being carried out to adopt more sustainable alternatives. A partial replacement of cement with basalt rock powder, will not only reduce cost in concrete production, decrease gas emissions leading to greenhouse effect, minimize harmful environmental impacts, reduce the consumption of natural resources and the energy but also improve the compressive strength of concrete (Qiao, 2019).

A study shows that 10 to 25% basalt rock is appropriate for replacing Portland cement partially, while still another study indicates that the optimum fine aggregate replacement is about 20–30% and it depends more on rock dust fineness. So, there's need to carry out a profound-research to establish the optimum ratio for partial replacement of cement in concrete with regard to the fineness of the basalt rock powder. This will help to produce a high-performance concrete with improved strength properties, economically cheap and environmentally friendly.

1.3 OBJECTIVES OF STUDY

1.31 MAIN OBJECTIVE

To investigate the use of Basalt Rock Powder in the Partial replacement of cement in concrete.

1.3.2 SPECIFIC OBJECTIVES

1. To determine the physical and mechanical properties of concrete aggregates
2. To determine the physical properties and chemical composition of basalt rock powder

3. To determine the properties of fresh concrete at different proportions of basalt rock powder with cement.
4. To determine the properties of hardened concrete at different proportions of basalt rock powder.

1.4 RESEARCH QUESTIONS

1. What are the physical and mechanical properties of the concrete aggregates?
2. What are the physical properties and chemical composition of Basalt rock powder?
3. How is the properties fresh concrete mixes at different proportions of basalt rock powder with cement determined?
4. What is the properties of hardened concrete at different proportions of basalt rock powder determined?

1.5 SCIENTIFIC JUSTIFICATION

According to previous research, basalt rock powder is proven to have good durability, strength and resistance to wear and erosion, readily available at an economically sustainable cost and suitable for use in concrete (Qiao, 2019). Also, basalt can be utilized in its natural state depending on its grain size for cementitious composites, due to its influence as a pozzolanic active component (Scheinherrová, 2022)

This study therefore investigates the partial replacement of cement with a natural pozzolanic material to improve the strength of concrete while providing a natural alternative for cement, thereby reducing carbon emission, energy consumption and natural resource depletion among others.

1.6 SCOPE

1.6.1 GEOGRAPHICAL SCOPE

The basalt rocks were collected from a quarry site called Mugarama in Kibbale after being crushed with a geo-crusher. The course and fine aggregate materials collected from Zirobwe Quarry site under China State Company. The cement (Tororo Portland Cement CEM I/42.5) was collected from a Hardware shop in Namasuba

The laboratory tests were carried out from China State Laboratory in Nyanama Zone, Mutundwe.

1.6.2 TIME SCOPE

This research started in September 2023. After approval the laboratory tests started on 11th January 2024 and the report was produced on 9th April 2024

1.6.3 CONTENT SCOPE

This research focused on the use of basalt rock powder in concrete and is limited to;

1) Collection and crushing of basalt rock samples from the field in Kibaale district.
2) Breaking down of basalt rock samples into powder and testing for their physical, mechanical and chemical properties.
3) Carrying out laboratory tests on workability of fresh concrete, compressive strength of hardened concrete and obtain optimal replacement percentage of cement in concrete with basalt rock powder. The various tests were carried at China State laboratory in Kampala

CHAPTER TWO: LITERATURE REVIEW

2.0 INTRODUCTION

This chapter provides theoretical literature review about basalt rock powder, its properties and its constituents and previous research about the use of basalt rock powder in concrete. This chapter also provides a critique of existing literature and identifying the research gap thus contributing to the scientific knowledge of the research. It also includes reviews on the research problem with reference to existing theories and studies in regards to the research topic. The part of Empirical literature review is also included which covers largely the studies carried out by different researchers about the use of basalt rock powder as a partial or full replacement of fine aggregates in conventional concrete in the construction industry.

2.1 THEORETICAL REVIEW

2.1.1 CONCRETE

Type of concrete in our study is plain concrete which is the common, conventional concrete that contain the major ingredients; fine aggregates (sand), coarse aggregates (gravel), cement and water. Concrete is preferred for its ability to be easily molded into various structures and also having sufficient strength and structural properties highly regards its need in the construction environment now and the future to come, although it is not homogeneous (Narayanan, 2013). Due to advancement in technology and the need for a sustainable environment, there has been considerable discoveries and studies towards concrete to future exhaustion of concrete materials, carbon foot print, excessive energy usage and economic concerns. As a result, thorough research is being undertaken of supplementary cementitious materials such as agricultural waste, mining waste, stone powders among others (Qiao, 2019).

2.1.1.1 TYPES OF CONCRETE GRADES AND THEIR USES

Concrete are graded depending on their strength and composition, since different grades are suitable for a different purpose and this strength is determined after the 28 days of initial construction. The following are the most available concrete grades according to Warsaw, 2014;

i. Concrete grade M10, mix ratio (design mixes) 1:3:6 and Strength of 10Mpa. This is used for constructing pathways and non-structural work
ii. Concrete grade M15, mix ratio (design mixes) 1:2:4 and Strength of 15Mpa. This is used for constructing pavement kerbs and floor binding
iii. Concrete grade M20, mix ratio (design mixes) 1:1.5:3 and Strength of 20Mpa, used for constructing domestic floors and foundations with light weight. It is also good for workshop bases, garages, driveways, internal floor slabs and low volume roads
iv. Concrete grade M25, mix ratio (design mixes) 1:1:2 and Strength of 25Mpa, used for construction in all areas of multi-purpose concrete mix, usually in deep foundations
v. Concrete grade M30, mix ratio (design mixes) 1:1:1 and Strength of 30Mpa. This is the most weather resistant grade and can take heavy road traffic. It is the lowest grade of concrete mix

2.1.1.2 CONSTITUENTS OF CONCRETE

Concrete is widely and extensively most used construction material in the works of civil and construction World. Concrete is used in the construction field in foundation, constructing roads, making pavements, parking structures, overpasses, and block walls among others.

Concrete as a material consists at least 75% of aggregate by volume and is obtained from a proportionate mixture of cement binder, sand, aggregates, and water. Sand, cement and water forms a paste which hardens as result of chemical reaction between the water and cement. The formed paste binds the aggregates together into a solid rock. The strength and durability of concrete is dependent on the properties of its ingredients, mix proportions, method of compaction with other factors and also control during placing, compaction and curing.

The properties of concrete are divided into two; fresh concrete properties and harden concrete properties.

Fresh concrete properties: These include workability, segregation and bleeding. To determine the workability of fresh concrete tests such as slump tests, compaction factor test and flow table test are carried out and this helps to determine the strength and durability of concrete.

Harden concrete properties: various tests are carried out on hardened concrete to determine properties such as strength, durability, and permeability. Tests on hardened concrete such as compressive strength test, flexural strength test, tensile strength test, modulus of elasticity test are carried out to determine the strength properties of concrete

2.1.1.2.1 CEMENT

This is a pulverized material produced by blending a mixture of lime containing materials and clay materials such that it exhibits adhesive and cohesive properties which make it capable of bonding mineral fragments into compact whole for use in building of structures. Ingredients such as lime (CaO), silica (SiO_2), aluminium oxide (Al_2O_3) and iron oxide (Fe_2O_3) are heated at very high temperatures to form a rock like substance which is ground into fine powder called Cement. Cement it itself is not a binder, but develops the binding property as a result of hydration from chemical reactions between cement minerals and water. (Proxald. 2015). The most common type of cement is known as Portland cement, which is used as an ingredient in concrete production (Kaushik, 2004). There are majorly two types of Portland cement, namely; Ordinary Portland Cement (OPC) which is produced by an automated, dry manufacturing process under strict quality assurance at all manufacturing stages and Portland Pozzolana Cement (PPC) which is produced by using a pozzolanic material as the main ingredients used in the preparation and should not exceed 30% of the total OPC (Kim, 2010). Cement is classified into five classes according to ASTM C 150 from Type I to Type V depending on the purpose and use in the building and construction industry.

Ordinary Portland Cement (OPC)

This is produced by an automated, dry manufacturing process under strict quality assurance at all stages. It comes in a range of specifications to suit a number of conditions and applications such as dry lean mixes, general purpose ready mixes, high strength pre-cast and pre-stressed concrete (Ashok et al., 2016).

Portland cement clinker is typically made by heating a mixture of limestone and clay to a temperature of about 1400^0C to 1600^0C. The main compounds in the clinker are Cao, SiO2, Al2O3 and Fe2O3, which account for 61-67%, 19-23%, 2.5-6% and 0-06% of the mass of the clinker respectively (Aslantas, 2010). The available grades in Uganda are OPC-42 Grade and OPC-52 Grade.

Portland Pozzolana Cement (PPC)

PPC id produced by using pozzolanic materials as one of the main ingredients. The percentage of pozzolanic material used in the preparation should not exceed 30% of the total OPC (Kim 2010). There is reduction in the cement strength with exceeded percentage. PPC is gains higher compressive strength with age, highly resistant to Sulphur attacks, better workability during concrete production, low heat generation during the setting and gains high tensile strength.

Cement consist of types that are primarily classified according to ASTM C 150 into five classes;

I. Type I cement is general purpose cement suitable for all uses not requiring the special properties of other types. It is commonly used for pavements, floors, reinforced concrete buildings, bridges, tanks, reservoirs, pipe, masonry units and precast concrete products, thus more economical than type II cement. 7

II. Type II cement is used where relatively low heat generation is desired or where moderate sulfate attack may occur. The C3A content increase of early heat is comparatively lower than that of other cement types.

III. Type III cement provides more rapid development of strength at an early age after contact with water because of its higher surface area and increased C35 content. It is mostly used when high strength is desirable

IV. Type IV cement is needed where heat generation from hydration should be minimized such as in mass concrete structures. It generates less heat at a slower rate than the other cement types since its C25 content is higher and C35 content increased. As a result, this type has greater resistance to sulfate attack than for type I or type II, with less rapid strength development having equal strength at advanced ages.

V. Type V cement is used where high sulfate resistance is desired say in foundation and marine structures. The C3A content of the cement is limited to less than 5% in the specification when a sulfate expansion test is not available.

2.1.1.2.2 AGGREGATE

Aggregates make up 70% of the concrete volume, hence the main constituent materials in concrete production according to Gnanavel 2014. Aggregates are mostly derived from crushed solid rock or weathered rock, resulting to broad category of grains, classified by particle size and consistency in construction. Coarse aggregates have particle size larger than 4.75mm (No. 4 sieve) while the fine particles have particle sizes smaller than 4.75mm but larger than 75mm (No. 200 sieve) (Newman, 2013). Aggregates exhibits properties which affect the performance of the concrete, since they form mortar grout and fill voids in concrete along with cement past.

2.1.1.2.3 WATER

Water plays a vital role in cement hydration where minerals in cement form chemical bonds with water molecules and makes the concrete workable (Kucche, 2015). Water greatly affects the workability of concrete which largely depends on the water/ratio; an increase in the sizes of aggregates, a reduction in water/cement ration and use of rounded aggregates will reduce the water demand, thus leading to a reduced slump. For strong and workable concrete, the water/cement ration should be balance, since too much water reduces concrete strength, while overly reduced water makes the concrete unworkable (Kosmatka, 2014).

2.1.2 BASALT ROCK POWDER

This is a fine-grained material that is obtained by crushing basalt rocks and is typically dark in color, ranging from black to dark gray, due to its high content of dark-colored minerals such as pyroxene and olivine. Basalt rock has been used in the construction industry for various applications but majorly as aggregates due to its availability, sustainability, durability and strength properties (Qiao, 2019). Basalt rock powder (BRP) has a large specific surface area and high $SiO2$ and $Al2O3$ contents thus when used as a supplementary cementitious material, it can have a positive impact on the mechanical properties. This is because basalt rock powder forms a gel on hydration, when Calcium Oxide from Cement reacts with $SiO2$, resulting into nucleation of the C-S-H and strengthening the bond between basalt and the matrix (Li, 2022).

Figure 1: Basalt rock powder

2.1.3 AREA OF APPLICATION

The BRP concrete will be largely utilized in construction of columns, pavements and sidewalks. This is because the study aims at producing a compressive structure with the ability resist compressive loads other than tensile Loads

2.2 EMPIRICAL LITERATURE REVIEW

2.2.1 BASALT ROCK POWDER

Basalt rock powder can be used as a supplementary material in concrete to improve its mechanical strength. A study investigated the feasibility of using BRP and Superfine sand as partial replacement for Portland cement and artificial sand in mortar. The results showed that the use of BRP and superfine sand as partial replacement materials for Portland cement and artificial sand respecting in cement mortar is feasible (Qiao, 2019). Another study investigated the effect of basalt powder on hydration, rheology and strength development of cement past. The results showed that the use of basalt powder can improve the strength development of cement paste (Li, 2022). Also, another study investigated the effect of Basalt Powder on the properties of Cement Composites. The results obtained show that the basaltic powder has a positive effect on the consistency of fresh cement composites and strength of the hardened composite (Unčík, 2013). Also, when carried out on Basalt powder as a supplementary cementitious material in cement past for CCS wells, due to basalt powder characteristics, the chemical resistance increased resistance for formulation of cement having low Basalt powder quantity as a result of porosity and permeability reducing, due to the gaps getting filled in the network of porous cement (Ponzi, 2021). According to Dobiszewska M (2018), the addition of waste basalt powder as a replacement of sand in concrete improves its compressive and flexural strength due to the filler effect, and also results in a denser and stronger interfacial transition zone microstructure. Also, according to the microstructural analysis, the presence of basalt powder in concrete mixes is beneficial for cement hydration products and basalt powder substituted concretes have lower porosity within the interfacial transitional zone (Dobiszewska, 2020).

2.3 RESEARCH GAP

Several researches have been carried out on basalt rock powder as a partial replacement of cement in cement mortar and partial replacement of sand in concrete and lots of evidence have been provided for the improvements in strength. However, the research on determining the optimum percentage of basalt rock powder with known fineness for partial replacement of cement in conventional concrete is lacking and this is what our research is focusing to archive.

CHAPTER THREE: METHODOLOGY

3.0 INTRODUCTION

This chapter contains the descriptions of materials used in the experimentations during the study. The chapter gives explanations of various tests performed to achieve our set of objectives such as the sieve analysis test (particle size distribution, aggregate crushing value, aggregate impact value (AIV), water absorption, flakiness index, specific gravity, compressive strength test, abrasion test, porosity and permeability test. All in all, this chapter gives details on;

a) The materials acquired from various locations; Sand, cement, coarse aggregates and basalt rock powder.
b) Properties of concrete ingredients and basalt rock powder; sieve analysis of both fine and coarse aggregates, flakiness index, specific gravity, water absorption, aggregate impact value, aggregate crushing value, silt content.
c) The mix design proportions, slump test, casting of cubes and curing of the cubes
d) Properties of optimized BRP concrete; compressive strength, porosity and permeability.

3.1 MATERIAL ACQUISITION

The following materials were acquired from various locations; Sand, cement, coarse aggregates and basalt rock powder;

3.1.1 NATURAL COARSE AGGREGATE, FINE AGGREGATE (SAND)

The coarse aggregates, fine aggregates (fine sand) were given freely by a team of technicians at China lab which reduced on the hustle for materials. A number of tests were conducted on these materials like sieve analysis test, ACV, AIV, specific gravity, abrasion value test, flakiness etc.

3.1.2 CEMENT

The type of cement used in this study was Portland Tororo cement (Portland Pozzolana Cement) as it conforms to the KS EAS 18-1 cement standards as adopted from the EN-197 specification that is equivalent to the Uganda specification US EAS 18-1. Cement as a material act as a binding agent when it’s mixed with water, since a chemical reaction takes during the hardening process of cement while binding together with aggregates.

3.1.3 WATER

National water and sewage cooperation was the provider for our water source. It is important to note that water as material influences workability and strength of concrete greatly and this depends on the quantity used during mix of fresh concrete.

3.1.4 BASALT ROCK POWDER

The basalt rock powder was obtained by crushing basalt rocks at Mugarama Stone Quarry in Kibaale District with a geo crusher and then pounded to the smallest particle size of 5mm and below, that were sieved for various tests and experiments such as; sieve analysis tests, specific gravity, x-ray fluorescence etc.

3.2 PROPERTIES OF CONCRETE MATERIALS TO BE USED IN THE BASALT ROCK POWDER CONCRETE (BRP CONCRETE)

3.2.1 SIEVE ANALYSIS

This method is used for the determination of the particle size distribution of the materials and the test will be carried out to determine the physical property of course and fine aggregates (sand). The result will help in the understanding of aggregates distribution with size so as to conform to standard of design and control requirements and specifications. The following steps are taken to determine the particle size distribution of aggregates

1. Sample to be tested are dried to a constant weight at a temperature of 110+5^{0}C and weighed
2. The samples are then sieved through sieves of different sizes in accordance with BS EN 1629 or IS sieves. After sieving, the material on each sieve is weighed
3. Cumulative weight passing through each sieve is calculated as a percentage of total sample weight
4. Fineness modulus is obtained by adding cumulative percentage of aggregates retained on each sieve and diving the sum by 100
5. A graph of cumulative percentage passing against sieve sizes is plotted on a semi-log graph with particle size as abscissa (log scale) and the aggregates are classified using unified classification system.

3.2.2 FLAKINESS INDEX (FI) – BS 812: SECTION 105.1 1990

Flakiness index is one of the tests used to classify aggregates and stones. Aggregates are classified as flaky when they have a thickness of less than 60% of their mean sieve size. Flaky particles are separated from the mass of aggregates retained on FI sieves expressed as a percentage. Thus, FI is the mass of aggregates in percentage with minimum dimension less than 0.6 times its mean dimension. The test only applies to material that are passing 63 mm sieve and is retained on a 6.30 mm BS test sieve.

3.2.3 WATER ABSORPTION

The water absorption test was carried out to determine the maximum amount of water the coarse aggregates can absorb as per BS: 812: 1975. This test gives an idea on the strength of coarse aggregates and their internal structure. From analysis of results, it's easier whether your aggregates are more porous or less porous in nature.

3.2.4 SPECIFIC GRAVITY/RELATIVE DENSITY

The specific gravity test is performed to measure the quality or strength of coarse aggregates to be used in construction. It is observed at the end of this test that aggregates with low specific gravity are known to be weak material compared to aggregates with higher specific gravity.

While carrying out these tests, a sample not less than 2kg is used and the apparatus include perforated wire basket, plastic coated with wire hangers for suspending it from the balance, dry soft absorbent cloth, water-tight container for suspending the basket, shallow tray of minimum 650 sq.cm area, air-tight container of a capacity similar to the basket and an oven are used in the process.

Both water absorption test and specific gravity test are considered to be a measure of strength of the material. Specific gravity is the ratio of the weight of a given volume of aggregate to the weight of an equal volume of water. It is the measure of strength or quality of the specific material. The apparent specific gravity of the commonly used rocks ranges from 2.6 to 2.7 as per standards BS: 812: 197

3.2.5 AGGREGATE CRUSHING VALUE (ACV)

ACV test is conducted to understand how coarse aggregates resist gradually applied compressive load up to crushing point (A measure of resistance). For weak aggregates, the integrity of the structure is likely to be adversely affected. The ACV is determined by measuring the material passing a specified sieve after crushing under a load of 400kN. The test can be applied to a standard fraction aggregate passing a 14mm sieve and retained on a 10mm sieve. Note that the method is not suitable for testing aggregates with an ACV higher than 30. In such cases the method for Ten percent fines value (TFV) is applicable, as per CML Test no. 2.7

3.2.6 AGGREGATE IMPACT VALUE (AIV)

The AIV test is performed to assess the mechanical degradation of coarse aggregates by subjecting them to a known load and their resistance determined. The test is a measure of toughness of coarse aggregates to resist their disintegration on due to impact as per BS 812: Part 112: 1990. A 28 cylindrical measure and plunger, compression testing machine and test sieves of sizes 14mm and 10mm were used to determine the AIV of the aggregates.

3.3 PHYSICAL AND CHEMICAL PROPERTIES OF BASALT ROCK POWDER

3.3.1 SIEVE ANALYSIS – BS EN 933-1:1997

Sieve analysis is the method of determining the particle size distribution of the materials. This test will be carried out to determine the physical property of stone dust. This test was carried out to know particles distribution with size so as to conform to design standards and control requirements.

3.3.2 RELATIVE DENSITY AND WATER ABSORPTION

The relative density test is carried out to measure the quality or strength of basalt rock powder to be used in the construction while the maximum amount of water that the basalt rock powder absorbs was determined by carrying out the water absorption test as per BS: 812: 1975. To get the idea on strength of basalt rock powder and the internal structure, the water absorption test is key.

3.3.3 BULK DENSITY

During the determination of the mass or weight of the basalt rock powder that is required to fill a specific unit volume of concrete, the bulk density test is used. The higher the bulk density, the higher the volume of basalt rock powder that the concrete mix will occupy

3.3.3 X-RAY FLOURESCENCE (XRF)

This is a technique that analytically determines the composition of elements of several materials like rocks, sediments and fluids. In X-ray fluorescence, the emitted X-rays are detected and analyzed to determine the elemental composition.

Sample Preparation

Basalt rock powder (BRP) is typically prepared by two common forms; compressed powder pellets where the powdered sample is compressed into pellet using a hydraulic press and Fused Glass Discs where the sample is mixed with a flux usually Lithium compound and heated to form a glass disc. These sample forms ensure uniformity and facilitate X-ray penetration.

The XRF spectrometer consists of X-ray tube, sample holder, X-ray detector and spectrometer which is calibrated using known standard samples. After detection, analysis, quantification and calibration, the software analyses the XRF data and provides elemental concentrations with major elements; Na Mg, Al, Si, Ca etc.

3.4 CONCRETE MIX DESIGN FOR M25

There is various mix design but for our project the M25 is the most favorable since the concrete in our study has a pozzolana material. With reference to various literature studied, this research has been able to develop the mix design. So, several trial mixes were carried out based on literature, so as to get the final mix to be used to get the results presented in the report

Test: Compressive Strength

During compressive strength test, numerous cubes were to be used for triplicates per replacement with basalt rock powder. Three cubes were casted for each set of replacement, therefore using the standard for experiment referred to as "triplicates" for the compressive strength test which had two sets of days i.e. 7 and 28 curing days. There was casting of control experiment and the following percentages; 0%, 10%, 15%, 20%, 25% and 30%. As a result, the cubes casted were 36 in total.

3.5 DETERMINING PROPERTIES OF THE OPTIMIZED CONCRETE MIX WITH BASALT ROCK POWDER

3.5.1 FRESH CONCRETE SLUMP TEST

This slump test was carried out to evaluate the flow characteristics of freshly mixed concrete containing basalt rock powder and the other normal concrete ingredients and it will be carried out in accordance with BS 1881: Part 102: 1983. The slump test was performed by concrete placing in a cone of inverted shape at three levels, and then the concrete tamped down up to when it's full using a metal tamping rod. Using the handles on both sides, lifting of the cone off working surface is performed carefully. Measuring of the height between the slumped height of fresh concrete and slump cone original height. Normally, the desired slumps for fresh concrete should range between 4 to 5 inches to obtain an ideal balance between workability and consistency

Preparation of test cubes from fresh concrete

This process involves the making of concrete cubes for testing of compressive strength, porosity and permeability where 3 concrete cubes shall be casted for each trial mix and then place for 7 and 28 curing days.

Procedure

A thin layer of oil is applied on the inside faces of cube mold plates, after carrying out the slump test of already mixed fresh concrete. Then a sample of fresh concrete is put into the mold in three layer and after every layer a tapping rod is used to compact the concrete in order to remove voids.

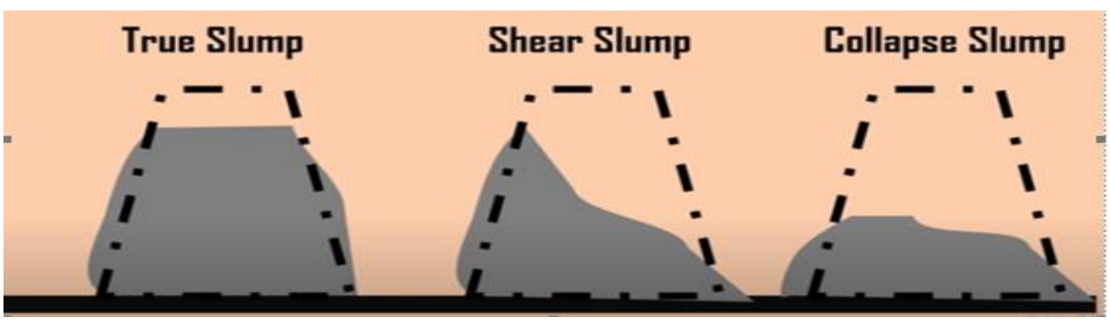


Figure 2: Types of Slumps
(Image source: civiltoday.com)

3.5.2 HARDENED CONCRETE COMPRESSIVE STRENGTH TEST

The term compressive strength defines the ability of material or structure to carry the loads on its surface without any crack or deflection. The test is carried out in accordance with BS 1881 part 116: 1983 and it will be performed on cubes of hardened concrete containing basalt rock powder after curing of 7 days and 28days

Procedure for performing compressive strength test on concrete cubes

Fresh concrete is poured in the mold of 15x15x15cm (150x150mx150) in three layers and after every layer it is compacted using tamping rod properly to remove voids. After it is left for 24 hours and then the molds are removed and cubes placed in water for curing of 7 and 28 days. After the set of curing days, the cubes are tested by compression machine where load is applied gradually at the rate of 140kg/cm2 per minute till the specimen fails, then the compressive strength computed by dividing the applied Load with cross-sectional area of the cube.

Table 1: The material cost for the cube that is replaced 15% of Cement with BRP in the concrete mix

Material	Unit	Quantity (Kgs)	Rate (Ugshs)	Total cost (Ugshs)
Sand	Kgs	675	55	37125
Coarse aggregate	Kgs	1007	55	55385
Cement	Kgs	430	700	301000
Water	Ltrs	206	3.5	721
BRP	Kgs	64.5	35	2258
Total		2318		396489

CHAPTER FOUR: RESULTS AND DISCUSSION

4.0 INTRODUCTION

This chapter shows the results obtained from the various tests conducted on the materials used in the concrete mix and explained using tables and graphs.

4.1 DETERMINATION OF PHYSICAL PROPERTIES OF CONCRETE AGGREGATES

4.1.1 SIEVE ANALYLSIS TEST ON AGGREGATES

This test also known as gradation test, is very essential as it helps technicians in the quality control of aggregate samples. This is used in determining the distribution of aggregate particles by size in order to comply with the design, production control requirements and verification specifications. This test ensures the separation of fine particles with the coarse ones during test process using various sieves sizes for the sample material. As a result the retained mass of a material on every sieve size is used for fineness modulus determination.

Table 2: Sieve analysis results of coarse aggregates

Sieve size Standard	Partial Retained	Cumulative Retained	Cumulative Retained %age	Passing	Governing Specification Passing (BS 882:1992 Table 3)	
mm	g	G	%	%	Lower Limit	Upper Limit
37.5	0.0	0	0.0	100.0	**100**	**100**

20.0	11.0	11	0.2	99.8	**90**	**100**
14.0	963.0	974	21.6	78.4	**40**	**80**
10.0	1494.0	2468	54.8	45.2	**30**	**60**
5.0	1884.0	4352	96.7	3.3	**0**	**10**
2.36	104.0	4456	99.0	1.0		

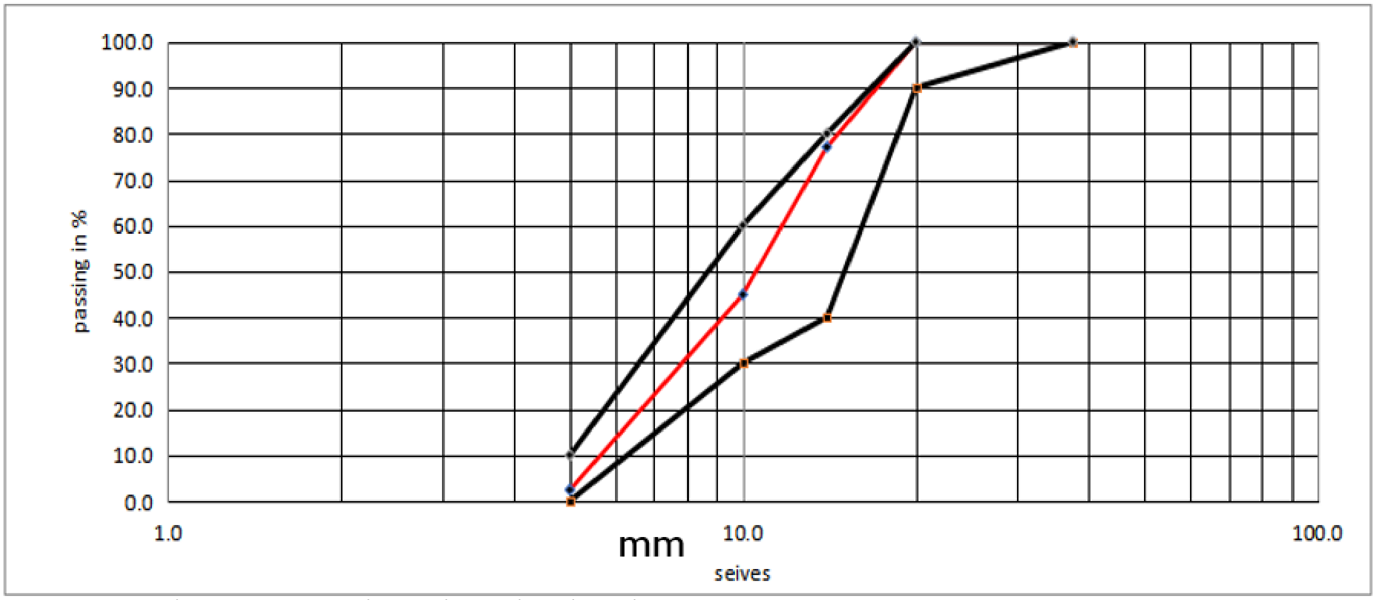


Figure 3: Particle size distribution chart for coarse aggregates

From the above graphs, each of the sieve sizes fall shows a percentage passing within the envelopes according to BS 812:1992 Table 3 and thus suitable for use in concrete. Aggregate size affect much on the properties of hardened concrete and fresh concrete a major component of the mix design.

Table 3: Sieve analysis results for fine aggregates (Sand)

	Sand 5 mm	Mass after washing on 0.075mm sieve(g)	961.6

Sieve size:(mm)	Lower limit	Upper limit	Wt. Retained on size	Cumulative mass Retained on size	Cumulative percentage retained on size	Percentage Passing
14.0	—	—	0	0	0.0%	100.0%
10.0	100%	100%	0.0	0.0	0.0%	100.0%
5.0	89%	100%	1.2	1.2	0.1%	99.9%
2.36	60%	100%	8.0	9.2	0.9%	99.1%
1.18	30%	100%	95.6	104.8	10.4%	89.6%
0.60	15%	100%	381.4	486.2	48.4%	51.6%
0.30	5%	70%	345.0	831.2	82.8%	17.2%
0.15	0%	15%	76.2	907.4	90.4%	9.6%

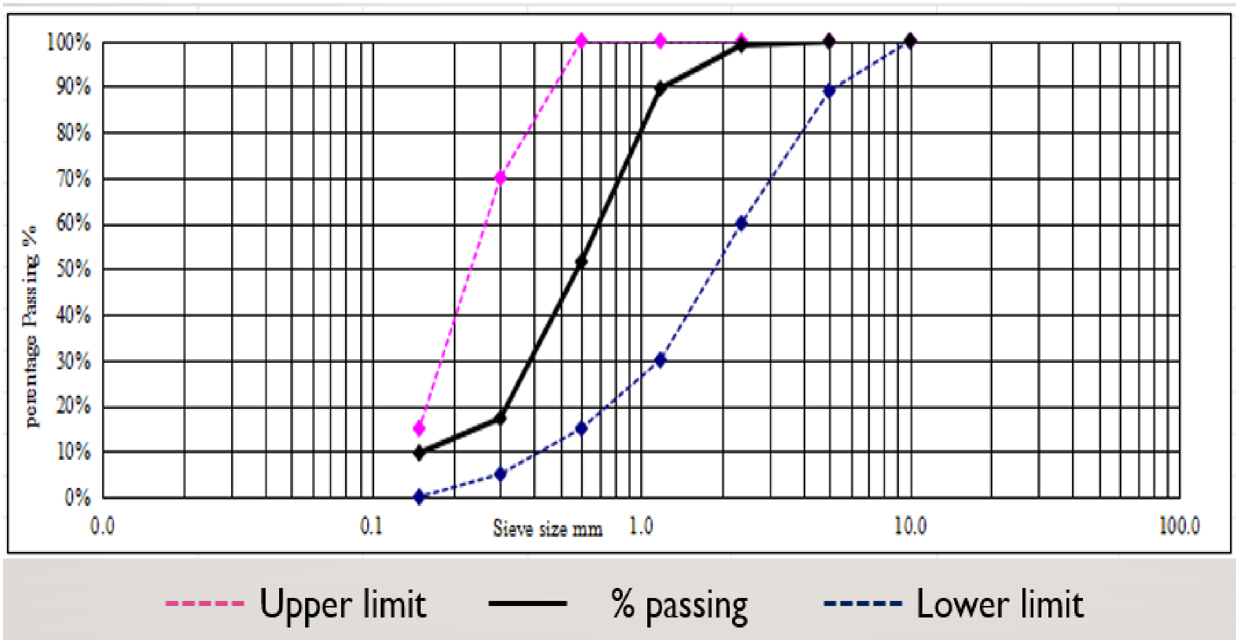


Figure 4: Particle size distribution chart for fine aggregates

A well graded aggregate with a narrower particle size distribution. The fineness modulus also gives lower value of 2.3 hence finer sand. The visualized date in the grading curve indicates fine aggregates being within the standard for use in the concrete mix.

4.1.2 FINENESS MODULUS

This is a numerical index of fineness that gives idea of the mean size of the particles in the aggregates and used as a method of standardization of the grading of the aggregates. It can therefore be used as the measure of workability of sand according to ASTM (ASTM C33 1954). Fineness modulus can be computed as 600 minus total sums of cumulative percentages retained on sieve and then divided by 100. The fineness modulus is also used in mix design since the gradation of fine aggregates determines the density and permeability of the concrete, high fineness modulus implies low density and low permeability of concrete. Thus a fineness modulus of **2.3** is fine aggregate suitable for concrete matrix used good strength and durability.

4.1.3 FLAKINESS INDEX (FI)

This is the percentage by weight of particles whose average least dimension is less than three-fifths (0.6 times) of their mean dimension, thus the particle is considered as flaky if its thickness is less than o.6 times the mean sieve size of the fraction. Flaky particles have a large surface area relative to its small volume, hence it decreases the workability of concrete mix. The flaky particles can affect the durability of concrete as they tend to be oriented in one plane, with water and voids forming underneath.

Table 4: Flakiness index value

Sum of Mass retained	g	3302.2
Sum of Corrected Mass passing slots	g	516.2
Flakiness Index FI = (M_3/M_2)*100	%	**15.6**

A flakiness index value of 15.6% a good unflaky sample of aggregates as these particles affect the durability of concrete. The value is within the acceptable range for many concrete applications and suitable to improve concrete performance and mix design optimization.

4.2 AGGREGATE CRUSHING VALUE (ACV) TEST ON COARSE AGGREGATES

This is the percentage by weight of crushed material obtained when test aggregates are subjected to a specified load under standardized conditions. Aggregate crushing value test on coarse aggregates gives a relative measure of the resistance of an aggregate crushing under gradually applied compressive load. According to BS 8122 PART 110, ACV gives the relative measure of crushing under an increasing compressive load. The method is applicable to aggregates passing a 14.0 mm test sieve and retained on a 10.0 mm test sieve.

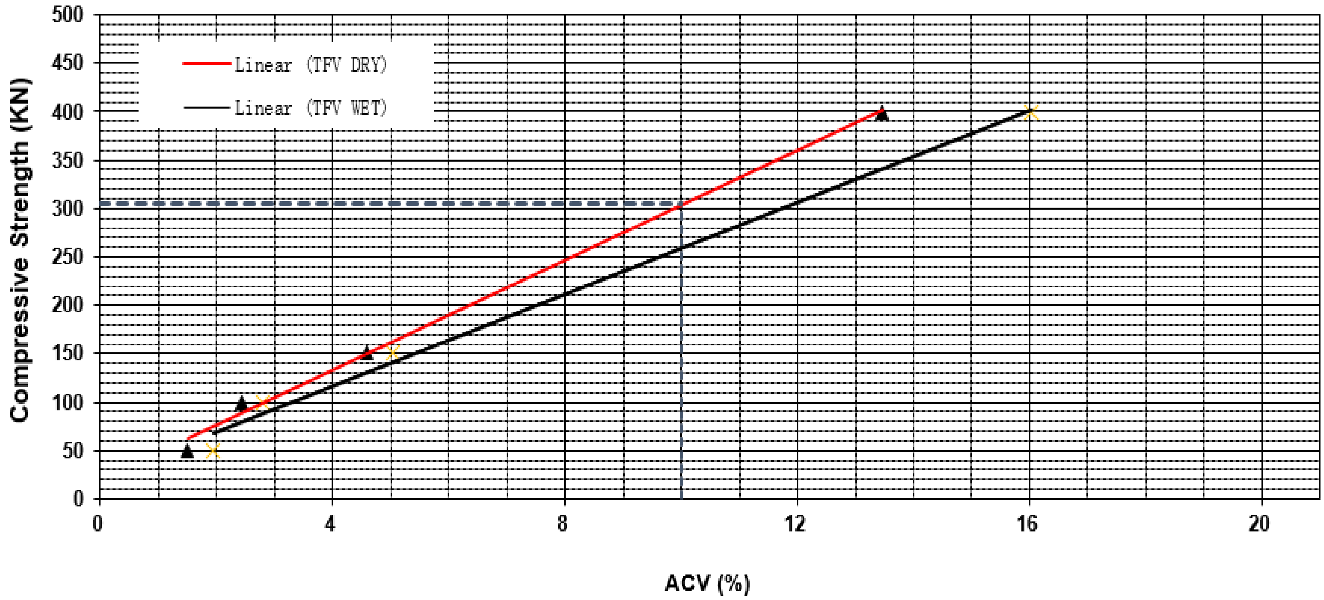


Figure 5: Graph for ACV

The graph gives an ACV of 13.5% against the maximum value 25, indicating a good aggregate strength hence less disintegration against pressure. Lower ACV implies the aggregates are stronger, which indicates that the aggregates are more durable with longer service life thus very valuable performance. The crushing value should not exceed 25% for construction as per standard BS 812 PART 110: 1990. If the ACV is 25 or more, the result may be anomalous and thus the ten percent fines value should be determined instead.

4.3 AGGREGATE IMPACT VALUE (AIV) TEST ON COARSE AGGREGATES

The ACV test is used to determine the aggregate impact value which gives a relative measure of the resistance of an aggregate of sudden shock or impact, which in some aggregates differ from their resistance to a slowly applied compressive load. The AIV is obtained by calculating the percentage loss of weight particles passing 2.36 mm sieve by the application of load by means of 15 blows of standard hammer and drop under specified condition.

Table 5: AIV mean value calculations for coarse aggregates

Number of blows	n	15	15
Mass of tray + test specimen (g)		1292.4	1304.2
Mass of tray alone (g)		964	964
Mass of original test specimen (g)	M_1	328.4	340.2
Mass of material passing 2.36mm sieve (g)	M_2	53.2	56.8
Mass of material retained on 2.36mm sieve (g)	M_3	275.2	283.4
Aggregate Impact Value (in %) - Dry		16.2	16.7
Aggregate Impact Value (in %) - Soaked	$m = \frac{M_2}{M_1} x100$	16.1998	16.6961
AIV - mean value (%)		16.4	

As per BS 812 PART 110: 1990 and the above specifications, the AIV for concrete in non-wearing areas is to be less than 45% by weight and 25% in wearing areas say runaways. From the results above of coarse aggregates, a mean value of **16.4 %** was obtained and thus the coarse aggregates are suitable for use in concrete.

4.1 LOS ANGELES ABRASION VALUE (LAAV) TEST ON COARSE AGGREGATES

Table 6: LAAV calculations for coarse aggregates

Sample Description	**Concrete Agg(5-20)mm**				
Grading Used	**Grading B**				
Specimen reference		1	2	Average	
Mass of tray + test specimen (g)		5266.9	5269.1		
Mass of tray alone (g)		257.1	257.1		
Mass of original test specimen (g)	M_1	5009.8	5012.0		
Mass of material retained on 1.7mm sieve (g)	M_2	4032.5	4023.5		
Mass of material passing 1.7mm sieve (g)	M_1-M_2	977.3	988.5		
LAA Value (%)	$\frac{M_1 - M_2}{M_1} x100$	19.5	19.7	19.6	

LAAV of 19.6% suggests a strong resistance to abrasion. The LAAV represents the percentage of material lost by weight during the abrasion test. A higher LAAV indicates a greater abrasion of the aggregate and by extension, potentially reduced durability of the concrete. If the LAAV exceeds allowable limits, adjustments can be made in the aggregate selection or mix design to improve resistance

4.2 RELATIVE DENSITY AND WATER ABSORPTION FOR COARSE AGGREGATES

Table 7: The calculated relative density and water absorption values

Particle density on an oven-dry basis	Mg/m^3	2.637	2.642	2.640
Particle density on a saturated and surface-dry basis	Mg/m^3	2.647	2.651	2.649
Apparent Particle density	Mg/m^3	2.665	2.665	**2.665**
Water Absorption		0.4	0.3	**0.36**

Water absorption test is to determine the amount of water absorbed by aggregate using the specified conditions. According to the test carried out, little quantity of water is absorbed by the coarse aggregates as shown in results that **is 0.36%** thus meaning water absorption consideration can be neglected in the mix design, as per BS 882: Part 2 1995, the standard water absorption should less than 2%

Relative density test is carried out as a measure of quality for coarse aggregates and it is also denotes a measure of the specific gravity of the aggregates

The apparent specific gravity of the commonly used rocks ranges from 2.6 to 2.7 as per standards BS 882: 1992. According to the results obtained as shown in appendix apparent specific gravity of the coarse aggregates used was **2.665** coarse aggregates thus the aggregates are suitable for use in concrete since they are in recommended range as per standard.

Table 8: Summary of coarse and fine aggregates classification results

TEST	Units	Results	Concrete works
Aggregate impact value (AIV)	%	16.47	25 Maximum
Aggregate Crushing Value (ACV)	%	13.5	25 Maximum
Los Angeles Abrasion Value (LAAV)	%	19.6	50 Maximum
Fineness Modulus	-	2.30	Fine Sand
10% Fines Value (Dry)	kN	305.0	110 Minimum
Flakiness Index	%	15.6	</= 35
Specific Gravity	-	2.665	-
Water Absorption	%	0.4/0.69	2 Maximum

4.3 DETERMINATION OF THE PHYSICAL PROPERTIES OF BASALT ROCK

4.3.1 PARTICLE SIZE DISTRIBUTION TEST ON AGGREGATES

Table 9: Sieve Analysis results for Basalt Rock Powder

Sieve size (mm)	Partial Retained (g)	Cumulative Retained (g)	Cumulative Retained %age (%)	Passing (%)
5.00	0.0	0.0	0.0	100.00
2.36	0.2	0.2	0.0	99.96
1.18	0.2	0.4	0.1	99.92
0.60	2.5	2.9	0.6	99.44
0.30	65.2	68.1	13.1	86.88
0.15	97.2	165.3	31.8	68.16
0.075	183.3	348.6	67.2	32.85

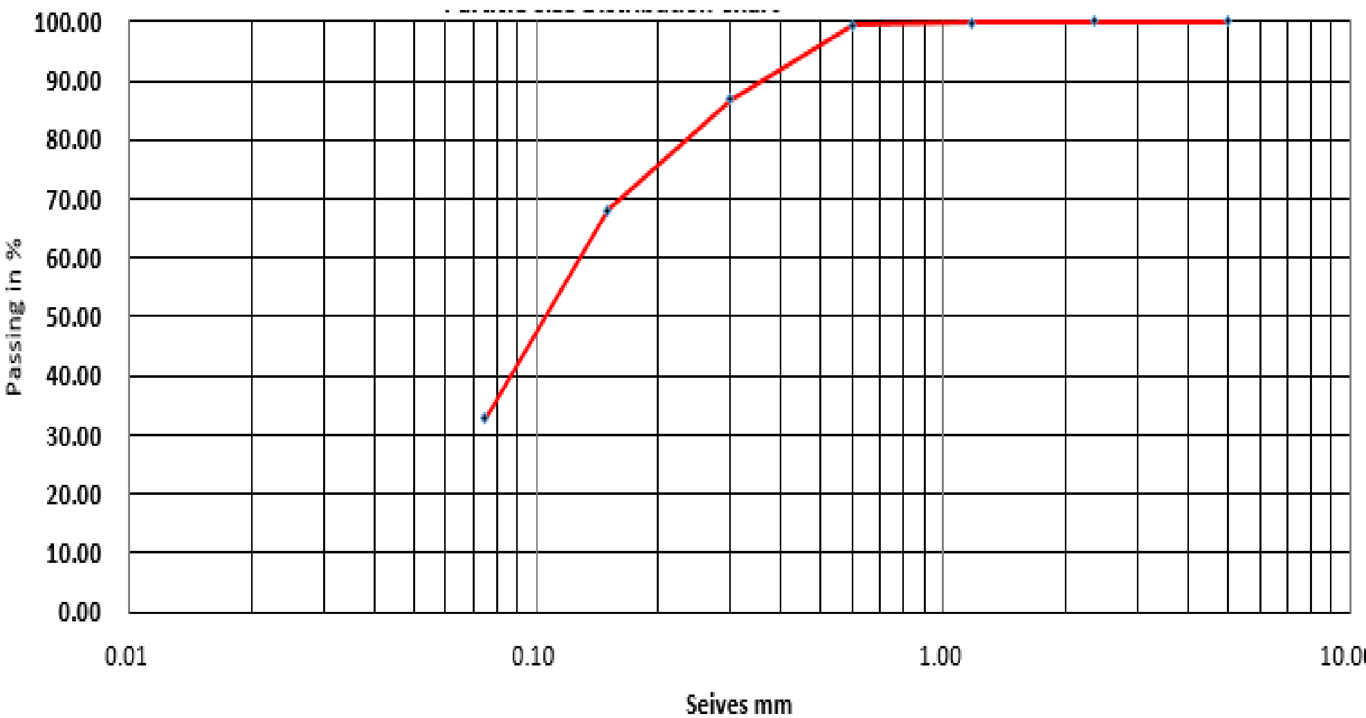


Figure 6: BRP particle size distribution chart

The powder is composed of both fine particles and coarse particles compared to the fine aggregates. About 32.8% passes through the 0.075mm sieve, the percentages to be used in casting concrete cubes so as to have finer powder reacting with other concrete ingredients. The sieve analysis test was conducted for BRP with maximum particle size of 5mm and grading curve indicates that 32.85% passed through the 0.075mm, the target particle size. However, since the powder (BRP) exhibited relatively uniform particle characteristics throughout its composition, the additional insights gained from a hydrometer test will not substantially alter the conclusion drown from the sieve analysis results (Mir, 2021).

4.3.2 PARTICLE DENSITY AND WATER ABSORPTION FOR BASALT ROCK POWDER

Table 10: The calculated particle density and water absorption results

Mass of oven-dry aggregate in air	g	521.7	526.8	
Particle density on an oven-dry basis	Mg/m^3	2.733	2.770	2.751
Particle density on a saturated and surface-dry basis	Mg/m^3	2.839	2.875	2.857
Apparent Particle density	Mg/m^3	3.056	3.095	**3.076**
Water Absorption	%	3.9	3.8	**3.8**

The apparent particle density which relates to the relative density (specific gravity) is 3.0376mg/m3 indicating that the mass of BRP particles per unit volume, taking into account any void spaces within the particles. The Water absorption of 3.8% indicates the absorption capacity of BRP weight in the water when fully saturated. Since BRP moderately absorbs water, the total water content of the mixture shall be adjusted to compensate, and this is vital in achieving desired workability, strength and durability of concrete with calculated W/C ratio in accordance to BS 812: Part 2: 1995

4.4 DETEMINATION OF THE CHEMICAL COMPOSITION OF BRP

4.4.1 X-RAY FLOURESCENCE TEST

Table 11: Results for Chemical composition of Basalt Rock Powder

	SiO2	Fe2O3	CaO	Al2O3	MgO	K20	NaO	P2O5	TiO2	Eu2O3	Cl
Content (%/m/m)	42.16	14.88	12.16	10.68	7.66	5.44	2.91	1.02	0.83	0.19	0.07

The X-ray fluorescence indicates that in chemical composition, the, SiO2, Fe2O3, CaO and Al2O3 are most dominant. These chemical compositions in concrete, influence strength, durability, setting time, color effects and also indicates the presence of mineral compositions of plagioclase, pyroxene and olivine (Ponzi, 2021). The powder is from a mafic rock, resulting to Pozzolanic reaction during concrete mix.

4.5 STIPULATIONS FOR PROPORTIONING

(a) Concrete Strength/Cylindrical/ (Mpa) = 21.3 *Cylindrical Strength, 150 x 300mm*

Cube = Cylinder/0.85= 25.1

(b) Type of Cement = PPC *PPC 32.5 N/mm2, Portland Cem II*

(c) Maximum Nominal Size of Aggregate = 19 mm *as per ACI standards*

(d) Minimum Cement Content = 320 kg/m3 *for 20mm Nominal size as per ACI 302*

(e) Max. Water-Cement ratio = 0.50 *from ACI 211.1-91, Table A1.5.3.4 (b) for Severe conditions*

(f) Exposure conditions = Severe

(g) Workability, Slump (mm) = 100 mm *from ACI 211.1,1991, Table A1.5.3.3*

(h) Method of Concrete Placing = Chute *Non-Pumpable*

(i) Placing & Mixing Condition = Good *from ACI 318-19*

(j) Type of Coarse Aggregate = Crushed *Angular Aggregate*

(k) Maximum Cement Content = 500 kg/m3 *as per Uganda General Specification, Section 6404 (a)*

(l) Fine Aggregate Type = Natural Sand

Laboratory Trial Batch	**For 1m3**	**for 0.2025m3 (6 cubes)**
1. Cement	= 430 kg	= 8.708 kg
2. Water	= 206 kg	= 4.169 kg
3. Fine Aggregate FA	= 675 kg	= 13.679 kg
4. Coarse aggregate CA	= 1007 kg	= 20.401 kg
5. Total in the mix	= 2319 kg	= 47.0 kg

Average **W/C ratio** **= 0.48 (Approximately 0.50)**

4.6 OPTIMAL PERCENTAGE REPLACEMENT OF PHYSICAL AND MECHANICAL PROPERTIES OF CONCRETE INCORPORATED WITH BASALT ROCK POWDER AND CEMENT

4.6.1 SLUMP TEST

This test is carried out to determine the workability accordance to BS 1881: 1983 British Standards so as to ascertain the workability of fresh concrete for each mix in the research. The test is a measure of the consistency of the fresh concrete and how easily the concrete can be cast and compacted to form the required shape without any segregation

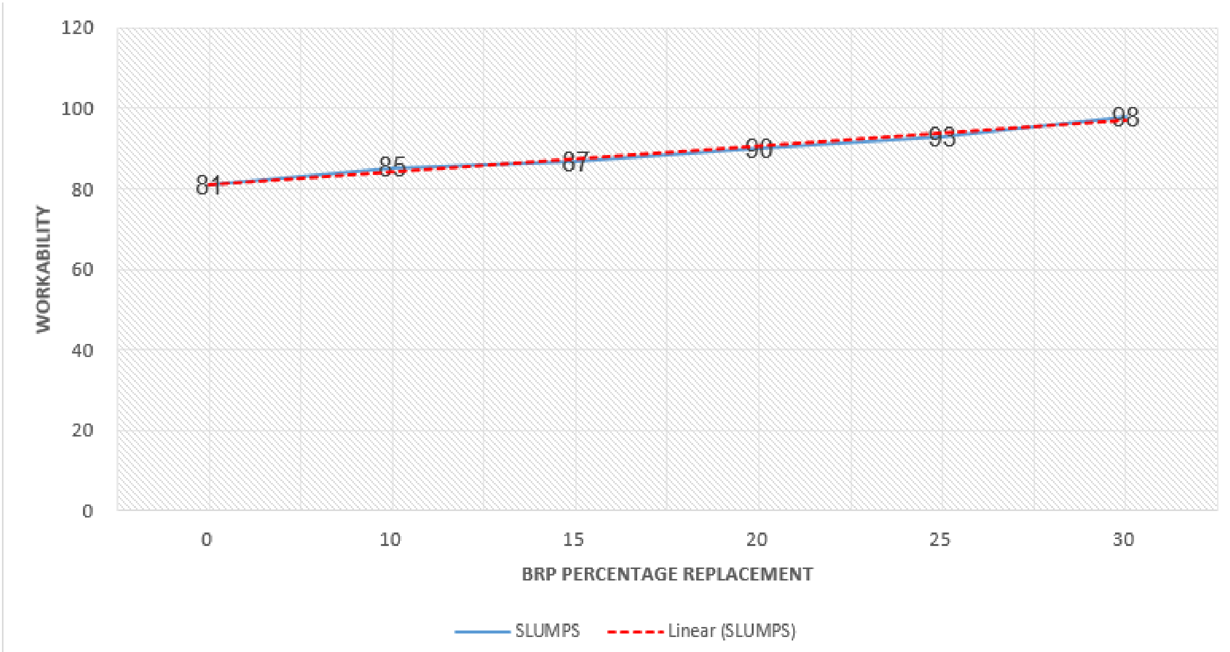


Figure 7: A graph for workability of BRP concrete

From the graph above, it can be noticed that the slump increases with increase in BRP content in the concrete mix. As the percentage of BRP increases from 0% to 30%, the slump values also show a general increasing trend. A slump value of 81mm for 0% BRP suggests a moderately stiff concrete mix, whereas higher slump values for BRP incorporated mixes indicated improved workability.

This increase in slump indicates that the addition of BRP enhances the workability of the concrete mixes, potentially due to the finer particle size and smoother surface texture of the BRP compared to cement particles according to Li, 2022

Standard Deviation

The standard deviation is the average amount of variability in your dataset, telling us on average how far each value lies from the mean. A high standard deviation means that values are generally far from the mean, while a low standard deviation indicates that the values are clustered close to the mean (Bhandari, 2021)

Sample, 81mm, 85mm, 87mm, 90mm, 93mm, 98mm for 0%, 10%, 15%, 20%, 25% and 30% BRP content by volume fraction respectively

$$Mean = \frac{81 + 85 + 87 + 90 + 93 + 98}{6}$$

$$Mean = 89mm$$

$$Variance$$

$$= \frac{(81-89)^2 + (85-89)^2 + (87-89)^2 + (90-89)^2 + (93-89)^2 + (98-89)^2}{6}$$

$$Variance = 30.33mm$$

$$Standard\ Deviation\ (SD) = \sqrt{Variance}$$

$$Standard\ Deviation = \sqrt{30.33} = 5.51mm$$

This gives an approximate deviation of 6 SD. This means that the average deviation of individual values form the mean slump value of 89 mm is approximately 7mm, providing a valuable information about the variability and precision of slump measurements in the study on BRP concrete. It helps to assess the reliability of the mean value and informs decisions related to mix design, construction practices and quality control in concrete production.

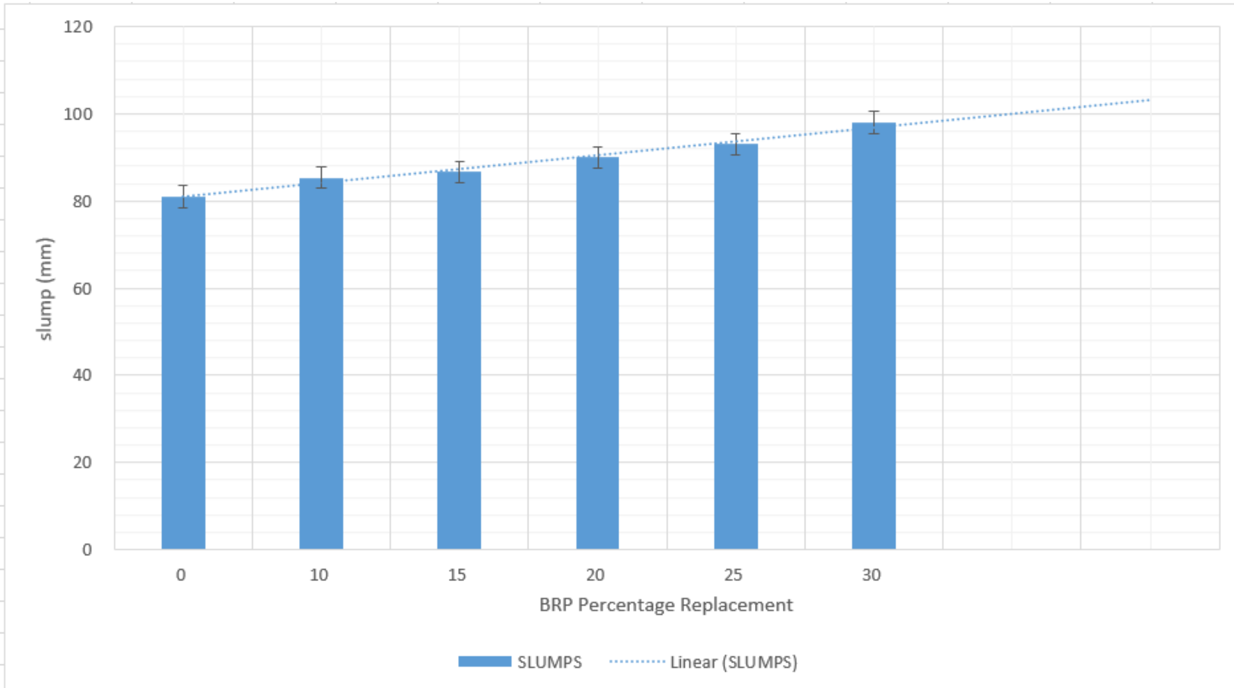


Figure 8: A graph for workability of BRP concrete showing the standard error bars and a linear forecast trend line

4.6.2 SETTING TIME

The setting time of concrete, including both initial and final setting times, is an important parameter that influences construction practices, such as formwork removal and finishing operations. The values for the setting times of BRP concrete at different percentages of BRP replacement offers insights into the effects of BRP on the setting characteristics of the concrete.

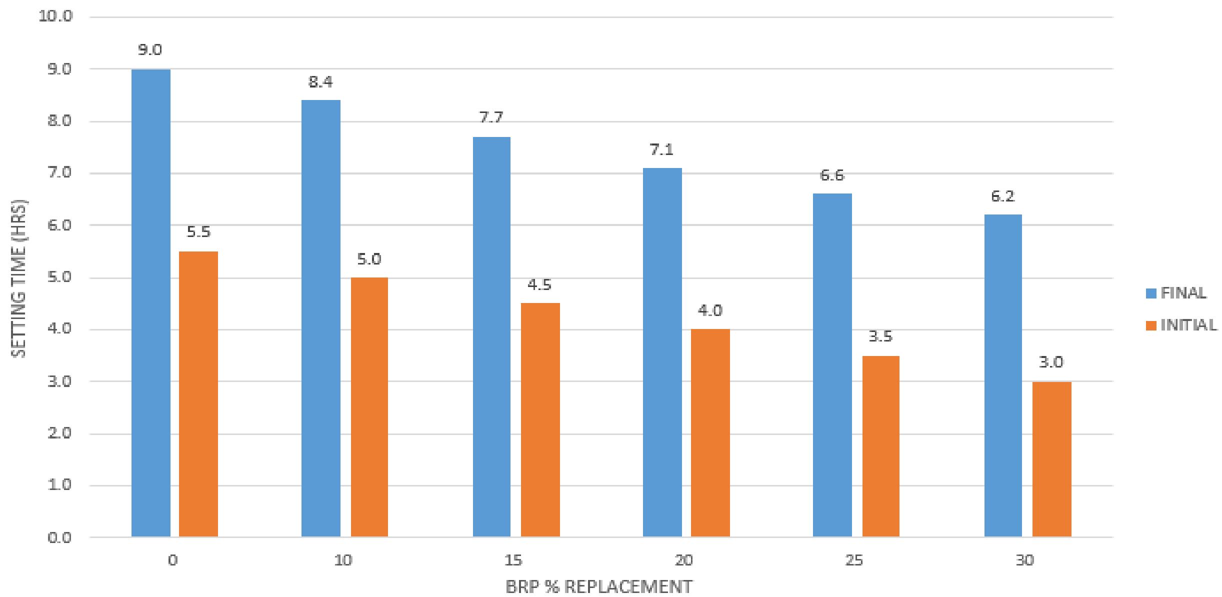


Figure 9: A graph for setting time of BRP concrete

From the graph the setting time gradually decrease with increase in BRP replacement percentages for both initial and final setting time

Initial setting time: This explains the time taken for the concrete to transition from a plastic to a rigid state, making it suitable for initial finishing and construction operations.

Final setting time: This is the point at which the concrete achieves sufficient rigidity to resist applied loads without deformation. Similar to the initial setting time, the final setting time also decreases as the percentage of BRP replacement increases. This trend indicates that BRP incorporation accelerates the rate of strength development and setting of the concrete mix, since increase in BRP content, results to increase in the amount of reactive minerals. The finer particle size and increase surface area of BRP enhance the pozzolanic reactions and accelerate the formation of hydration products, leading to earlier attainment of setting time (Mehta, 2016).

4.6.3 COMPRESSIVE STRENGTH TEST

This test was carried out to assess quality of concrete mix in terms of its strength, on about 36 cubes (150X150X150) mm dimension and the test was performed using a compression machine in accordance to BS EN 12390-3: 2002. This test was performed on concrete cubes which had cured for 7days and 28days and the obtained results have been attached in the appendix and below is a summary of the results presented in graphical form.

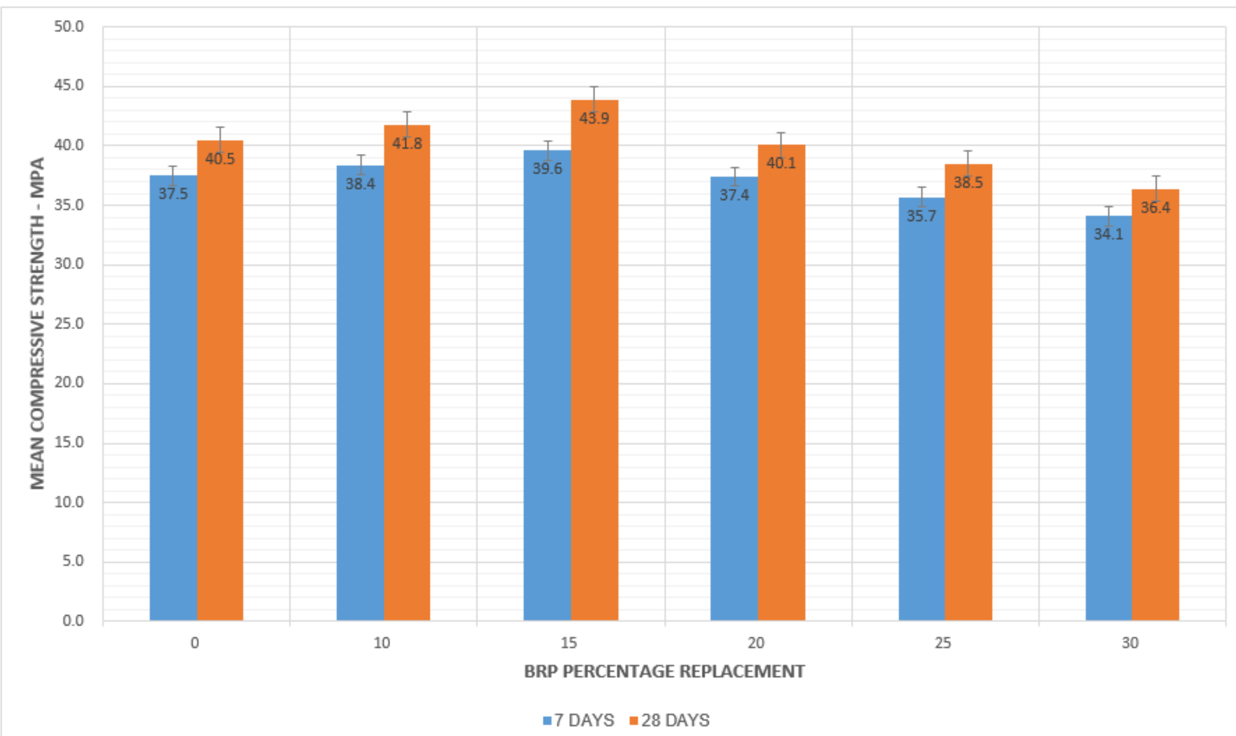


Figure 10: A graph for the mean compressive strength values of BRP concrete

From the graph above, it can be observed that there is a general increase in the compressive strength with increase in the BRP percentage replacement up to 15% BRP. This was then followed by a continuous decrease in compressive strength with increasing BRP percentage replacement up to 30%. It can be observed that there are variations in compressive strength values for the two sets of curing days i.e. 7 and 28 days, depending on the BRP percentage.

When 15% BRP is used, the compressive strength is highest at 39.6Mpa and 43.9Mpa, for 7 days and 28 days respectively, suggesting that the 15% BRP mixture achieved the highest ultimate strength, showing good strength development within the BRP concrete. This increase in the compressive strength specifically for the recommended 28 curing days, from 40.5MPa for control concrete to 43.9Mpa for BRP concrete, a positive difference of 3.4Mpa can be attributed to;

a) Pozzolanic activity of BRP as it contains reactive minerals that can react when mixed with calcium hydration forming a cement hydration as a byproduct with water. This results to the development of strength and durability as cementitious products are formed (Li, 2022).

b) Particle size distribution which impacts the hydration process and also the microstructure of the concrete as finer voids in the cement particles are effectively being filled, resulting to a denser concrete with improved strength (Dobiszewska, 2020).

But as BRP content increases, there is a gradual decline in compressive strength values, decreasing for both 7days and 28days i.e. 34.1Mpa and 36.4Mpa respectively, at 30% BRP replacement. This reduction in compressive strength can be attributed to several factors;

a) Higher BRP particles do not contribute as effectively to the cementitious matrix and hydration process as cement particles do, leading to decreased strength development (Dobiszewska, 2020).

b) Higher BRP content result in reduced parking density and increased porosity within the concrete matrix, compromising its compressive strength. Also, the interfacial transition zone (ITZ) within the BRP particles and cement paste become less effective during the transfer of stress, leading to reduction in strength (Dobiszewska, 2018).

c) Excessive BRP beyond 15% replacement do not fully contribute to pozzolanic reactions resulting to incomplete or delay in the development of strength (Qiao, 2019).

d) The increased BRP particles provides reduced interlocking and bonding effect within the concrete matrix, especially with reducing cement particles hence affecting its structural integrity (Özgan, 2019).

CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS.

5.0 INTRODUCTION

This chapter serves as the climax of the research study, providing the summary of the key findings and future directions for the field of civil and environmental engineering.

5.1 CONCLUSION

The Purpose of this study was to investigate the usage of basalt rock powder as a supplementary cementitious material in conventional concrete. The study focuses on pounding basalt rock powder into finer particles for use in concrete mix and the following conclusions are formed from the described findings and discussion;

The concrete ingredients provided suitable results for various tests conducted; Fineness modulus of 2.3, flakiness index of less than 35 and Water absorption of 0.4% indicated that the aggregates are suitable for the concrete mix.

The powder is composed of both fine particles and coarse particles compared to the fine aggregates since 32.8% passes through the 0.075mm sieve. The X-ray fluorescence test indicated that in chemical composition, the $SiO2$, $Fe2O3$ and CaO are most dominant. Hence, the powder is from a mafic rock, resulting to Pozzolanic reaction during concrete mix.

Slump generally increased with increase in Basalt Rock powder replacement, hence improved workability. There's finer particle size and smoother surface texture of the Basalt Rock powder compared to cement particles which resulted to improved workability from 81mm at 10% to 98mm at 30% BRP replacement.

The optimal compressive strength of 43.9 MPa after 28 days of curing was discovered from the 15% BRP replacement with a relative density of 0.24, workability of 87mm and setting time of 7.7hrs showing a relatively good balance, considering the control concrete with strength 40.5 MPa. Thus the BRP can be used in the production of normal concrete as a supplementary cementitious material to increase the compressive strength.

Incorporating BRP in normal concrete as a partial replacement in cement results to improved compressive strength of concrete which is environmental friendly and economically feasible, hence a more cost effective concrete product.

5.2 RECOMMENDATION

I recommend that these BRP should be used in the production of normal concrete at 15% replacement. The BRP concrete can be used in the construction columns of buildings which requires improved compressive strength.

I also recommend that more study be done on the concretes permeability, porosity and resistance to chemical attacks

REFERENCES

1. Adrian, S., Cătălina, G., Radu, M., Nicanor, C. & Serbanoiu, B., 2022. Corn Cob Ash versus Sunflower Stalk Ash: Two Sustainable Raw Materials in an Analysis of Their Effects on the Concrete Properties
2. Aitcin, P.-C. (1986). Concrete structure, properties and materials. Canadian Journal of 41 Civil Engineering, 13(4), 499–499. https://doi.org/10.1139/l86-075
3. Bandhari, P. (2021, December 9). *Standard Deviation / A step by Step Guide with Formulas*. Retrieved from Scribbr: https://www.scribbr.com/statistics/standard-deviation/
4. Devi, V.S., Gnanavel, B.K., 2014. Properties of concrete manufactured using steel slag. Procedia Eng. 97, 95–104
5. Dobiszewska, M., & Beycioğlu, A., 2020. Physical Properties and Microstructure of Concrete with Waste Basalt Powder Addition. Materials, 13. https://doi.org/10.3390/ma13163503.
6. Dobiszewska, M., Schindler, A., & Pichór, W., 2018. Mechanical properties and interfacial transition zone microstructure of concrete with waste basalt powder addition. Construction and Building Materials. https://doi.org/10.1016/J.CONBUILDMAT.2018.05.133.
7. Francisco G. E., 2007. Tensile strength and fracture toughness of brittle materials.
8. Hosam, M. S., & Rehab O. A., 2018. Properties and Applications of Cement-Based Materials. DOI: 10.5772/intechopen.73784

9. Kucche, K. J., Jamkar, S. S., & Sadgir, P. A. (2015). Quality of Water for Making Concrete: A Review of. International Journal of Scientific and Research Publications, ISSN:2250-3153, 5(1), 1–10.

10. Li, J., Che, D., Liu, Z., Yu, L., & Ouyang, X., 2022. Effect of Basalt Powder on Hydration, Rheology, and Strength Development of Cement Paste. Materials 15. 8632.10.3390/ma15238632.

11. Mehta, P.K., & Monteiro, P.J.M. (2016). Concrete: microstructure, properties, and materials. McGraw-Hill Education.

12. Mir, B. 2021. Particle Size Distribution Analysis be the Hydrometer Method

13. Narayanan, S. (2013, January). *Introduction to Reinforced Concrete*. Retrieved from Research Gate: https://www.researchgate.net/publication/3213155552

14. Özgan, İ., & Özgan, E. (2019). Investigation the Effect of Stone Dust on Concrete Compressive Strength with Statistical. E-Journal of New World Sciences Academy, 14(4), 217–224. https://doi.org/10.12739/nwsa.2019.14.4.1a0443

15. Ponzi, G., Santos, V., Martel, R., Pontin, D., Stepanha, A., Schütz, M., Menezes, S., Einloft, S., & Vecchia, F., 2021. Basalt powder as a supplementary cementitious material in cement paste for CCS wells: chemical and mechanical resistance of cement formulations for CO2 geological storage sites. International Journal of Greenhouse Gas Control. https://doi.org/10.1016/J.IJGGC.2021.103337.

16. Qiao, H., Ndahirwa, D., Li, Y., & Liang, J., 2019. The Feasibility of Basalt Rock Powder and Superfine Sand as Partial Replacement Materials for Portland Cement and Artificial Sand in Cement Mortar.

17. Scrivener, K., Sneilings, R., & Lothenbach, B. (2018). A Practical Guide to Microstructural Analysis of Cementitious Material. CRC Press.

18. Sood, H. S., & Hermant. (2017). Effect of addition of granite powder and polypropylene fibres in concrete - A review. International Journal of Applied Science and Engineering Technology.

19. Unčík, S., & Kmecová, V., 2013. The Effect of Basalt Powder on the Properties of Cement Composites. Procedia Engineering, 65, pp. 51-56. https://doi.org/10.1016/J.PROENG.2013.09.010.

20. Yang, K.-H., Jung, Y.-B., Cho, M.-S., & Tae, S.-H. (2015). Effect of supplementary cementitious materials on reduction of CO2 emissions from concrete. Journal of the Korea Institute of Building Construction.

APPENDICES

Appendix A: Preliminary Design

- Concrete class = C 25/20
- Characteristic compressive strength at 28 days = 21.3 Mpa
- Target strength for mix proportioning at 28 days = 35.1 Mpa
- Water cement ratio = 0.48
- Workability, Slump (mm) = 81 mm
- Fine aggregate type = Natural sand
- Cement used = PPC

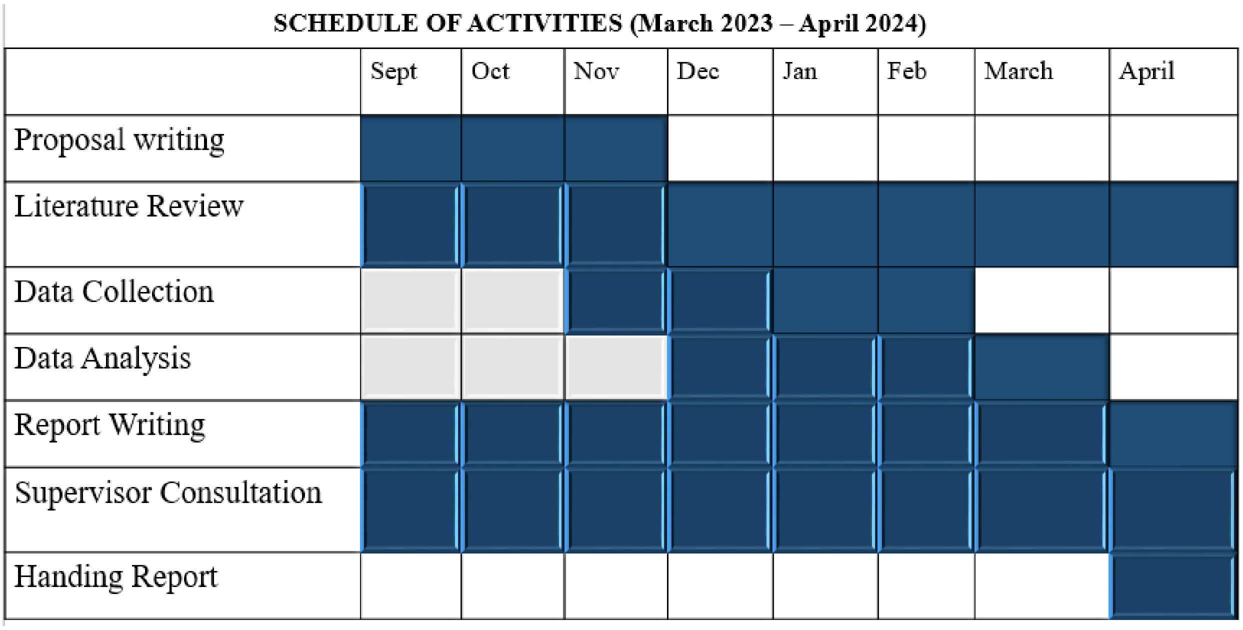
Laboratory trial batch

	For 1m3	For 0.02025m3 (6 cubes)
Cement	430 kg	8.708 kg
Water	206 kg	4.169 kg
Fine aggregate	675 kg	13.679 kg
Coarse aggregate	1007 kg	20.401 kg

Appendix B: Design Mix

Mix proportions (%)	0	10	15	20	25	30
Basalt (kg)	0	43	64.5	86	107.5	129
Cement (kg)	430	387	365.5	344	322.5	301
Coarse aggregate (kg)	1007	1007	1007	1007	1007	1007
Fine aggregate(kg)	675	675	675	675	675	675
Water (kg)	206	206	206	206	206	206

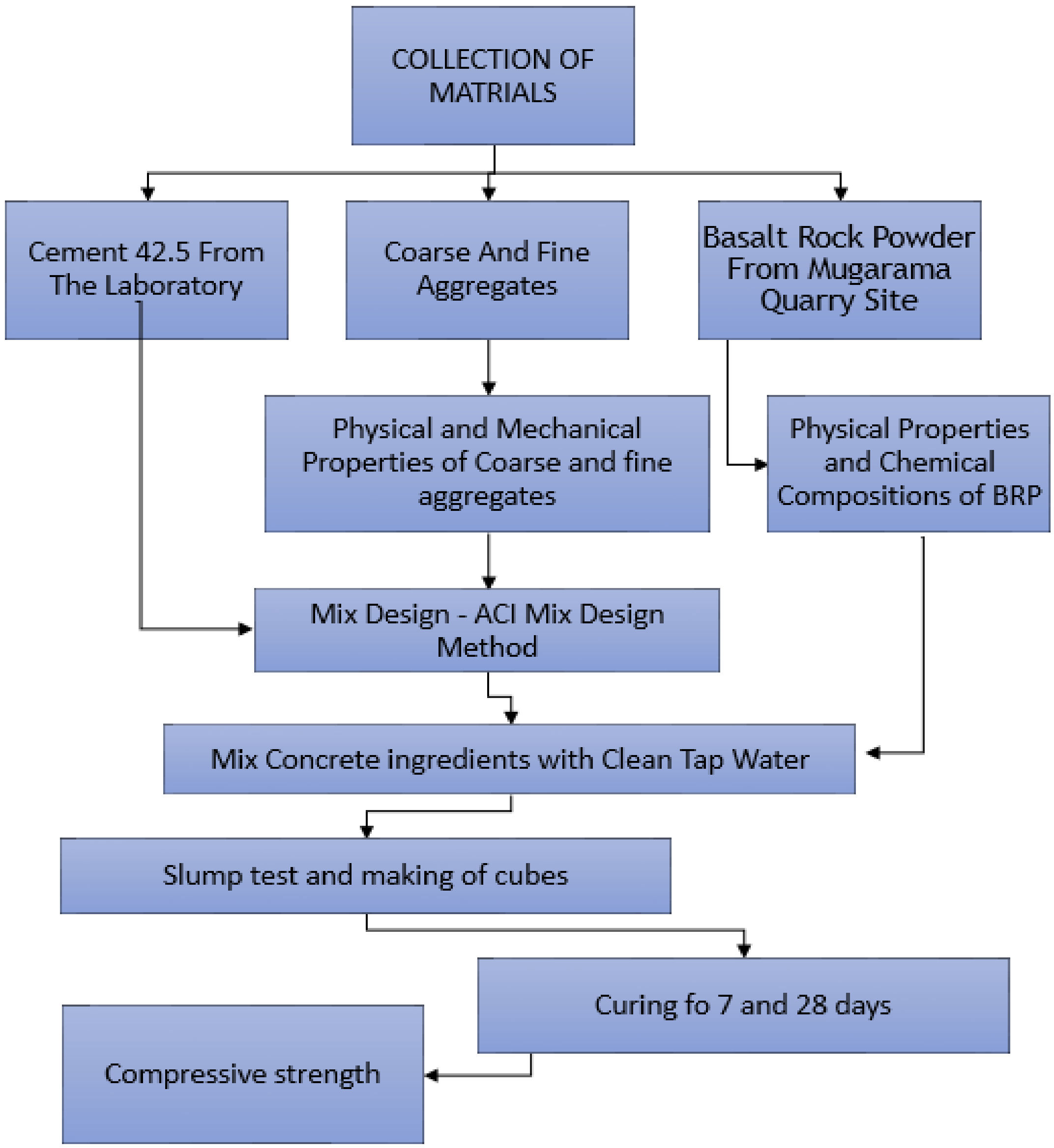
Appendix C: Activities Grant Chart



Appendix D: Budget for Activities

N°	Item	Unit Cost	Quantity	Total Cost
1	Proposal Writing printing and binding	Ugx 15,000	4	Ugx 60,000
2	Cement	Ugx 800	50kg	Ugx 40,000
3	Sand	Ugx 500	100kg	Ugx 50,000
4	Aggregates	Ugx 250	200kg	Ugx 50,000
5	Transport and Communication	-	-	Ugx 400,000
6	Laboratory			Ugx 900,000
7	Final Report printing and binding	Ugx, 55,000	3	Ugx 165,000
Grand Total		Ugx 1,665,000		
		Approximated Grand Total Ugx 1,700,000		

Appendix E: Design Mix Manual



Appendix F: Certified Results

CSCEC

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: csceciiangbo@gmail.com

CONCRETE MIX DESIGN USING ACI 211.1-91 METHOD

***DESIGN METHOD**: ACI COMMITTEE 211.1-91 ACI Committee 211, Standard Practice for Selecting Proportions for Normal, Heavyweight and Mass Concrete, ACI 211.1-91, American Concrete Institute, Farmington Hills, Michigan, 1991.*

(1) STIPULATIONS FOR PROPORTIONING:

(a) Concrete Strength/Cylinderical/ (Mpa)	=	21.3	*Cylinderical Strength, 150 x 300mm* | Cube = Cylinder/0.85= 25.1
(b) Type of Cement	=	PPC	*PPC 32.5 N/mm2, Portland Cem II*
(c) Maximum Nominal Size of Aggregate	=	19 mm	*as per ACI standards*
(d) Minimum Cement Content	=	320 kg/m^3	*for 20mm Nominal size as per ACI 302*
(e) Max. Water-Cement ratio	=	0.50	*from ACI 211.1-91, Table A1.5.3.4(b) for Severe conditions*
(f) Exposure conditions	=	Severe	
(g) Workability , Slump (mm)	=	100 mm	*from ACI 211.1,1991, Table A1.5.3.3*
(h) Method of Concrete Placing	=	Chute	*Non-Pumpable*
(i) Placing & Mixing Condition	=	Good	*from ACI 318-19*
(j) Type of Coarse Aggregate	=	Crushed	*Angular Aggregate*
(k) Maximum Cement Content	=	500 kg/m^3	*as per Ungonda General Specification, Section 6404 (a)*
(l) Fine Aggregate Type	=	Natural Sand	

(2) TEST DATA FOR MATERIALS:

(a) Cement Used	=	*PPC 32.5 N/mm2, Portland Cem II*	
(b) Specific Gravity of Cement	=	3.150	
(c) Specific Gravity of :-			
(1) Coarse Aggregate at Oven Dry Condition	=	2.640	*Combined CA*
(2) Fine Aggregate at Oven Dry Condition	=	2.601	
(d) Oven Dry Rodded unit weight :-			
(1) Coarse Aggregate (CA)	=	1,571 kg/m3	*Combined CA*
(e) Water Absorption:-			
(1) Coarse Aggregate (CA)	=	0.36 %	
(2) Fine Aggregate (FA)	=	0.69 %	
(f) Moisture Content of Aggregate:-			
(1) Coarse Aggregate (CA)	=	0.20 %	
(2) Fine Aggregate (FA)	=	0.80 %	
(g) Sieve Analysis:-			
(1) Coarse Aggregates (CA)	=		

Grading Requirments for Coarse Aggregates

US Sieve mm	Analysis of Coarse Aggregate Fractions	Percentage of Different Fractions		Specification
	I (19-9.5mm)	I 100%	100%	*BS EN 933-1:1997 Graded 19-4.75mm*
[1]	[2]	[4]	[6]	[7]
37.5	100	100	100	100-100
20	100	100	100	90-100
14	78	78	78	40-80
10	45	45	45	30-60
5	3	3	3	0-10

Hamza
16/02/2024

17/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
P.O.Box 29285 Kampala
17 FEB 2024
(CSCEC)

Page 1 of 4

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: csceclianzbo@gmail.com

CONCRETE MIX DESIGN USING ACI 211.1-91 METHOD

(2) Fine Aggregate (FA) :-
Conforming to ASTM C-33-03, Section 6.1

US Sieve Designation	Analysis of Fine Aggregate (% of Passing)	
	Grading	Grading ASTM C-33
[1]	[2]	[3]
19.0mm	100	-
12.5mm	100	-
9.5mm	100	100
4.75mm	100	95-100
2.36mm	99	80-100
1.18mm	90	50-85
600µm	52	25-60
300µm	17	5-30
150µm	10	0-10

(3) Comined - In-Aggregate Grading (for 19mm Nominal size)
as per BS 882, Table 5

% of passing			Combined		Remarks
40%	60%		100%		
FA (N/Sand)	CA (19mm)		Combined	Specification	
100	100		100	95-100	Ok!
100	100		100	-	
100	78		87	-	
100	45		67	35-70	Ok!
99	3		41	-	
90	0		36	-	
52	0		21	10-35	Ok!
17	0		7	-	
10	0		4	0-8	Ok!

(4) Fines Modulus (FM) of Fine Aggregate = 2.3 *Eq: FM=[500 - % of pass(2.36 + 1.18 + 0.6 + 0.3 +0.15)]/100*

(3) TARGET STRENGTH FOR MIX PROPORTIONING:

(a) Characteristic Comp. Strength at 28 days, f_{ck} = 21.3 N/mm^2 or Mpa
(b) Placing & Mixing Condition Good *from ACI 318-19*
(d) Target Strength, f'_{ck} at 28 days (Cylinderical) :
(1) Target Strength when data is not Available = 29.8 N/mm^2 or Mpa *from ACI 318 Table 9-11*
(2) Convert to Cube Target Strength f'_{ck}: = 35.1 N/mm^2 or Mpa *Cube Strength by dividing the result with 0.85 factor*
Cube Strength = Cylinderical strength/0.85
fck is in cylinderical characterstic strength

Note: Since 6 tests(cubes) are to be tested and they are less than 10
Table 9-11 is to be used to compute for average strength

(4) APPROXIMATE AIR CONTENT:

(a) Approximate amount of entrapped air = 2.0 % *from ACI 211.1-91, Table A1.5.3.3*
air content Non-airentrained is less than 3%

(5) SELECTION OF WATER - CEMENT RATIO:

(a) Free Water - Cement ratio required = 0.469 < 0.50 *for target strength shown in 3(d) = 35.1 Mpa*
(b) Check required W/C < Max W/C ratio = OK! *from ACI 211.1-91, Table A1.5.3.4(a)*
(c) Adopted Free Water - Cement ratio = 0.47 *Take the smallest of the two W/C ratios.*
W/C ratio max is for durability consideration

(6) SELECTION OF WATER CONTENT:

(a) Type of Concrete = Non-air-entrained
(b) Target Slump (mm) = 100 mm
(c) Estimated Water content for Target Slump = 205.0 kg/m3 *For nominal size of 19.0mm agg. & slump indicated in 6(b)*
(d) Do you use Chemical Admixture? = NO! *If YES, Water content is needed to reduced*
If NO, The above estimated water content is adopted

Hmza
16/02/2024

17/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: csceclianzbo@gmail.com

CONCRETE MIX DESIGN USING ACI 211.1-91 METHOD

(7) CALCULATION OF CEMENT CONTENT:

(a) Water - Cement ratio from (5)(a) above	=	0.47		*from ACI 211.1-91, Table A1.5.3.4(a)*
(b) Water Content from (6)(c,)	=	205.0	kg/m3	
(c) Cement Content (kg), Calculated *C=(b)/(a)*	=	436.9	kg/m3	> *320 kg/m3* Ok!
(d) Minimum Cement Content	=	320	kg/m3	*for 20mm nominal size as per ACI*
(e) Adopted Cement Content	=	430.0	kg/m3	> *320 kg/m3* Ok!
(f) Adjusted Water - Cement ratio	=	0.48		< *0.50* Ok!

(8) PROPORTION OF VOLUME OF COARSE AGGREGATE (CA):

(a) Nominal size	=	19	mm	
(b) Fineness Moduli of Fine Aggregate	=	2.3		*from 2(h)(4)*
(c) Volume of dry -rodded CA per unit volume	=	0.640	/m3	*from ACI 211.1-91, Table A1.5.3.6*
(d) Dry Rodded Density of CA	=	1,571	kg/m3	
(e) Weight of Coarse Aggregate (CA) - Dry	=	1005	kg	
(F) Volume of Coarse Aggregate (CA) - Dry	=	0.381	m3	*for 1m3 of concrete*

(9) MIX CALCULATIONS (Using Absolute Volume Method):

The mix calculations per unit volume of concrete shall be as follows:

(a) Total volume , V_t	=	1.0	m3
(b) Volume of entrapped air in wet concrete, Va	=	0.020	m3
(c) Volume of Cement, Vc *V_c=(Mass of Cement/Sp.gr)*(1/1000)*	=	0.137	m3
(d) Volume of Water, V_w *V_w=(Mass of Water/Sp.gr)*(1/1000)*	=	0.205	m3
(e) Volume of Coarse Aggregate V_{CA}	=	0.381	m3
(f) Volume of Fine Aggregate V_{FA} *V_{FA}=[(a)-(b)] - [(c.)+(d)+(f)+(g)]*	=	0.258	m3
(g) Mass of Coarse Aggregate (M_{CA}) - Dry *M_{CA}=V_{CA} x Spec.gr. CA x 1000*	=	1,005	kg
(h) Mass of Fine Aggregate (M_{FA}) -Dry *M_{FA}=V_{FA} x Spec.gr. FA x 1000*	=	670	kg

(10) MIX PROPORTION FOR DRY CONDITION:

(a) Cement	=	430	kg/m3	
(b) Water	=	205	kg/m3	
(c) Fine Aggregate FA (Dry)	=	670	kg/m3	40% *% of Fine aggregate out of total aggregates*
(d) Coarse Aggregate CA (Dry)	=	1005	kg/m3	
(e) Total Density of Wet Concrete	=	2,311	kg/m3	
(f) Free Water-Cement Ratio	=	0.48	kg/m3	*(g)=(b) / (a)*

Hmga.
16/02/2024

17/02/2024

Page 3 of 4

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: csceciiangbo@gmail.com

CONCRETE MIX DESIGN USING ACI 211.1-91 METHOD

(11) ADJUSTMENT ON WATER, FINE AGGREGATE & COARSE AGGREGATE FOR ACTUAL MOISTURE CONDITION:

(a) Fine Aggregate Adjusted $M_{FA}=M_{FA(Dry)}*(1+W/100)$	=	675 kg/m3	*Ajusted for Actual Moisture content*
(b) Coarse Aggregate Adjusted $M_{CA}=M_{CA(Dry)}*(1+W/100)$	=	1,007 kg/m3	*Ajusted for Actual Moisture content*
(c) Extra Water to be adjusted:	=	0.9 kg/m3	
(1) For Fine Aggregate:	= -	0.7 kg/m3	*Extra Water=FA dry x (Absorption-Moisture)for FA*
(2) For Coarse Aggregate:	=	1.6 kg/m3	*Extra Water=CA dry x (Absorption-Moisture) for CA*
(d) Water Adjusted :	=	206 kg/m3	

(12) MIX PROPORTIONS AFTER ADJUSTMENT FOR ACTUAL MOISTURE CONDITION:

(a) Cement	=	430	kg/m3
(b) Water (Adjusted)	=	206	kg/m3
(c) Fine Aggregate FA (Adjusted)	=	675	kg/m3
(d) Coarse Aggregate CA (Adjusted)	=	1007	kg/m3
(e) Total Density of Wet Concrete	=	2,319	kg/m3
(f) Free Water-Cement Ratio	=	0.48	kg/m3

(13) LABORATORY TRIAL BATCH:

		For 1m3		For 0.02025m3(6 cubes)
(a) Cement	=	430 kg	=	8.708 kg
(b) Water (Adjusted)	=	206 kg	=	4.169 kg
(c) Fine Aggregate FA (Adjusted)	=	675 kg	=	13.679 kg
(d) Coarse Aggregate CA (5-20mm)_ 100%	=	1007 kg	=	20.401 kg
(e) Total in the Mix:	=	2,319 kg	=	47.0 kg

(14) ACTUAL SLUMP TEST RESULTS & ACTUAL W/C RATIO:

(a) Target slump (mm)	=	100	mm	*75-100mm*
(b) Average Actual slump Recorded (mm)	=	81	mm	
(c) Average Actual W/C ratio	=	0.48		

(15) CONCRETE CUBE COMPRESSIVE STRENGTH TEST RESULTS:

Date of Casting: 19-Jan-24 ***CUBE STRENGTH***

Curing Time		**7 days**			**28 days**		
Sample No.		1	2	3	4	5	6
Strength (Mpa)		36.8	37.9	37.7	41.7	40.0	39.8
Average Strength (Mpa)		**37.5**			**40.5**		

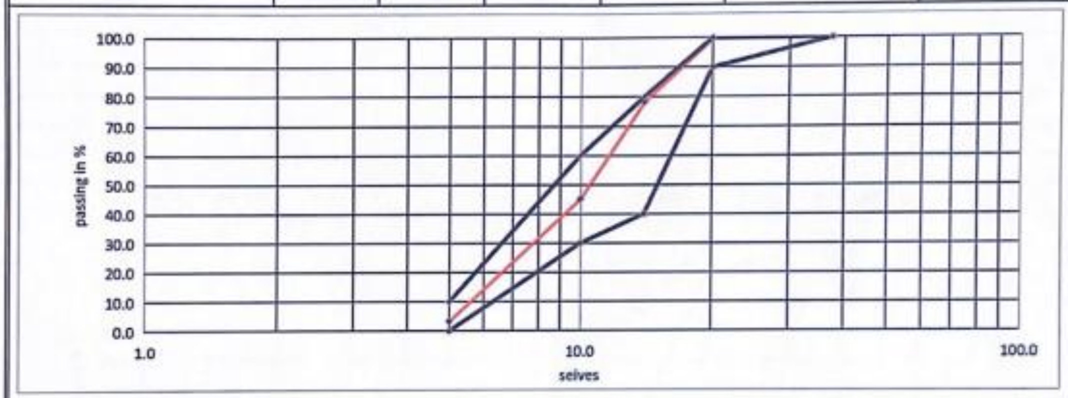
Target Strength after 28days (Mpa) = **35.1**
Ok! Final!

Contractor's Representative （CSCEC）	
Technician	Materials Engineer
Sign: Hmza	Sign: CK
Date: 16/02/2024	Date: 17/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

SIEVE ANALYSIS OF COARSE AGGREGATES(BS EN 933-1:1997)

Sample Ref:	Sample A			Method	Dry Sieving	
Location				Sample Date	7 Jan 2024	
Source:	Zirobwe quarry			Testing Date:	9 Jan 2024	
Initial wt.before washing	4501.0			Description:	(5-20 mm) Aggregates for Concrete	
Dry wt.after washing				Tested by	Lab Team	
Sieve size Standard	Partial Retained	cumulative Retained	cumulative Retained %age	Passing	Governing Specification Passing (BS 882:1992 Table 3)	
mm	g	g	%	%	Lower Limit	Upper Limit
37.5	0.0	0	0.0	100.0	100	100
20.0	11.0	11	0.2	99.8	90	100
14.0	963.0	974	21.6	78.4	40	80
10.0	1494.0	2468	54.8	45.2	30	60
5.0	1884.0	4352	96.7	3.3	0	10
2.36	104.0	4456	99.0	1.0		



Remarks

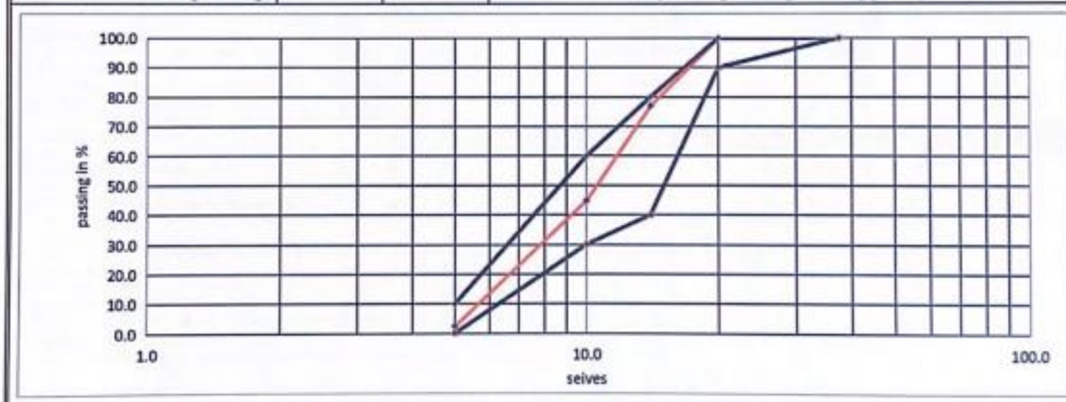
For the Representative (CSCEC)

Materials Technician		Materials Engineer	
Sign:		Sign:	
Date:	09/01/2024	Date:	09/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

SIEVE ANALYSIS OF COARSE AGGREGATES(BS EN 933-1:1997)

Sample Ref:	Sample B			Method	Dry Sieving	
Location				Sample Date	7 Jan 2024	
Source:	Zirobwe quarry			Testing Date:	9 Jan 2024	
Initial wt.before washing	4468.0			Description:	(5-20 mm) Aggregates for Concrete	
Dry wt.after washing				Tested by	Lab Team	
Sieve size Standard	Partial Retained	cumulative Retained	cumulative Retained %age	Passing	Governing Specification Passing (BS 882:1992 Table 3)	
mm	g	g	%	%	Lower Limit	Upper Limit
37.5	0.0	0	0.0	100.0	100	100
20.0	0.0	0	0.0	100.0	90	100
14.0	1025.0	1025	22.9	77.1	40	80
10.0	1436.0	2461	55.1	44.9	30	60
5.0	1900.0	4361	97.6	2.4	0	10
2.36	97.0	4458	99.8	0.2		
Pan						
Wash Loss						
Total						
% Grading Error [g]:	<1%		Equals weight loss/gain during grading.			



Remarks

For the Representative (CSCEC)			
Materials Technician		Materials Engineer	
Sign:	Hmza .	Sign:	
Date:	9/01/2024	Date:	09/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

FLAKINESS INDEX (FI)

AVERAGE LEAST DIMENSION (ALD) BS 812: SECTION 105.1 1990

Sample Ref	N/A	Sample Date	7 Jan 2024
Location		Testing Date:	9 Jan 2024
Source	Zirobwe quarry	Technician	Lab Team
Sample Description	(5-20 mm) Aggregates for Concrete		

		Fractioned Guaged					
Passing Sieve	mm	**50**	**37.5**	**28**	**20**	**14**	**10**
Retained on Sieve	mm	**37.5**	**28**	**20**	**14**	**10**	**6.3**
Slot width	mm						
% Retained (X)			0.0	0.0	31.0	43.5	25.5
(a) Mass retained	g		0	0.0	1025.0	1436.0	841.2
(b) Mass to be gauged (X>5%)	g				1025	1436	841.2
(c) Riffled mass	g		0	0	1025	601.5	334
(d) Correction factor (b/c)					1.000	2.387	2.519
(e) Mass passing Slot	g		0	0	151.0	65.2	83.2
(f) Mass retained on gauge	g				874.0	1280.3	631.7
(g) Corrected mass passing gauge (d*e)	g				151.0	155.7	209.5

Sum of Mass retained	g	3302.2
Sum of Corrected Mass passing slots	g	516.2
Flakiness Index FI = (M_3/M_2)*100	%	**15.6**

Remarks

For the Representative (CSCEC)

Materials Technician	Materials Engineer
Sign: Hamza	Sign: [signature]
Date: 9/01/2024	Date: 10/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&71 1,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

RELATIVE DENSITY AND WATER ABSORPTION FOR COARSE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:	0	Sampling Date:	7 Jan 2024
Material Source:	Zirobwe quarry	Tested Date:	9 Jan 2024
Sample description	(5-20mm) Coarse aggregates	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of Saturated Surface-dry aggregates in air	A	g	1933.2	1917.7	
Mass of basket + Sample in Water	B	g	1203.0	1194.2	
Mass of Oven-dryaggregates	D	g	1925.7	1911.4	
Particle density on an oven-dry basis	$P_d = \frac{D}{A-(B-C)}$	Mg/m^3	2.637	2.642	2.640
Particle density on a saturated and surface-dry basis	$P_s = \frac{A}{A-(B-C)}$	Mg/m^3	2.647	2.651	2.649
Apparent Particle density	$P_a = \frac{D}{D-(B-C)}$	Mg/m^3	2.665	2.665	**2.665**
Water Absorption	$W_{abs} = 100x\left(\frac{A-D}{D}\right)$		0.4	0.3	**0.36**

Remark:

For the Representative (CSCEC)

Materials Technician		Materials Engineer	
Sign:	Amz	Sign:	[illegible]
Date:	9/01/2024	Date:	10/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: csceejiangbo@gmail.com

LOOSE DENSITY FOR COARSE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:		Sampling Date:	7 Jan 2024
Material Source:	Zirobwe quarry	Tested Date:	8 Jan 2024
Sample description	(5-20mm) Coarse aggregates	Tested By:	Lab Team

Specimen reference			1	2	Average
Volume of the cotainer	A	g	10000	10000	
Mass of empty container	B	g	3151.0	3151.0	
Mass of container + Sample	C	g	17950.0	18165.0	
Mass of sample	D = (C - B)	g	14799.0	15014.0	
Loose Density	$P_d = \frac{D}{A}$	Mg/m^3	1.480	1.501	**1.491**

Remark:

For the Representantives (CSCEC)

Materials Technician		Materials Engineer	
Sign:	Hmga.	Sign:	
Date:	8/01/2024	Date:	08/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

RODED DENSITY FOR COARSE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:		Sampling Date:	7 Jan 2024
Material Source:	Zirobwe quarry	Tested Date:	8 Jan 2024
Sample description	(5-20) mm	Tested By:	Lab Team

Specimen reference			1	2	Average
Volume of the cotainer	V	m^3	10000.0	10000	
Mass of empty container	T	g	3151	3151	
Mass of container + Sample (AGG +SAND)	G	g	18850	18866	
Mass of sample	D = (G - T)	g	15699.0	15715.0	
Roded Density	$P_d = \frac{D}{V}$	Mg/m^3	1.570	1.572	1.571

Remark:

For the Representantives (CSCEC)

Materials Technician		Materials Engineer	
Sign:	Atenga .	Sign:	[illegible]
Date:	8/01/2024	Date:	09/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

LOS ANGELES ABRASION VALUE (LAAV)

TEST METHOD ASTM C131-2001

Location:	Zirobwe quarry	Sampling Date:	7 Jan 2024
Material Source:	Zirobwe quarry	Tested Date:	10 Jan 2024
Sample description	Concrete Agg	Tested By:	Lab Team

Sieve Size		Mass of indicated sizes (g)			
Passing	Retained on	Grading to be used			
		A	B	C	D
37.5mm	25.0mm	1250±10			
25.0mm	19.0mm	1250±10			
19.0mm	12.5mm	1250±10	2500±10		
12.5mm	9.5mm	1250±10	2500±10		
9.5mm	6.3mm			2500±10	
6.3mm	4.75mm			2500±10	
4.75mm	2.36 mm				5000±10
Total		5000±10	5000±10	5000±10	5000±10

Sample Description	Concrete Agg(5-20)mm				
Grading Used	Grading B				
Specimen reference		1	2	Average	
Mass of tray + test specimen (g)		5266.9	5269.1		
Mass of tray alone (g)		257.1	257.1		
Mass of original test specimen (g)	M_1	5009.8	5012.0		
Mass of material retained on 1.7mm sieve (g)	M_2	4032.5	4023.5		
Mass of material passing 1.7mm sieve (g)	M_1-M_2	977.3	988.5		
LAA Value (%)	$\frac{M_1 - M_2}{M_1} x100$	19.5	19.7	19.6	

Remark:
Grading A was used since it is one suitable for Graded Crushed Stone and Natural Gravel for Base Course

For the Representative(CSCEC)

Materials Technician	Materials Engineer
Sign: Hmga .	Sign: Cky
Date: 10/01/2024	Date: 11/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Ssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

AGGREGATE IMPACT VALUE (AIV_{dry})

TEST METHOD BS 812 : Part 112 : 1990

Location:		Sampling Date:	7 Jan 2024
Material Source:	Zirobwe quarry	Tested Date:	9 Jan 2024
Sample description	14/10mm	Tested By:	Lab Team

Specimen reference		1	2	3	4
Number of blows	n	15	15		
Mass of tray + test specimen (g)		1292.4	1304.2		
Mass of tray alone (g)		964	964		
Mass of original test specimen (g)	M_1	328.4	340.2		
Mass of material passing 2.36mm sieve (g)	M_2	53.2	56.8		
Mass of material retained on 2.36mm sieve (g)	M_3	275.2	283.4		
Aggregate Impact Value (in %) - Dry	$m = \frac{M_2}{M_1} x100$	16.2	16.7		
AIV - mean value (%)		16.4			

Remark:

For the Representative (CSCEC)

Materials Technician	Materials Engineer
Sign: Amza	Sign: [illegible]
Date: 9/01/2024	Date: 10/01/2024

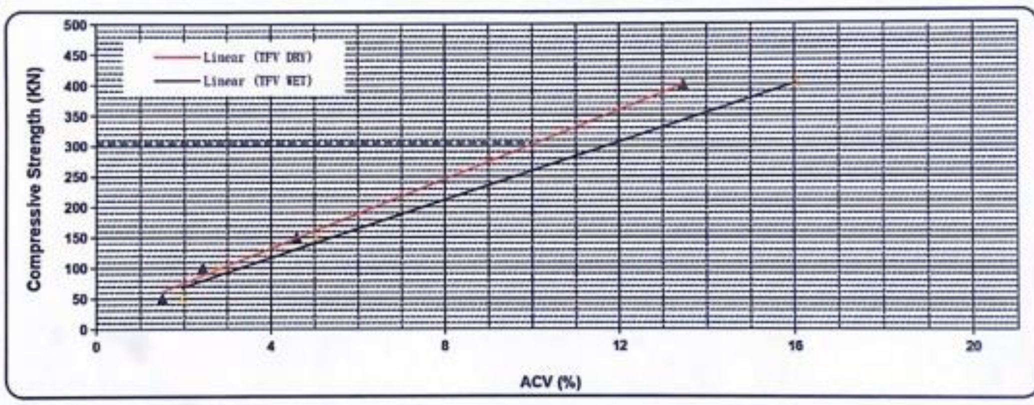
CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Ssesuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

SAMPLE STATION	N/A		SAMPLE NO.	N/A
MATERIAL TYPE	Concrete AGG		DATE SAMPLED	7-Jan-24
MATERIAL SOURCE	Zirobwe quarry		DATE TESTED	11-Jan-24
MATERIAL DESRIPTION	(5-20)mm		SAMPLED BY	Lab Team

DETERMINATION OF TEN PERCENT FINES VALUE

BS 812 Part 111 : 1990

Sample Number	Method	Compressive Strength (KN)	Load (min)	Weight of total specimen (W1 g)	Weight of fine Passing 2.36 mm (W2 g)	Aggregate Crushing Value (W2/W1*100%)	Remark
A-1	Dry condition		50	2421.2	36.4	1.50	
A-2			100	2418.0	58.7	2.43	
A-3			150	2415.8	110.9	4.59	
A-4			400	2416.5	325.4	13.47	
B-1	Soaked condition		50	2461.4	48	1.95	
B-2			100	2475.1	69	2.79	
B-3			150	2480.4	125.0	5.04	
B-4			400	2482.3	398.1	16.04	



Compressive Strength for 10% Fines values in Dry condition (TFV Dry):	305 KN
Compressive Strength for 10% Fines values in Soaked condition (TFV Wet):	261 KN
TFV Ratio Wet / Dry Test (%)	86 %
ACV (%)	13

Representative (CSCEC)

Lab Technician	Materials Engineer
Sign: Ahoza .	Sign: [signature]
Date: 11/01/2024	Date: 12/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

RODED DENSITY FOR COARSE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:		Sampling Date:	7 Jan 2024
Material Source:	Zirobwe quarry	Tested Date:	8 Jan 2024
Sample description	(5-20) mm	Tested By:	Lab Team

Specimen reference			1	2	Average
Volume of the cotainer	V	m^3	10000.0	10000	
Mass of empty container	T	g	3151	3151	
Mass of container + Sample (AGG +SAND)	G	g	18850	18866	
Mass of sample	D = (G - T)	g	15699.0	15715.0	
Roded Density	$P_a = \frac{D}{V}$	Mg/m^3	1.570	1.572	1.571

Remark:

For the Representantives (CSCEC)

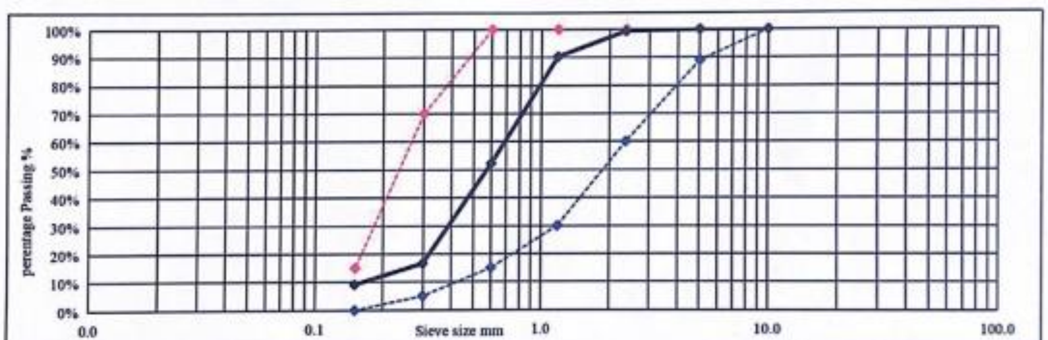
Materials Technician		Materials Engineer	
Sign:	Ahenga .	Sign:	[illegible]
Date:	8/01/2024	Date:	09/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Sieve Analysis for Sand

Location:	Lukaya	Sample Date:	4-Jan-2024
Material description:	NATURAL SAND	Job ref:	mix design
		Sand Size:	5mm
		Date:	6-Jan-2024

Test method:	BS882 1992 table 4		Initial dry mass(g)	1002.9		
Sieve size:(mm)	Sand 5 mm		Mass after washing on 0.075mm sieve(g)			957.8
	Lower limit	Upper limit	Wt. Retained on size	Cumulative mass Retained on size	Cumulative percentage retained on size	Percentage Passing
14.0	—	—	0	0	0.0%	100.0%
10.0	100%	100%	0.0	0.0	0.0%	100.0%
5.0	89%	100%	0.3	0.3	0.0%	100.0%
2.36	60%	100%	6.5	6.8	0.7%	99.3%
1.18	30%	100%	90.4	97.2	9.7%	90.3%
0.60	15%	100%	381.6	478.8	47.7%	52.3%
0.30	5%	70%	357.4	836.2	83.4%	16.6%
0.15	0%	15%	75.5	911.7	90.9%	9.1%
PAN			80.9	992.6	99.0%	



Fine modulus(M=(A2.36+A1.18+A0.6+A0.3+A0.15-5A4.75)/(100-A4.75))	2.3

For the Representative(CSCEC):

Tested by;	**Approved by;**
Name & Signature; Hamza .	**Materials & QC Engineer;**
Date; 6/01/2024	**Date;** 06/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

SAND EQUIVALENT TEST

Ref: ASTM D 2419: 95

Sample Reference:		Sampling Date:	4-Jan-2024
Location:	Lukaya	Testing Date:	6-Jan-2024
Sample Description:	NATURAL SAND	Technician:	Lab Team
		Material Source:	Lukaya
Specimen Number	1	2	3
Clay Reading, mm (after 20 mins or max. 30 mins sedimentation)	117	116	121
Sand Reading, mm (top edge of indicator)	84	82	84
Sand Equivalent = 100*Sand Reading /Clay Reading	71.8	70.7	69.4
Rounded to the next whole number	72	71	69
Average of the rounded values (rounded to the next whole number)	71		

For the Supervisor's Representative:

Tested by;	**Approved by;**
Name & Signature; Hmza	**Materials & QC Engineer;**
Date; 06/01/2024	**Date;** 06/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Ssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

SILT CONTENT OF NATURAL SAND BS 812 PART2 1975

Sample Reference:	N/A	Sampling Date:	4-Jan-2024
Location:	Lukaya	Testing Date:	6-Jan-2024
Sample Description:	Natural sand	Technician:	Lab Team
		Material Source:	Lukaya
Specimen Number	1	2	3
Clay Reading, mm (after 20 mins or max. 30 mins sedimentation)	102	102	
Sand Reading, mm (top edge of indicator)	91	90	
Silt content	10.8	11.8	
Rounded to the next whole number	11	12	
Average of the rounded values (rounded to the next whole number)	11		

For the Representative(CSCEC):	
Tested by; Name & Signature;.....Hamza ..... Date;.....06/01/2024.....	Approved by; Materials & QC Engineer;.......... Date;.....06/01/2024.....

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Summary of Natural Sand Test Results

Sample Reference:	N/A	Sampling Date:	4-Jan-2024
Location:	Lukaya	Testing Date:	6-Jan-2024
Sample Description:	Natural sand	Technician:	Lab Team
		Material Source:	Lukaya
Test Property		Results	*Standard & Specification*
Finess Modulus	-	2.3	*BS882 1992 table 4*
Silt content	%	11	*BS 812 PART2 1975*
Sand Equivalent	%	72	*ASTM D 2419: 95*
Water Absorption	%	0.69	*BS 812 Part 2 1995*

For the Representative(CSCEC):

Tested by;	**Approved by;**
Name & Signature; Hmza	**Materials & QC Engineer;**
Date; 6/01/2024	**Date;** 06/01/2024

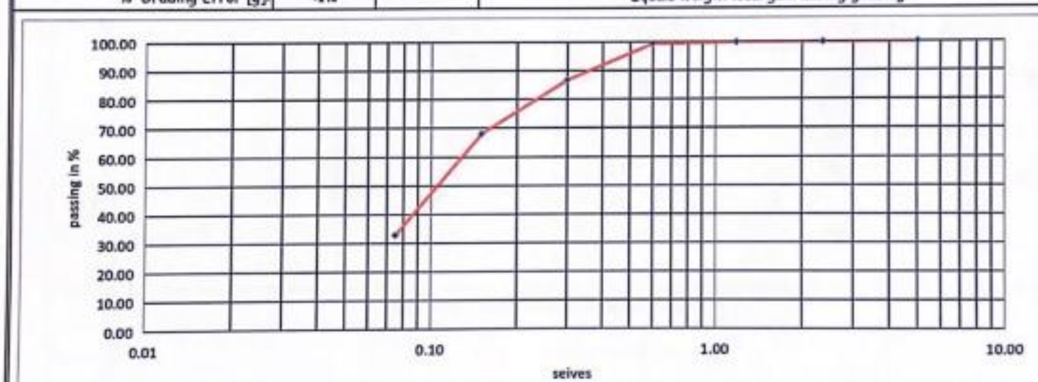
CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
P.O.Box 29285 Kampala
06 JAN 2024
(CSCEC)

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

SIEVE ANALYSIS OF CONCRETE AGGREGATES(BS EN 933-1:1997)

Sample Ref:	Sample A	Method	WET Sieving
Location		Sample Date	8 Jan 2024
Source:	Kibale Districk	Testing Date:	15 Jan 2024
Initial wt.before washing	519.1	Description:	Basalt Rock Powder
Dry wt.after washing	413.4	Tested by	Lab Team

Sieve size Standard	Partial Retained	cumulative Retained	cumulative Retained %age	Passing		
mm	g	g	%	%		
5.00	0.0	0.0	0.0	100.00		
2.36	0.2	0.2	0.0	99.96		
1.18	0.2	0.4	0.1	99.92		
0.60	2.5	2.9	0.6	99.44		
0.30	65.2	68.1	13.1	86.88		
0.15	97.2	165.3	31.8	68.16		
0.075	183.3	348.6	67.2	32.85		
Pan	65.2	413.8	79.7	20.29		
Wash Loss	97	511	98.4			
Total	3034.2					
% Grading Error [g]:	<1%		Equals weight loss/gain during grading.			



Remarks

For the Representative (CSCEC)

Materials Technician		Materials Engineer	
Sign:	Amza	Sign:	
Date:	15/01/2024	Date:	16/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

SILT CONTENT OF NATURAL SAND BS 812 PART2 1975

Sample Reference:	N/A	Sampling Date:	4-Jan-2024
Location:	Lukaya	Testing Date:	6-Jan-2024
Sample Description:	Natural sand	Technician:	Lab Team
		Material Source:	Lukaya
Specimen Number	1	2	3
Clay Reading, mm (after 20 mins or max. 30 mins sedimentation)	102	102	
Sand Reading, mm (top edge of indicator)	91	90	
Silt content	10.8	11.8	
Rounded to the next whole number	11	12	
Average of the rounded values (rounded to the next whole number)	11		

For the Representative(CSCEC):

Tested by;	**Approved by;**
Name & Signature; Hamza	**Materials & QC Engineer;**
Date; 06/01/2024	**Date;** 06/01/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

RELATIVE DENSITY AND WATER ABSORPTION FOR FINE AGGREGATES

TEST METHOD BS 812: Part 2 : 1995

Location:	Kibale Districk	Sampling Date:	2024-01-08
Material Source:	Kibale Districk	Tested Date:	2024-01-13
Sample description	Basalt Rock Powder	Tested By:	Lab Team

Specimen reference			1	2	Average
Mass of saturated surface-dry aggregate in air	A	g	541.9	546.8	
Mass of Pycnometer + sample + water	B	g	1898.6	1904.2	
Mass of Pycnometer filled with water only	C	g	1547.6	1547.6	
Mass of oven-dry aggregate in air	D	g	521.7	526.8	
Particle density on an oven-dry basis	$P_d = \frac{D}{A-(B-C)}$	Mg/m^3	2.733	2.770	2.751
Particle density on a saturated and surface-dry basis	$P_s = \frac{A}{A-(B-C)}$	Mg/m^3	2.839	2.875	2.857
Apparent Particle density	$P_a = \frac{D}{D-(B-C)}$	Mg/m^3	3.056	3.095	**3.076**
Water Absorption	$W_{abs} = 100x\left(\frac{A-D}{D}\right)$	%	3.9	3.8	**3.8**

Remark:

Representative(CSCEC)			
Materials Technician		Materials Engineer	
Sign:	Ahmzo	Sign:	[signature]
Date:	13/01/2024	Date:	14/01/2024

Telephone
+256 (0) 414 250 464 (Gen)
+256 (0) 414 250 474
Email: dgal@mia.go.ug
Website: www.mia.go.ug

In any Correspondence on
this subject please
quote No.......... GE 121/2024

THE REPUBLIC OF UGANDA

MINISTRY OF INTERNAL AFFAIRS
DIRECTORATE OF GOVERNMENT ANALYTICAL LABORATORY
Plot No. 2 Lourdel Road
Wandegeya,
P.O. BOX 105639
Kampala - Uganda

14th March 2024

MR. KUGONZA MARTIN AND MR WAYOMIRWOTH KELLY
REG NO. S20B32/020 & S18B32/802
UGANDA CHRISTIAN UNIVERSITY
P.O BOX 4,
MUKONO-UGANDA
Tel: 256-778-051449

REPORT OF ANALYSIS

Description of the Samples

One sample in a black polythene bag containing Basalt rock powder sample was submitted by Mr. Kugonza Martin, on 07th March 2024, and analysed on 11th March 2024. A summary of the sample received is shown in table below

S/N	Description	Quantity	Assigned Lab ID
1	Grey powdered sample packed in a black polythene bag.	01	Sample "A" GE 121/2024

Analysis Requested

Elemental analysis

Method of Analysis

Elemental analysis was done using the XRF Method.

Results of Analysis

The above sample has been analyzed with the following results as below,

Parameter	Units	Results Basalt rock sample GE 121/2024
Silicon dioxide	% m/m	42.16
Iron (III) Oxide	% m/m	14.88
Calcium Oxide	% m/m	12.16
Aluminum Oxide	% m/m	10.68
Magnesium Oxide	% m/m	7.66
Potassium Oxide	% m/m	5.44
Sodium oxide	% m/m	2.91
Phosphorous pentoxide	% m/m	1.02
Titanium di oxide	% m/m	0.83
Europium (III) oxide	% m/m	0.19
Chlorine	% m/m	0.07

Remarks

1. Results relate to sample analyzed and are reported as on received basis.

14/03/24

Semalago Fredrick
Government Analyst

"Go Scientific for a Safe and Just Society"

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Ref. Test Method:BS EN 12390-3: 2002

Concrete Class	C25/20	**Cube Dimension（mm)**	150 x 150x 150
Mix Description	Neat	**Cement Type**	Tororo Portland CEMI 42.5 N

Cube No.	Slump (mm)	Casting/ Sampling Date	Testing Date	Weight (Kg)	Density (Kg/m^3)	Crushing Load (KN)	Ult. Comp. Strength (MPa)	Average Strength (Mpa)
7 DAYS								
1	83	19-Jan-24	26-Jan-24	8.550	2533.3	827.4	36.8	**37.5**
2	81			8.510	2521.5	852.3	37.9	
3	78			8.590	2545.2	848.3	37.7	
28 DAYS								
1	**81**	19-Jan-24	16-Feb-24	8.660	2565.9	937.4	41.7	**40.5**
2				8.640	2560.0	900.4	40.0	
3				8.710	2580.7	895.2	39.8	

For the Representative (CSCEC)

Materials Technician	Materials Engineer
Sign: Hmza.	Sign:
Date: 16/02/2024	Date: 17/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Ref. Test Method:BS EN 12390-3: 2002

Concrete Class	C25/20	**Cube Dimension（mm)** 0 x 150x 1	150 x 150x 150
Mix Description	**10% Basalt Powder**	**Cement Type** Portland CEM	Tororo Portland CEMI 42.5 N

Cube No.	Slump (mm)	Casting/ Sampling Date	Testing Date	Weight (Kg) Before Soaking	Weight After soaking	Water Absorption	Crushing Load (KN)	Ult. Comp. Strength (MPa)	Average Strength (Mpa)
7 DAYS									
1	85	20-Jan-24	27-Jan-24	8.710	8.720	0.11	861.8	38.3	**38.4**
2	87			8.690	8.700	0.12	866.3	38.5	
3	84			8.730	8.742	0.14	864.0	38.4	
28 DAYS									
1	**85**	20-Jan-24	17-Feb-24	8.480			940.5	41.8	**41.8**
2				8.370			940.5	41.8	
3				8.450			938.3	41.7	

For the Representative (CSCEC)

Materials Technician	Materials Engineer
Sign: Amza .	Sign:
Date: 17/02/2024	Date: 18/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Ref. Test Method:BS EN 12390-3: 2002

Concrete Class	C25/20	**Cube Dimension (mm)**	0 x 150x 1	150 x 150x 150
Mix Description	15% Basalt Powder	**Cement Type**	ortland CEM	Tororo Portland CEMI 42.5 N

Cube No.	Slump (mm)	Casting/ Sampling Date	Testing Date	Weight (Kg) Before Soaking	Weight After soaking	Water Absorption	Crushing Load (KN)	Ult. Comp. Strength (MPa)	Average Strength (Mpa)
7 DAYS									
1	86	20-Jan-24	27-Jan-24	8.650	8.671	0.24	891.0	39.6	39.6
2	85			8.540	8.560	0.23	888.8	39.5	
3	89			8.660	8.680	0.23	891.0	39.6	
28 DAYS									
1	87	20-Jan-24	17-Feb-24	8.350			987.8	43.9	43.9
2				8.410			985.5	43.8	
3				8.430			987.8	43.9	

For the Representative (CSCEC)

Materials Technician	Materials Engineer
Sign: Hmasa .	Sign:
Date: 17/02/2024	Date: 18/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Ref. Test Method:BS EN 12390-3: 2002

Concrete Class	C25/20	**Cube Dimension（mm)** 0 x 150x 1	150 x 150x 150
Mix Description	**20% Basalt Powder**	**Cement Type** Portland CEM	Tororo Portland CEMI 42.5 N

Cube No.	Slump (mm)	Casting/ Sampling Date	Testing Date	Weight (Kg) Before Soaking	Weight After soaking	Water Absorption	Crushing Load (KN)	Ult. Comp. Strength (MPa)	Average Strength (Mpa)
7 DAYS									
1	90	20-Jan-24	27-Jan-24	8.740	8.760	0.23	839.3	37.3	**37.4**
2	88			8.510	8.540	0.35	841.5	37.4	
3	92			8.440	8.470	0.36	843.8	37.5	
28 DAYS									
1	**90**	20-Jan-24	17-Feb-24	8.300			904.5	40.2	**40.1**
2				8.340			900.0	40.0	
3				8.290			902.3	40.1	

For the Representative (CSCEC)	
Materials Technician	Materials Engineer
Sign: Hmza .	Sign:
Date: 17/02/2024	Date: 18/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Ref. Test Method:BS EN 12390-3: 2002

Concrete Class	C25/20	**Cube Dimension（mm)**	0 x 150x 1	150 x 150x 150
Mix Description	**25% Basalt Powder**	**Cement Type**	Portland CEM	Tororo Portland CEMI 42.5 N

Cube No.	Slump (mm)	Casting/ Sampling Date	Testing Date	Weight (Kg) Before Soaking	Weight After soaking	Water Absorption	Crushing Load (KN)	Ult. Comp. Strength (MPa)	Average Strength (Mpa)
				7 DAYS					
1	96	20-Jan-24	27-Jan-24	8.480	8.500	0.24	803.3	35.7	**35.7**
2	97			8.520	8.550	0.35	805.5	35.8	
3	86			8.560	8.580	0.23	803.3	35.7	
				28 DAYS					
1	**93**	20-Jan-24	17-Feb-24	8.240			866.3	38.5	**38.5**
2				8.190			868.5	38.6	
3				8.250			864.0	38.4	

For the Representative (CSCEC)

Materials Technician	Materials Engineer
Sign: Hmza .	Sign:
Date: 17.02.2024	Date: 18/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Ref. Test Method:BS EN 12390-3: 2002

Concrete Class		C25/20		**Cube Dimension （mm)**		0 x 150x 1	150 x 150x 150		
Mix Description		**30% Basalt Powder**		**Cement Type**		ortland CEM	Tororo Portland CEMI 42.5 N		
Cube No.	**Slump (mm)**	**Casting/ Sampling Date**	**Testing Date**	**Weight (Kg) Before Soaking**	**Weight After soaking**	**Water Absorption**	**Crushing Load (KN)**	**Ult. Comp. Strength (MPa)**	**Average Strength (Mpa)**
7 DAYS									
1	101	20-Jan-24	27-Jan-24	8.320	8.360	0.48	765.0	34.0	**34.1**
2	99			8.290	8.310	0.24	767.3	34.1	
3	95			8.400	8.430	0.36	771.8	34.3	
28 DAYS									
1	**98**	20-Jan-24	17-Feb-24	8.270			821.3	36.5	**36.4**
2				8.150			814.5	36.2	
3				8.190			823.5	36.6	

For the Representative (CSCEC)

Materials Technician	Materials Engineer
Sign: Hamza .	Sign: [illegible]
Date: 17.2024	Date: 18/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD
Block 36, Plot 95, 11&711,Kitebi Kibuga Kampala,Sssuna II Road, Nyanama Zone
Mutundwe, Lubaga Division
P.O.Box 29285 KAMPALA
Tel: +256(0)755046031/708898888
Email: cscecjiangbo@gmail.com

Ref. Test Method:BS EN 12390-3: 2002

Concrete Class	C25/20	Cube Dimension	150 x 150x 150	
Mix Description		Cement Type	Tororo Portland CEMI 42.5 N	

Proportions by weight	CEMENT	Water	Agg(6-20)	Sand	W/C ratio
	10.5	5.2	25.8	17.3	0.50
%	17.9	8.8	43.9	29.4	

Casting Date	Testing Date	% Basalt	Av. Slump (mm)	Compressive strength @7 days	Compressive strength @28 days	Water Absorption %	Setting Time (hrs) Initial	Setting Time (hrs) final
19-Jan-24	16-Feb-24	0	81	37.5	40.5	0.00	5.5	9.0
19-Jan-24	16-Feb-24	10	85	38.4	41.8	0.12	5.0	8.4
19-Jan-24	16-Feb-24	15	87	39.6	43.9	0.24	4.5	7.7
19-Jan-24	16-Feb-24	20	90	37.4	40.1	0.31	4.0	7.1
19-Jan-24	16-Feb-24	25	93	35.7	38.5	0.27	3.5	6.6
19-Jan-24	16-Feb-24	30	98	34.1	36.4	0.36	3.0	6.2

For the Representative (CSCEC)

Materials Technician		Materials Engineer	
Sign:	Hamza	Sign:	[illegible]
Date:	16/02/2024	Date:	17/02/2024

CHINA STATE CONSTRUCTION ENGINEERING CORPORATION LTD P.O.Box 29285 Kampala 17 FEB 2024 (CSCEC)

Appendix G: Laboratory tests and materials

Concrete mix

Slump test

Casting of concrete cubes

Curing of cubes

Compressive strength test

Project Partners