EVALUATION OF THE POTENTIAL USE OF EGGSHELL POWDER AS PARTIAL REPLACEMENT OF CEMENT AND NATURAL CORN FIBER AS ANADDITIVE IN CONCRETE

By

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PLAIGARISM

CERTIFICATION

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DEDICATION

I humbly dedicate this project to God, the source of all wisdom and guidance. With heartfelt gratitude for His unwavering support, I entrust this work into His hands, acknowledging that every step has been guided by His grace.I dedicate this project to my loving family. Your unwavering support, encouragement, and understanding have been my pillars throughout this journey.

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ABSTRACT

The primary objectives of this research is to develop a suitable mix design to achieve high strength concrete by replacing cement with eggshell powder and addition of corn fiber as an additive. This study aims to understand the effect of using egg shell powder and corn fiber in concrete production in construction works.

This methodology used for the development of high strength concrete through partial replacement of cement with eggshell powder and corn fiber as an additive entails using a methodical approach which includes using a suitable mix design and conducting series of tests on the concrete, these tests include: slump test, sieve analysis, aggregates impact value test, specific gravity test, durability test, compression test and flexural test on the concrete.

As seen in the research work, there was a noticeable but minute decrease in the slump as the replacement % increases , an increase in durability as the eggshell powder % increases for 5% and 10% but reduced by 15% replacement, there was also an increase in the compressive strength for the 5% and 15% replacement concrete with 5% having the highest strength but a decrease in strength occurred in the 10% replacement concrete. It was also noted that the flexural strength of the concrete increased as the replacement % increases with 10% having the highest strength.

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ACRONYMS

ESP- Egg Shell Powder

CF- Corn Fiber

OPC- Ordinary Portland Cement

SDA- Saw Dust Ash

CCA- Corn Cob Ash

RHA- Rice Husk Ash

PF- Polypropylene fibers

CBA- Cost Benefit Analysis

ASR- Alkali-Silica Reaction

ESP/CF- Egg Shell Powder and Corn Fiber

GGBFS- Ground Granulated Blast Furnace Slag

CHAPTER ONE

INTRODUCTION

1.1 Background of Study

The frequent use of concrete has caused the cost of building materials to increase very rapidly in some parts of the world even in developing countries like India, which has reduced its affordability to industries, government, business organizations and a few individuals.

According to Long (2008) stated that concrete is defined as material used in construction structures such as beam, column, and slab due to his sustainability in carrying load. But it should be noted that concrete strength has its limits when it comes to excessive force exerted that may lead to concrete failure even though concrete is an indispensable material in every construction. Concrete is the second largest material used in the world hence its high price. Few researches over the years has shown that there are many alternative materials that can be used in place of cement. There are many alternatives examples are: rice husk ash, fly ash, egg shell, glass powder etc. When choosing an alternative in construction we must ensure it is economical and easily available.

Though the European Commission classifies eggshell as a hazardous material, using eggshell powder in place of cement can aid in waste reduction and contribute to sustainability initiatives. Eggshell powder replaces cement in concrete manufacturing due to its high calcium content**.** Nigeria has the largest annual egg production and second largest chicken population in Africa. The partial incorporation of eggshell into concurrent mix will not only reduce the cost of production but also reduces the rate of wastage in Nigeria.

Eggshells contain calcium carbonate, a mineral that reacts with cementitious materials, contributing to the formation of calcium silicate hydrates – the compounds responsible for concrete strength. The use of eggshells can also enhance the workability and reduce the permeability of the concrete mix. However, it's crucial to conduct thorough research and testing to determine the optimal proportions and assess the performance of eggshell-incorporated concrete in specific construction applications.

Natural corn fiber, as a cellulose-based material, being a fibrous material, can act as a reinforcement in cement composites. It enhances the tensile strength and toughness of the concrete, addressing some of the limitations of conventional concrete, which is weak in tension,. The addition of corn fiber can help reduce shrinkage and cracking. It is a renewable resource, making it a sustainable choice. Incorporating such organic materials into concrete aligns with eco-friendly practices and reduces dependence on non-renewable resources. Corn fiber is lightweight, and adding it to concrete can result in a reduction of overall material density. This can be advantageous in applications where weight is a critical factor, such as in construction or transportation.

1.2 Statement of Problem

The conventional production of concrete, primarily reliant on cement, poses significant environmental and sustainability challenges. The high demand for construction materials, coupled with the environmental impact of cement production, necessitates exploration into alternative additives. While recent studies like Obinna.(2021) “Cement replacement materials’, khalid et al.,(2010) ‘Comparison of different waste materials as cement replacement in concrete’, have investigated various materials a partial replacements for cement, there remains a distinct gap in understanding the synergistic effects and practical applicability of eggshell and corn fiber as additives in concrete mixtures. This research aims to address this gap by systematically evaluating the mechanical, durability, and environmental implications of partially replacing cement with eggshell and using corn fibers an additive, providing crucial insights for sustainable construction practices

1.3 Aim and Objective

The aim of the study is to evaluate the potential use of eggshell powder as partial replacement of cement and natural corn fiber as an additive in concrete.

The objectives of the study are

1.To examine the impact of eggshell and corn fiber on the mechanical properties (slump test, compressive strength, tensile strength and flexural strength) of concrete.

2.To investigate how the addition of eggshell and natural corn fiber affects the strength of concrete.

3.To analyze the economic implication of partial cement replacement using eggshell and natural corn fiber(additives)

1.4 Scope of study

The scope of study involves the use of chicken egg shell powder as part of cement (Ordinary Portland Cement(OPC) grade 42.5N) and natural corn fiber in concrete production. The study will assess the impact of these local materials (eggshell and natural corn fiber) on the mechanical properties and the durability of concrete, and also analyze the implications of using these local materials in concrete production.

1.5 Justification of study

The justification of the study are

1.Eggshell and corn fiber are agricultural waste products, making their use in concrete an environmentally friendly option. This aligns with global efforts towards sustainable construction practices.

2.Utilizing eggshells and corn fiber in concrete provides a means to repurpose waste materials that would otherwise be discarded, contributing to waste reduction and resource efficiency.

3.As waste products, eggshells and corn fiber may offer a cost-effective alternative to traditional concrete additives, potentially reducing overall construction costs.

4.Studies suggest that the inclusion of certain organic materials in concrete can enhance its mechanical properties, such as increased compressive strength and durability.

5. The study allows for investigating how the combination of eggshell and corn fiber influences the specific properties of the concrete, such as workability, setting time, and resistance to cracking.

6. It will help a country's economy growth since eggshell and corn fiber are readily available.

CHAPTER TWO

LITERATURE REVIEW

2.1 Review of related works

Karthick et al.,(2015) investigated the replacement of fine aggregate with egg shell. Here they had replaced the Egg shell up to 10%, 20%, 30%, 40% & 50%. They concluded that, the tensile strength, flexural strength was decreased with increasing eggshells percent. The tensile strength decreased from (2.36N/mm²) to (0.21 N/mm²) with increasing egg shell from (0 wt %) to (50 wt %).

Prasad et al.,(2017) investigated the workability and flexural strength of cement concrete containing silica fume and polypropylene fibers. Silica fume content used was 0%, 5%, 10% and 15% by replacement of equal weight of cement in concrete. Polypropylene fibers were added in 0%, 0.20%, 0.40% and 0.60% by volume fraction of concrete. Silica fume appeared to have an adverse effect on the workability of fiber concrete. It is observed from slump test results of PF0S0 to PF0.6S15 that there is continuous decrease in workability of concrete with increase in polypropylene fiber content. The increase in flexural strength was found to be around 40% with the use of polypropylene and silica fume compared to the reference concrete.

Kumar et al.(2021)has investigated the combined use of eggshell and silica fumes as an alternative to cement. Egg shell powder replaces 10%, 20% and 30% in addition with the silica fume by 5%, 10%, 15% of weight of cement in the M30 concrete. The compressive strength of concrete with egg shell powder increases up to 15 percent without silica fume. Addition of silica fume also enhances the strength but in economical point of view only the egg shell powder replacement is sufficient enough for getting higher strength. The split tensile strength of the egg shell powder concrete decreases with the addition of egg shell powder. The flexural strength of the egg shell concrete increases with the addition of egg shell powder up to 15 percent.

Yerramala et al.,(2015) studied the properties of concrete with eggshell powder as cement replacement. This paper describes research into use of poultry waste in concrete through the development of concrete incorporating Egg Shell powder (ESP). Different ESP concretes were developed by replacing 5-15% of ESP for cement. The results indicated that ESP can successfully be used as partial replacement of cement in concrete production. The data presented cover strength development and transport properties. With respect to the results, at 5% ESP replacement the strengths were higher than control concrete and indicate that 5% ESP is an optimum content for maximum strength. In order to investigate properties of ESP concretes, five mixes were employed in this study. Several laboratory trial mixes were carried out with 300kg/m3 cement. Water to cementitious ratio, coarse and fine aggregate quantities was arrived for concretes to be tested from the trial mixes. In this study, Compressive loading tests on concretes were conducted on a compression testing machine of capacity 2000 KN. For the compressive strength test, a loading rate of 2.5 kN/s was applied as per IS: 516.1959. The test was conducted on 150mm cube specimens at 1, 7 and 28 days. Compressive strength was higher than control concrete for 5 % ESP replacement at 7 and 28 days of curing ages. ESP replacements greater than 10 % had lower strength than control concrete. Addition of fly ash improved compressive strength of ESP concrete.

D.Gowsika et al.,(2014) experimentally investigated the Egg Shell Powder as Partial Replacement with Cement in Concrete. This paper reports the results of experiments evaluating the use of egg shell powder from egg production industry as partial replacement for ordinary Portland cement in cement mortar. The chemical composition of the egg shell powder and compressive strength of the cement mortar was determined. The cement mortar of mix proportion 1:3 in which cement is partially replaced with egg shell powder as 5%, 10%, 15%, 20%, 25%, 30% by weight of cement. The compressive strength was determined at curing ages 28 days. There was a sharp decrease in compressive strength beyond 5% egg shell powder substitution. The admixtures used are Saw Dust ash, Fly Ash and Micro silica to enhance the strength of the concrete mix with 5% egg shell powder as partial replacement for cement. In this direction, an experimental investigation of compressive strength, split tensile strength, and Flexural strength was undertaken to use egg shell powder and admixtures as partial replacement for cement in concrete.

Freire et al.(2016) carried out the investigation on egg shell waste and found out its use in a ceramic wall tile paste. Based on the presence of $CaCO_3$ it can be used as a alternative raw material in the production of wall tile materials they also found that egg shell can be used as an excellent alternative for material reuse and waste recycling practices.

Anjaneyulu.,(2017) evaluated the effects of partially replacing cement in concrete with waste Materials. Concrete cubes of size 150mm x 150mm x 150mm with different percentages of Corn Cob Ash(CCA) and Saw Dust Ash(SDA) to cement in the order of 0 %, 10 % and 15 % were cast. The concrete cubes were tested at the ages of 7, 14, 21, 28 and 56 days. The highest compressive strength was 24.9 N/mm2 and 22.4 N/mm2 at 56 days for 0 % and 10 % of CCA (M25) and 24.9 N/mm2, 23.9 N/mm2 for SDA (M25) respectively. The researcher concluded that the use of CCA and SDA as a partial replacement for cement in concrete, particularly in plain concrete works and non-load bearing structures, will improve waste to wealth initiative through only 10 % CCA and SDA replacement.

Binici et al.,(2008) found in their study that an increase in ash content caused a significant increase in the sodium sulphate resistance of the concretes. The researcher reported that microscopic analysis showed that Corn Cob Ash(CCA) as an additive had a more condensed physical structure than Portland cement, making it more resistant to sulphate attack.

Dhanalakshmi et al.,(2023) investigated the partial replacement of Egg Shell Powder (ESP) and Fly Ash(FA). The carbon dioxide produced by cement industries causes environmental pollution and global warming. In 1000Kg of cement manufacturing processes approximately 900Kg of CO_2 is emitted. In order to reduce the impact of cement production on atmosphere, wastes by products are used as admixture in this study, so that environmental pollution and natural resources consumption is reduced.

Raji et al.,(2015) investigated the potential use of used egg shell as a concrete material. The used egg shells were used as fine concrete aggregate. In the laboratory test, conventional fine aggregate was replaced at 100% replacement level. A total of 18 cubes were cast, cured and tested. The strength development of the concrete mixes containing egg shell aggregates was compared to that of conventional concrete with sand as fine aggregate. The result showed a reduction in compressive strength of the concrete but still falls within limits of lightweight concrete.

Okonkwo et al.,(2012) investigated the effect of eggshell ash on the strength properties of cement-stabilized lateritic soil. The lateritic soil was classified to be A-6(2) in AASHTO rating system and reddish-brown clayey sand (SC) in the Unified Classification System.

Constant cement contents of 6% and 8% were added to the lateritic soil with variations in eggshell ash content of 0% to 10% at 2% intervals. All proportions of cement and eggshell ash contents were measured in percentages by weight of the dry soil. The Compaction test, California Bearing Ratio test, Unconfined Compressive Strength test and Durability test were carried out on the soil-cement eggshell ash mixture.

Yalley et al.,(2021) utilized corn husk as cementitious material to improve the strength of fiber reinforced. Corn husk ash was found to compensate the strength losses due to pores caused by the coconut fiber.

Ahumada et al.,(2021) investigated the improvement in setting time and adhesive property and properties of the material optimized with partial replacement in the mixture up 15 to 20%.

Fisal et al.,(2015)investigated the use of corn husk and snake plant fiber for paper production. This study aims to produce quality paper out of corn husks and snake plant fibers. It also seeks to determine the qualities of produced paper through laboratory experiment and sensory evaluation. Experimental design was utilized in developing paper. In line with this, increasing demand for paper was leading to rapid environment destruction.

Priya et al.,(2017) studied the partial replacement of cement with Corn Cob Ash (CCA) and coarse aggregate with steel slag. The CCA was used to replace cement partially in 5 % and 10 % ratio while steel slag was used to replace aggregate partially in 40 % and 50% ratio. They carried out compressive strength test, split tensile strength test and flexural strength test at ages of 7, 14 and 28 days. The researcher concluded that concrete acquires maximum increase in strength of concrete at 5% replacement of cement by CCA and 40% coarse aggregate replacement by steel slag.

Antonio et al.,(2014) evaluated the benefits of replacing Ordinary Portland Cement (OPC) with Corn Cob Ash(CCA) blended cements. They carried out an experiment to designate an appropriate percentage replacement of CCA that would comply with specific standards of cement production. The experimental plan was designed to analyze compressive strength, workability and thermal performance of various CCA blended cements. The researchers concluded that up to 10 % CCA replacement could be used in cement production without compromising the structural integrity of OPC and that the compressive strength and workability of the resulting concrete could be improved when CCA is added to the mixtures.

Kumari et al.,(2018) investigated the partial replacement of cement with corn cob. It can be replaced up to 7.5% level with cement for load bearing structure and for non–bearing structures up to 12.5%. corn cob ash concrete or Corn cob- rice husk ash concrete are alternate cementitious material and use of these ashes can help in reducing emission of carbon dioxide in atmosphere, impacts on environment and reduce cost of cement.

Shruthi.,(2022) examined the partial replacement of cement with Corn Cob Ash(CCA) and Rice Husk Ash(RHA) in concrete. The maximum compressive strength of t he concrete was obtained when 15% of RHA and CCA was used to replace cement in the concrete.

2.2 Partial replacement

Partial replacement refers to a situation where a component or part of a system is replaced with a new one, while the rest of the system remains intact. This concept is commonly applied in various fields such as engineering, manufacturing. In engineering and manufacturing, partial replacement might involve replacing only certain components of a machine or system that have become worn out or obsolete, without replacing the entire system. This approach is often more cost-effective and time-efficient compared to replacing the entire system.Partial replacement in the context of concrete typically refers to the substitution of a portion of the cementitious materials used in concrete mixtures with alternative materials. This practice is primarily aimed at improving sustainability, reducing costs, and enhancing certain properties of concrete.The most common form of partial replacement in concrete involves substituting a portion of the cement with supplementary cementitious materials (SCMs) such as fly ash, slag cement, silica fume, or natural pozzolans like calcined clay or metakaolin. These materials react with calcium hydroxide in the presence of water to form additional cementitious compounds, thereby improving the strength, durability, and other performance characteristics of concrete. Partial replacement of cement in concrete involves substituting a portion of the cementitious materials with alternative materials while maintaining the desired performance and properties of the concrete mixture. This practice is commonly employed to improve sustainability, reduce costs, and enhance specific characteristics of concrete.The most common alternative materials used for partial replacement of cement include: Fly ash, Slag cement,Silica fumes, Natural pozzolans, Ground granulated blast furnace slag (GGBFS), Rice husk ash (RHA), Geopolymer cement, Calcium sulfoaluminate (CSA) and for this research Egg shell powder.

2.2.1 Benefit of partial replacement are

1. Environmental Sustainability

Many alternative materials, such as fly ash, slag, and recycled materials, reduce the demand for virgin resources and can lower carbon emissions associated with cement production.

2. Resource Conservation

By using waste byproducts like fly ash, slag, or recycled materials, partial replacement helps in reducing landfill waste and conserving natural resources.

3. Improved Durability

Some alternative materials, such as fly ash and slag, can enhance the durability and long-term performance of concrete, reducing the risk of cracking and deterioration.

3. Cost Savings

Depending on local availability and regulations, alternative materials may be more cost-effective than traditional cement, leading to potential cost savings in construction projects.

Mitigation of Alkali-Silica Reaction (ASR) Some alternative materials, such as fly ash and slag, have been shown to mitigate the risk of ASR, a chemical reaction that can lead to concrete deterioration overtime.

2.3Additives

Additives are substances added to the mixture during mixing or directly to the concrete mix to alter its properties or enhance its performance in various ways. These additives can include:

1. Plasticizers

Also known as water reducers, plasticizer are additives that improve the workability of concrete without increasing water content. They help in achieving higher slump values and reducing the water-cement ratio, which can improve strength and durability.

2. Superplasticizers

These are high-range water reducers that can significantly increase the slump of concrete without increasing water content. Superplasticizers are often used in high-performance concrete mixes to improve workability, especially in applications such as pumping and self-consolidating concrete.

3. Accelerators

Additives that speed up the setting and early strength development of concrete. They are particularly useful in cold weather concreting or when rapid construction schedules are required. Common accelerators include calcium chloride and non-chloride accelerators like calcium nitrate.

4. Retarders

These additives delay the setting of concrete, allowing for more extended placement and finishing times. They are beneficial in hot weather conditions or when long transportation times are involved. Common retarders include lignosulfonates and citric acid.

5. Air-entraining agents

These additives create small, stable air bubbles in concrete, which improves its resistance to freeze-thaw cycles, enhances workability, and reduces bleeding and segregation. Air-entraining agents are essential for concrete used in cold climates or exposed to de-icing salts

6. Fiber reinforcement

Fibers such as steel, polypropylene, or glass fibers can be added to concrete to improve its toughness, impact resistance, and durability. Fiber-reinforced concrete is commonly used in applications such as industrial floors, pavements, and shotcrete.

7. Corn fiber

Corn fiber can be used as a sustainable additive in concrete production. When added to concrete mixtures, corn fiber can enhance properties such as strengthand sustainability. It can also help reduce the carbon footprint of concrete production by replacing some of the traditional materials with renewable alternatives. Additionally, corn fiber can contribute to improving the thermal and acoustic insulation properties of concrete, making it a versatile additive in construction applications.

These additives play crucial roles in tailoring concrete mixes to meet specific performance requirements and project needs, ensuring the desired properties and characteristics are achieved.

2.4 Mix ratio

The mix ratio for concrete specifies the proportions of various components used to make concrete (cement, sand and granite), typically measured by volume or weight. Common mix ratios include:

1. Standard mix (by volume): 1 part cement : 2 parts sand : 3 parts granite
2. High-strength mix: 1 part cement : 2 parts sand : 2 parts granite
3. Lean mix: 1 part cement : 4 parts sand : 8 parts granite

Others are:

1. M5: 1:5:10 (1 part cement, 5 parts sand, 10 parts aggregate)
2. M7.5: 1:4:8 (1 part cement, 4 parts sand, 8 parts aggregate)
3. M10: 1:3:6 (1 part cement, 3 parts sand, 6 parts aggregate)
4. M15: 1:2:4 (1 part cement, 2 parts sand, 4 parts aggregate)
5. M20: 1:1.5:3 (1 part cement, 1.5 parts sand, 3 parts aggregate)
6. M25: 1:1:2 (1 part cement, 1 part sand, 2 parts aggregate)

2.5 Cost benefit Analysis

Cost-benefit analysis (CBA) is a systematic approach to evaluating the strengths and weaknesses of alternatives used to determine options which provide the best approach to achieving benefits while preserving savings. It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.The goal is to quantify these factors as much as possible to make informed decisions about whether a particular project or investment is worthwhile. It's a powerful tool used in various fields including economics, business, public policy, and environmental management.

CHAPTER THREE

METHODOLOGY

3.1 Materials and properties

3.1.1 Eggshell

Eggshells are composed mainly of calcium carbonate, a 2crystalline structure that gives them strength. The porous nature of eggshells allows for gas exchange, crucial during embryo development. The inner membrane provides an additional barrier, protecting the egg's contents. When finely ground, eggshells contribute to the mix by enhancing its compressive strength and durability. The calcium carbonate in eggshells reacts with the cement, forming additional binding materials. This can reduce the amount of cement needed, making the concrete more environmentally friendly. However, incorporating eggshells requires careful consideration of particle size and proper mix proportions to achieve optimal results in terms of strength and workability.

Preparation of Egg Shell Powder(ESP)

1.The eggshellswere gotten from a chicken poultry.

2.The eggshells were cleaned up and boiled to remove impurities.

3.The eggshell was grinded with a blender until it became very smooth.

Plate 3.1. Boiling eggshell

Plate 3.2. Grinded eggshell

Plate 3.3. Eggshell powder

Note: The eggshell is used to replace the cement in several percentages. For this project the percentages used are: 0%, 5%, 10% and 15%

3.1.2 Natural corn fiber

Natural corn fiber is a fibrous material derived from corn (maize) processing. Corn fiber may be used as a sustainable and eco-friendly additive. Researchers have explored incorporating agricultural byproducts like corn fiber into concrete mixes to improve its properties. The fibrous nature of corn fiber can enhance the concrete's toughness

Plate 3.4. Natural corn fiber

and reduce cracking. Additionally, using renewable resources like corn fiber aligns with the broader goal of making construction materials more environmentally friendly and cheap. The size and length of the natural corn fiber was considered, shorter fiber are often more effective in preventing cracking.

Note: The corn fiber is added at a percentage of the total concrete mix. For this project the corn fiber is added at 1.5% of the total concrete mix

3.1.3 Cement

Cement is a binder material used in construction, typically composed of limestone, clay, shells, and silica. When mixed with water, it forms a paste that binds aggregates like sand and gravel together. Concrete is a composite material made by combining cement with these aggregates. Cement acts as the glue, binding the particles in the concrete mix and solidifying it into a durable and versatile construction material. For this project Dangote cement of grade 42.5N is used.

3.1.4 Coarse aggregates

Coarse aggregate, typically in the form of crushed granite, is a fundamental component of concrete. Granite used as coarse aggregate typically ranges in size from 3/8 inch to several inches in diameter. It provides strength and stability to the concrete by reinforcing the matrix of cement paste. It enhances the overall mechanical properties, such as compressive strength and durability, of the concrete. Granite aggregates are denser than some other types of aggregates, contributing to the overall density of the concrete mix.

Granite is a durable and hard material, contributing to the long-term durability of the concrete structure. The gradation or distribution of particle sizes in the coarse aggregate affects the packing density and, consequently, the overall performance of the concrete.

3.1.5 Fine aggregates

Fine aggregate in concrete refers to the smaller particles of sand, typically passing through a 4.75 mm (No. 4) sieve. It plays a crucial role in concrete mixtures by filling the voids between coarse aggregates and cement particles, enhancing workability, and contributing to the overall strength and durability of the concrete. The properties of fine aggregate, such as particle shape, size distribution, and texture, influence the workability and strength of the concrete mix. Choosing the right type of fine aggregate is essential for achieving desired concrete characteristics.

3.1.6 Water

Water is a key component in the concrete mix. It reacts with cement to form a paste, binding the aggregates together. The amount of water used affects the workability and strength of the concrete. An optimal water-cement ratio is essential for achieving the desired properties without compromising durability. Also using more water than necessary in the mix, known as a high water-cement ratio, can weaken the concrete. It may lead to increased porosity, lower strength, and decreased durability. It's important to balance workability with the need to maintain the structural integrity of the concrete. Portable water obtained from Civil and Structural Engineering Laboratory, UNIBEN was used for this study.

3.1.7 Durability and permeability of concrete

For durability lower ratios generally lead to more durable concrete. Adequate curing during the early stages is crucial for achieving long-term durability. Using high-quality, well-graded aggregates enhances durability. Incorporating air bubbles helps resist freeze-thaw cycles in colder climates. For permeability lower ratios generally result in less permeable concrete. Proper curing reduces the permeability of concrete by promoting denser and less porous microstructures. Smaller, well-distributed pores contribute to lower permeability. Certain admixtures can reduce permeability by modifying the structure of the concrete.

Lower permeability often contributes to increased durability. A less permeable concrete is less susceptible to the ingress of harmful substances, protecting it from chemical attacks and proper mix design, curing practices, and material selection.

3.2 Test carried out on concrete and it's material

3.2.1 Slump test

The slump test is a standard test in civil engineering to measure the consistency of freshly mixed concrete. It helps assess the workability of concrete, indicating how easily it can be mixed, placed, and compacted.

Procedure for slump test

1. Gather necessary equipment: slump cone, tamping rod, scoop, base plate, and a tarpaulin or plastic sheet. Ensure the slump cone and tamping rod are clean and free from any residual materials.
2. Prepare a representative sample of the concrete mix to be tested.
3. Place the slump cone on a level, stable surface, such as a base plate. Moisten the inside of the slump cone to prevent the concrete from sticking.
4. Fill the slump cone with the concrete in three layers, each approximately one-third of the cone's height, compacting each layer using the tamping rod. Apply 25 strokes evenly distributed over the cross-section of each layer.
5. After the last layer, stroke off the excess concrete level with the top of the cone using the tamping rod.
6. Lift the slump cone vertically and without any lateral or twisting motion to avoid disturbing the concrete inside.

7. .Measure the difference in height between the top of the cone and the displaced concrete. This is the slump value.
8. Record the slump value in millimeters. The measured slump provides an indication of the consistency of the concrete.

3.2.2 Sieve Analysis

Sieve analysis is a technique used in engineering to determine the particle size distribution of a granular material. It involves passing a sample of the material through a series of sieves with progressively smaller openings and measuring the amount of material retained on each sieve. This data helps engineers understand the distribution of particle sizes within the material, which is crucial for various applications such as determining the suitability of aggregate for construction projects or assessing soil properties for geotechnical engineering purposes. For the Sieve Analysis of cement and eggshell powder the 75 micron Sieve is used since the eggshell powder is replacing part of the cement

Procedure for the Sieve analysis of granite

1. Obtain arepresentative sample of the coarse aggregate.
2. Choose a series of sieves with larger openings to accommodate the size of the coarse aggregate particles. These include 3/4 inch (19.0 mm), 0.52 inch (13.5 mm), 0.31 inches (8.0mm), and 0.19 inches (5.0 mm).
3. Record the initial weight of each sieve before starting the analysis.
4. Stack the sieves in order of decreasing mesh size, with the largest sieve at the top and the finest sieve (usually No. 200 or smaller) at the bottom. Place a catch pan or container at the bottom to collect the fines.

5. Place the prepared sample on the top sieve and cover it. Then, agitate or shake the stack of sieves manually or using a mechanical shaker. The sieving process may need to be adjusted for the larger particle sizes, and it's important to ensure thorough separation.
6. After sieving, weigh the material retained on each sieve, as well as the material collected in the catch pan.
7. Calculate the percentage of material retained on each sieve, as well as the cumulative percentage passing for each sieve size. Plot a particle size distribution curve using this data.
8. Analyze the results to understand the particle size distribution of the coarse aggregate.
9. Clean the sieves thoroughly after use to prevent contamination and ensure accurateresults for future analyses.

3.2.3 Specific gravity test

The specific gravity test is a technique used to measure the density of a substance compared to the density of a reference substance, usually water. It's commonly used in various industries like construction, medicine, and brewing to assess the purity or concentration of a sample.

Procedure for the specific gravity of cement

1. Gather the necessary equipment, including a specific gravity flask, balance, distilled water, and a thermometer

2. Weigh the clean, dry specific gravity flask on a balance and record its mass accurately.

3. Fill the specific gravity flask with distilled water at room temperature up to the calibration mark.

4. Weigh the flask with water accurately and record its mass.

5. Dry a representative sample of cement in an oven at a temperature of around 105°C to 110°C until it reaches a constant weight.

6. Weigh the dried cement sample accurately.

7. Calculate the specific gravity of the cement using the formula

Equation 3.1: Formula for the specific gravity of cement

$$\boldsymbol{S.G} = \frac{(\mathbf{w2} - \mathbf{w1})}{[(\mathbf{w2} - \mathbf{w1}) - (\mathbf{w2} - \mathbf{w4}) \times \mathbf{0.81}]}$$

W1: weight of empty flask

W2: weight of flask + cement

W3: weight of flask + water + cement

W4: weight of flask + water

8. Record the specific gravity of the cement sample and compare it with the standard specific gravity value, typically around 3.15.

9. Clean and dry all equipment thoroughly for future use.

3.2.4 Aggregate impact value test

The Aggregate Impact Value (AIV) test is used to determine the impact value of aggregates, which provides a relative measure of the resistance of an aggregate to sudden shock or impact. It's commonly used in construction to assess the suitability of aggregates for use in different applications like road construction and concrete.

Procedures for Aggregate impact value test

1. Obtain a representative sample of the aggregate to be tested. The sample should be clean and free from dust, dirt, and other impurities.
2. Set up the necessary apparatus, which usually includes an impact testing machine, cylindrical measure, tamping rod, balance, sieves, and oven.
3. Sieve the sample through the appropriate sieves to obtain the required particle sizes, typically 12.5 mm and 10 mm aggregates.
4. Take about 14-16 kg of the prepared sample and place it in the cylindrical measure. Compact the sample by giving 25 strokes of the tamping rod uniformly over the surface.
5. Place the prepared sample in the impact testing machine. Apply a total of 15 blows of specified weight and fall height evenly distributed over the surface of the sample.
6. After the impact testing, sieve the material through the appropriate sieve sizes (typically 2.36 mm sieve).
7. Lower AIV values indicate stronger aggregates, while higher values indicate weaker aggregates.
8. Record the test results accurately, including all relevant details such as sample identification, test apparatus used, test conditions, and the calculated Aggregate Impact. Use the test results to assess the quality and suitability of thegranite

3.2.5 Setting time

The setting time of cement refers to the period it takes for the cement paste to change from a fluid state to a solid state. Initial setting time is when the cement paste begins to stiffen, and final setting time is when it becomes hard and cannot be reshaped.

Procedure of setting time of cement

1. Mix the cement with water according to the specified water-to-cement ratio until a homogeneous paste is formed.
2. Ensure the Vicat apparatus is clean and properly assembled.
3. Fill the Vicat mold with the prepared cement paste, ensuring it's filled uniformly without any air gaps.
4. Lower the needle gently onto the surface of the cement paste, ensuring it touches without any pressure.
5. Note down the initial time when the needle touches the surface of the paste. This marks the starting point of the test.
6. Gradually lower the needle into the cement paste at a constant rate. Trabbihe rate of descent is typically around 1 mm per second.
7. Continue lowering the needle until it meets with noticeable resistance, indicating initial setting. Record the time at which this resistance is observed.
8. Thee setting time is calculated as the difference between the initial and final times recorded.
9. Perform the test at least three times to ensure accuracy, and take the average of the results.

10. Analyze the results to determine the initial setting time and the final setting time of the cement paste.
11. Clean the Vicat apparatus and dispose of the cement paste properly.
12. Record the results for future reference and analysis.

3.2.6 Compressive test

The compressive strength test is a crucial procedure in assessing the ability of concrete to withstand loads that tend to compress it. It is a fundamental test in the field of civil engineering and construction.

Procedure for compressive test

1. Cast cube-shaped concrete specimens with dimensions (100mm ×100mm). Ensure proper compaction during the casting process to eliminate voids and achieve uniform density.
2. Cure the cube specimens in a controlled environment, such as a curing tank or moist room, for a specified period (7, 14, 21, 28 days).
3. Before testing, ensure the surfaces of the cube specimens are flat and even. Using a grinder.
4. Place the cube specimen in the compression-testing machine, ensure it is centered and aligned. The load should be applied evenly to avoid eccentric loading.
5. Gradually apply a compressive load to the cube specimen at a specified rate, usually between 20 and 50 pounds per square inch (psi) per second.
6. Record the applied load and the corresponding deformation or strain at regular intervals. This data is used to create a stress-strain curve.

7. Continue applying the load until the cube specimen fails. The failure point is typically reached when the load starts to drop, indicating that the concrete has reached its maximum compressive strength.
8. Calculate the compressive strength by dividing the maximum load at failure by the cross-sectional area of the cube.
9. Report the compressive strength in pounds per square inch (psi) or megapascals (MPa) as per the project.

3.2.7 Water absorption test

The water absorption test on concrete is a common procedure to determine its porosity and permeability. It involves saturating the concrete sample, weighing it, allowing it to dry, and then weighing it again to measure the water absorbed. This helps assess its durability and suitability for various applications.

Procedure for water absorption test

1. Weigh each sample individually to obtain its initial weight (W1).Saturate
2. Immerse the samples in water for a specific duration, usually 24 hours, to ensure they are fully saturated.
3. After saturation, remove the excess surface water from each sample using a damp cloth or paper towel.
4. Weigh each saturated sample again to obtain its saturated weight (W2).
5. Place the samples in a ventilated area or oven at a specified temperature (usually around 105°C) until they are completely dry.
6. Weigh each dried sample again to obtain its final weight (W3).
7. Calculate the water absorption percentage using the formula

Equation 3.2: Formula of water absorption percentage

$$Water\ Absorption\ (\%) = \left[\frac{w1 - w2}{w1}\right] \times\ 100$$

W1: Saturated weight of the sample after soaking

W2: Dry weight of the sample after soaking

Interpret the results based on the water absorption percentage. Higher absorption indicates higher porosity and potential durability issues.

3.2.7 Flexural test

A flexural test, also known as a bending test, evaluates the strength and behavior of a material when subjected to bending forces.

Procedure for flexural test

1. Cut a specimen of the material with specified dimensions, often in the form of a rectangular beam.
2. Place the specimen on supports, usually two points or three points, depending on the testing standard. The distance between the supports and the loading point is crucial for accurate results.
3. Gradually apply a load at the center of the specimen until it reaches failure or a predefined deformation limit
4. Record the applied load and corresponding deflection or deformation at specified intervals. Plot a load-deflection curve to analyze the material's behavior under bending stress.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. Properties of Materials

Table 4.1: Chemical Composition of Eggshell Powder

Composition	**Chemical name**	**Percentage (%)**
$CaCO_3$	Calcium carbonate	95
CI	Chloride ion	0.63
SO_3	Sulfur trioxide	0.60
Na_2O	Disodium monoxide	0.15
SiO_2	Silicon dioxide	0.08
AI_2O_3	Aluminum Oxide	0.04
Fe_2O	Ferric Oxide	0.02
MgO	Magnesium Oxide	0.01

From Table 4.1above it shows that's eggshell powder is mainly calcium carbonate (95%) with minimal impurities (<1%) making it suitable as a pozzolanic or filler material, it's high $CaCo_3$ can enhance cement hydration and strength. Source:(Ahmed, 2019)

Table 4.2: Chemical Composition Cement

Component	**Content(%)**
CaO	64.64
SiO_2	21.28
AI_2O_3	5.6
MgO	2.06
SO_3	2.14

Fe_2O_3	3.36
Total Alkalis	0.05
Insoluble residue	0.22
Loss in ignition	0.64

Table 4.2 above shows that cement is rich in CaO (64.64%) with normal levels of other elements indicating good quality for concrete and strength development

Source: (Sardar et al.,2018)

Table 4.3: Chemical Composition of Corn Fiber

Components	Composition (% dry weight)
Starch	16
Cellulose	14
Hemicellulose	39
Xylose	18
Arabinose	12
Galactose	3.3
Protein	10
Lignin	57

Table 4.3 above shows that corn fiber is mainly fibrous, with high hemicellulose (39%) and lignin (57%), plus starch (16%) and protein (10%). These properties suggest it can reinforce composite material

Source: (Yingue et al.,2022)

Table 4.4: Physical Characteristics of Corn Fiber

Sample No	Mass (Mg)	Length (mm)	Diameter	Volume	Density
			(nm)	(mm³)	(Mass/vol)
1	0.8	151	450	450	147.17
2	3	180	350	350	595.24
3	3.4	190	380	380	588.64
4	3.2	185	390	390	554.40

Table 4.4 above shows that's fiber mass, length, diameter, volume and density indicate how well corn fiber can disperse in concrete and contribute to tensile strength and crack resistance

Source: (Yeng P.S et al.,2012)

Table 4.5: Various Properties of Materials

Property		**Materials**		
	Cement	**Coarse Aggregate**	**Fine Aggregate**	**Eggshell**
Fineness Modulus	0.75	5.90	2.60	2.40
Specific Gravity (kg/m³)	3.18	-	-	2.66
Setting time				
Initial	1:37	-	-	-
Final	3:39	-	-	-
Aggregate impact value (AIV) (g)	-	28.50	-	-

The properties of material provides a critical data which helps to select the right materials to obtain the required characteristics properties of the concrete. The results from Table 4.5

above shows the integrity of the materials as it falls in range of the results obtained by(Khan A.G et al.,2014) and (Sagaret al.,2023)

4.2. Concrete Mixture Test 4.2.1 Slump Test

Table 4.6: Slump Test of Concrete Mix

%Replacement	Slump
0% control	10
5% ESP, 1.5% CF	10
10% ESP, 1.5% CF	8
15% ESP, 1.5% CF	7.6

From Table 4.6 above, it was noted that as the ESP percentage increases, the slump of the concrete mix decreases, affecting its workability.This findings closely align with the

research by (Sagar et al.,2023)

4.2.2 Weight of Concrete Before Curing

Table 4.7: Weight of Concrete before Curing (for 0% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.472	2.455	2.470	2.466
14	2.475	2.446	2.503	2.475
21	2.478	2.451	2.431	2.453
28	2.474	2.448	2.450	2.457

Table 4.8: Weight of Concrete before Curing (for 5% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.454	2.455	2.477	2.462
14	2.486	2.401	2.423	2.437
21	2.527	2.498	2.511	2.512
28	2.410	2.377	2.367	2.385

Table 4.9: Weight of Concrete before Curing (for 10% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.563	2.435	2.470	**2.489**
14	2.451	2.432	2.473	**2.432**
21	2.485	2.483	2.308	**2.430**
28	2.386	2.425	2.362	**2.391**

Table 4.10: Weight of Concrete before Curing (for 15% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.429	2.532	2.565	2.509
14	2.562	2.453	2.524	2.513
21	2.401	2.321	2.419	2.380
28	2.492	2.316	2.410	2.406

4.2.3 Weight of Concrete after Curing

Table 4.11: Weight of Concrete after Curing (for 0% replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.506	2.502	2.626	2.545
14	2.479	2.536	2.509	2.508
21	2.401	2.413	2.399	2.471
28	2.509	2.486	2.452	2.482

Table 4.12: Weight of Concrete after Curing (for 5% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.501	2.489	2.504	2.498
14	2.512	2.451	2.458	2.473

21	2.587	2.510	2.572	2.556
28	2.496	2.452	2.432	2.460

Table 4.13: Weight of Concrete after Curing (for 10% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.592	2.507	2.531	2.543
14	2.507	2.496	2.516	2.506
21	2.526	2.527	2.416	2.489
28	2.426	2.493	2.458	2.459

Table 4.14: Weight of Concrete after Curing (for 15% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.476	2.593	2.605	2.558
14	2.597	2.510	2.596	2.567
21	2.490	2.439	2.492	2.475
28	2.507	2.401	2.519	2.475

4.2.4. Weight of Concrete after Air Drying for Twenty-four Hours (24 hours)

Table 4.15: Weight of Concrete after Air Drying for 24 Hours (for 0% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.255	2.227	2.475	I'm2.326
14	2.276	2.270	2.205	2.250
21	2.199	2.136	2.176	2.170
28	2.261	2.221	2.243	2.241

Table 4.16: Weight of Concrete after Air Drying for 24 Hours (for 5% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.401	2.404	2.402	2.402
14	2.432	2.387	2.389	2.403
21	2.407	2.409	2.411	2.409
28	2.397	2.4021	2.398	2.399

Table 4.17: Weight of Concrete after Air Drying for 24 Hours (for 10% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.489	2.455	2.582	2.478
14	2.432	2.387	2.413	2.411
21	2.407	2.409	2.407	2.407
28	2.412	2.402	2.398	2.406

Table 4.18: Weight of Concrete after Air Drying for 24 Hours (for 15% Replacement)

Curing days	ESP/CF 1	ESP/CF 2	ESP/CF 3	Average
7	2.401	2.536	2.516	2.532
14	2.506	2.432	2.510	2.482
21	2.389	2.327	2.397	2.371
28	2.413	2.369	2.423	2.402

From Table 4.7 to 4.18 above, it was noted that over several curing days, the weight of the concrete increases, while the water loss after air drying for 24 hours is lower in the partially replaced concrete due to the presence of corn fiber, thereby increasing it’s water retentive capability.

4.2.5. Durability of Concrete Mixture on Different Curing Days

Table 4.19: Water Absorption (%) of Concrete after 7, 14, 21 and 28 Curing Days

S/N	% of ESP	Water Absorption (%) for 7 days	Water Absorption (%) for 14 days	Water Absorption (%) for 21 days	Water Absorption (%) for 28 days	
1	0	8	10	12	9	
2	5	3	3	5.7	2.4	
3	10	3	3	3	2	
4	15	2	3.7	4	3	

From Tables 4.19 above, For 7 days of curing it was noted that, as the ESP % percentage replacement increases from(0%-15%) the water absorption % reduces which is similar to result obtained by(Deepak et al.,2019). For the other curing days It was noted that the water absorption% decrease in the 5% and 10% replacement concrete and increased slightly in the 15

4.2.6.Compressive Strength of Concrete Mixture on Different Curing Days

Table 4.20: Average Compressive Strength (N/mm^2) of Concrete Cubes on 7, 14, 21 and 28 Curing Days

S/N	% of ESP	Average Compressive Strength (N/mm^2) on 7 days	Average Compressive Strength (N/mm^2) on 14 days	Average Compressive Strength (N/mm^2) on 21 days	Average Compressive Strength (N/mm^2) on 28 days
1	0	18.21	18.31	18.68	20.95
2	5	23.07	23.82	24.01	24.64
3	10	8.24	12.35	22.11	16.58
4	15	18.81	21.90	19.94	18.94

The compressive strength test determines the maximum load a concrete sample can withstand before failure. Resultsfrom Table 4.20 aboveshows an increase in compressive strength for the concrete with 5% and 15% cement replacement, but a decrease for the 10% replacement compared to the control, with 5%

replacement yielding the highest strength, but this contradicts researches by (Arif et al.,2021)which had 10% replacement yielding the highest strength.

4.2.7. Cost Benefit Analysis

Table 4.21: Cost Benefit Analysis of Partial Replacement of Cement with ESP

Material	**Quantity** (bags)	**Cost** (Naira)	**Cost (15% ESP** replacement)
Cement	14	182,000	162,500
Sand	28	25,200	25,200
Gravel	56	72,800	72,800
	Total	280,000	260,500

For the analysis an area of 2mwidth,6mlength and 150mm depth is used as a case study.

Results from Table 4.21above shows a decrease in the cost of material if the cement is replaced by 15% ESP.

4.2.8. Flexural strength of Concrete Mixture on Different Curing Days

Table 4.22: FlexuralStrength (MPa) of Concrete Beams on 7, 14, 21 and 28 Curing Days

S/N	**% of ESP**	**Average Flexural Strength (MPa) on 7 days**	**AverageFlexural Strength (MPa) on 14 days**	**AverageFlexural Strength (MPa)on 21 days**	**AverageFlexural Strength (MPa) on 28 days**
1	0	1.80	2.52	-	-
2	5	2.80	3.10	-	-
3	10	2.70	3.50	-	-
4	15	2.70	2.90	-	-

This was done to measure the material's ability to resist deformation under bending. Result from Table 4.22 aboveshows an increase in the flexural strength of the concrete at 5%, 10%, 15% cement replacement compared to the control concrete with 10 % replacement yielding the highest strength (3.50MPa) after 28 days of curingas (Swain, 2013) has earlier reported.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

- In conclusion, from the results acquired the partial replacement of cement with egg shell powder and corn fiber as an additive shows promising potential for enhancing the sustainability and performance of concrete. This innovative approach not only utilizes waste materials but also offers benefits such as improved strength, durability, and reduced environmental impact.
- After the several days of curing the concrete, it had the highest increase in compressive strength of (24.64N/mm²) at 5% replacement of cement with Eggshell powder and 1.5 % of corn fiber as an additive compared to the conventional concreteof (20.95N/mm²) after 28 days of curing.
- Aftercuring the concrete, there was an increase in compressive strength (18.89N/mm²) at 15% ESP replaced concrete after 7 days of curing, which then decrease to 18.94N/mm² after 28 days
- The concrete experienced failure in compressive strength (5.57N/mm²) at 10% ESP replaced concrete, which was a decrease from 18.21N/mm² at 0% replacement.
- It is observed that the ESP/CF concrete is more durable than the conventional concrete at all the % replacement with 15% replacement being the most durable with 2% water absorption followed by 5% and 10% replacement with 3% water absorption. This is likely due to the presence of corn fiber in the concrete which act as a good absorbent due to its porous structure and high surface.

- A replacement of this nature can reduce the cost of concrete material as observed from the cost benefit analysis which can help reduce the unavailability of construction materials to small income earner.

5.2 Recommendation

Findings from the study indicated that the ESP/CF concrete can be used in Roads, bridges, dams, and tunnels to withstand heavy loads and environmental factors because of its durability. The use of 5% ESP replacement is the recommended replacement in terms of compressive strength due to the highest compressive strength of 24.64N/mm^2 observed after 28 days of curing and a water absorption percentage of 3% which confirms it’s durability.

The use of high percentage of eggshell powder to replace cement in concrete is not effective as it losses its all round capabilities as the percentage of cement reduces.

It is therefore recommended that further research including pilot study should be conducted to evaluate the practical performance of concrete produced by partially replacing cement with eggshell powder and corn fiber as an additive. Also optimizing the mix proportions for various construction project should be assessed.

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APPENDIX

APPENDIX A: Laboratory Test and Mix design.

• A.1 Specific gravity test of cement

Table A.1: Specific gravity test of cement

W1	**49.2**
W2	**101.9**
W3	**160.7**
W4	**128.4**
W5	**147.5**

Using the formula from Equation 3.1, the specific gravity of cement is 3.18kg/m³

• A.2 Mix Ratio

15(1:2:4) = 1+2+4=7

No of cube(12) = 2.6 × 12= 3.12

Cement = □ × 31.2 = 4.46

Replacing cement

5% = 4.46 × 0.05 = 0.223(ESP). Cement = 4.24

10% = 4.46 × 0.1= 0.446(ESP). Cement= 3.791

15%= 4.46× 0.15= 0.669(ESP). Cement= 3.791

Sand=2/7 × 31.2= 8.91

Gravel= 4/7 × 31.2= 17.82

Water= 0.6 × 4.46= 2.676

Corn fiber(15%)= 4.46 × 1.5= 6.69

APENDIX B: Physical properties of material

Table B.1: Physical properties of materials used for the study

Materials	Physical properties	Value
Eggshell powder	Particle size Bulk density Color/Texture	Fine,~50-150 ñm ~0.8-1.0 g/cm White/Powdery
Cement	Fineness Specific gravity Setting time	~320-350m²/kg 3.15 Initial 30-45 min
Corn fiber	Fiber length Diameter Density Lignin content	5-15 mm 0.1-0.3mm 1.4-1.5 g/cm³ ~57%

The fine particles, size and moderate density of eggshell powder allow it to partially replace cement effectively, while corn fibers, with their specific length, diameter and high lignin content, provide reinforcement and improve crack and resistance in concrete mix

APPENDIX C: Cost benefit analysis

1 bag of cement= #13,000

1 bag of fine aggregates= #900

1 bag of coarse aggregates= #1,300

For 2m width, 6m length (100mm depth and mix ratio of 1:2:4 grade M15)

The following is required:

14 bags of cement= #182,000

28 bags of fine aggregates= #25,200

56 bags of coarse aggregates= #72,800

Total cost=#280000

Note: mix ratio - 1:2:4

With 15% replacement of cement with ESP, for every 1.8 cubic meter of concrete about

1½ bag of cement= #19500

New cost= #280000 - #19500

New total = #260,500

APPENDIX D: Photographs from the Laboratory

Plate D1: Sieving of fine aggregate (sand) during sample preparation

Plate D2: Performing the slump test to determine the workability of fresh concrete

Plate D3: Tamping the concrete in the slump cone

Plate D4: Mechanical mixing of concrete constituents using a rotary drum mixer