UNIVERSITY OF NAIROBI

PARTIAL SUBSTITUTION OF CEMENT WITH CRUSHED CHICKEN EGG SHELL POWDER

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Preliminary Pages

Abstract

This project seeks to examine the use of crushed egg shells as a partial substitute for cement in concrete. Ideally, the concrete made with partially replaced cement ought to retain its strength for the experiments to be considered a success. The chemical composition of egg shells is roughly 95% similar to that of cement and the ability to replace it without too much change in performance should be easily noticeable.

Egg shells are readily available as a waste product in Kenya. Collection of egg shells can be done at the numerous restaurants and bakeries that use a lot of eggs for their operation. Even if they are not enough to meet the needs of the entire construction industry, the fact that they are free would prove a great incentive for contractors to adopt. As a developing nation, Kenya is faced with the problem of having numerous construction projects required to be implemented. However, against a backdrop of low funds, it is necessary that creative means of lowering this costs be adopted.

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Chapter One

1.0 Introduction

1.1 Background

Hawkins et al (2003) argued that allowing for the use of up to 5% limestone in ordinary Portland cement does not affect its performance. Limestone powder substitution for cement makes sense in concretes saving money and energy and reducing carbon dioxide emissions. However, being that limestone is a material that requires to be mined, there arise problems with the conservation of the environment and the use of a non-renewable source for an industry as big as the construction industry. Furthermore, lime production involves energy intensive process and consumes water. Therefore, it becomes important to identify analogous material from waste and using the same in concrete production.

Calcium rich egg shell is a poultry waste with chemical composition nearly same as that of limestone. Use of eggshell waste instead of natural lime to replace cement in concrete can have benefits like minimizing use of cement, conserving natural lime and utilizing a waste material. Eggshell waste can be used as fertilizer, animal feed ingredients and other such uses. However, majority of the eggshell waste is deposited as landfills. Eggshell waste in landfills attracts vermin due to attached membrane and causes problems associated with human health and environment.

The construction industry relies heavily on the use of concrete. In the preparation of concrete, cement is the most expensive material in use. It is therefore prudent to look for substitutes to it with the aim of reducing the cost of construction. The use of waste materials in partial substitution is a good way to go about this. This project would therefore seek to test the usability of chicken egg shells as partial substitutes to cement at 5%, 10% and 15% substitution. The concrete would then be tested for strength, workability and weight. Due to the different mix strengths used in the industry, class 25 concrete would be used being the most widely used in Kenyan construction projects.

1.2 Problem Statement

Construction is an expensive process that forces us to look for ways of mitigating cost over runs. Currently, one of the main reasons for increase in the cost of construction is the cost of concrete. Concrete in itself contains cement, coarse and fine aggregates, water, sand and admixtures in some cases. Therefore, in order to reduce costs, two solutions present themselves; either we reduce the cost of the materials comprising concrete or substitute them with cheaper materials.

1.3 Problem Justification

The use of waste materials is a sure way of reducing the costs involved with preparation of concrete. Additionally, recycling of waste materials goes a long way in ensuring effort is made to conserve the environment. These materials however have to be viable in their use so as not to compromise on the quality of construction. Testing for their usability becomes crucial in the search for cheaper yet equally adequate materials.

1.4 Objectives

This project seeks to test for the viability of replacing Portland cement in concrete with crushed chicken eggs powder. This is to be done through the creation of concrete mixtures with the substitution and then testing them for strength and weight.

Specific Objectives:

- To determine the properties of crushed chicken egg shell powder.
- To design concrete using chicken egg shell powder as a partial replacement for Portland cement.
- To check the structural and economic feasibility of using chicken egg shell powder as a partial replacement for concrete.

1.5 Hypothesis

Chicken egg shell powder can be used as a partial replacement for Portland cement and exhibit the same structural strength.

1.6 Scope and Limitations of Study

The study encompassed the testing of concrete with partial replacement of cement with crushed chicken egg shells in the values of 5%, 10% and 15% for strength in both compression and tension.

The main limitation of the study was with the crushing equipment. At the time of getting the 28 day results, the machines did not work. The readings were therefore taken after 39 days. Particles with diameters of 10μm take roughly 28 days for complete hydration. As over 50% of the sample had particle sizes greater than this, it provided more time for hydration. Therefore, the strengths obtained may have been greater than would otherwise have been the case.

Chapter Two

2.0 Literature Review

2.1 Overview

In the production of cement, there is typically the use of a binder and filler. The binder glues the filler together so they can work as one. Typically, cement is used as the binder and is mixed with water to from a paste that may then be used in the concrete. The filler may consist of either coarse or fine aggregate.

In the making of concrete, water is a key ingredient. It is mixed with cement to form a paste that binds the concrete together. Once this is done, it facilitates the hardening of the concrete through the process of hydration. Hydration is a chemical reaction in which the major compounds in cement form chemical bonds with water molecules and become hydrates. In order to gain full strength, the concrete needs to hydrate, or cure as more commonly referred to. Concrete with too little water may be dried but not fully reacted. The strength properties of such concrete would be less than that of wet concrete. The ratio of water added is essential for the workability of the concrete. Too little water will render the concrete unworkable while too much water reduces the strength of the concrete (Shetty, 2000).

Few investigations have been conducted to use egg shell waste in civil engineering applications. Tests have been for the use of the powder as a stabilizing material to improve oil properties as well as a subgrade material for road construction similarly in stabilizing soil. This study was aimed to use egg shell powder in concrete. Although egg shells are calcium rich and analogous to limestone in chemical composition, it is a waste material. Therefore, to initiate use of eggshell waste for partial replacement of cement in concrete, there is a need to understand concrete properties made with eggshell powder. Thus, the primary objective of this study is to understand the possibilities of use of egg shell powder in concrete.

2.2 Physical properties of Cement

Portland cements are commonly characterized by their physical properties for quality control purposes. Their physical properties can be used to classify and compare Portland cements. The challenge in physical property characterization is to develop physical tests that can satisfactorily characterize key parameters. They are:

- **Setting Time.** This is the time the cement takes to stiffen. It is affected by cement fineness, water-cement ratio, chemical content (especially gypsum content) and admixtures. Setting is important in order to ensure the cement is prepared to the specifications required for it to work effectively as a binder.
- **Soundness.** This is the ability of a hardened cement paste to retain its volume after setting without delayed expansion. This expansion is caused by excessive amounts of free lime (CaO) or magnesia (MgO). Most Portland cement specifications limit magnesia content and expansion. The cement paste should not undergo large changes in volume after it has set. However, when excessive amounts of free CaO or MgO are present in the cement, these oxides can slowly hydrate and cause expansion of the hardened cement paste. Soundness is therefore the volume stability of the cement paste.
- **Fineness.** Fineness refers to the particle size of Portland cement. It affects Hydration rate and thus the rate of strength gain. The smaller the particle size, the greater the surface area-to-volume ratio, and thus, the more area available for water-cement interaction per unit volume. The effects of greater fineness on strength are seen during the first seven days. When the cement particles are coarser, hydration starts on the surface of the particles. So the coarser particles may not be completely hydrated. This causes low strength and low durability. For a rapid development of strength a high fineness is necessary.
- **Strength.** Cement paste strength is typically defined in three ways: compressive, tensile and flexural. These strengths can be affected by a number of items including: water-cement ratio, cement-fine aggregate ratio, type and grading of fine aggregate, curing conditions, size and shape of specimen, loading conditions and age (Newman & Choo, 2005).

2.3 Physical properties of Chicken Egg Shells

The main ingredient in eggshells is calcium carbonate, the same material that chalks, limestone, sea shells, coral, and pearls are made of. The shell itself is about 95% $CaCO_3$. The remaining 5% includes calcium phosphate and magnesium carbonate and soluble and insoluble proteins.

Name	**Physical Properties**
Specific Gravity	0.85
Moisture Content	1.18
Bulk Density (g/m^3)	0.8
Particle Density (g/m3)	1.012
Porosity (%)	22.4

Table 1: Physical Properties of Chicken Egg Shells

2.4 Chemical properties of Cement

Cement is made by crushing and proportioning lime, silica, alumina, iron and gypsum. Lime is found limestone, the compound found most abundantly in shells. Additionally, alumina is from recycled aluminium, also found in egg shells. Iron occurs as itself in egg shells. Therefore, these similarities are enough to suggest the performance of egg shells when partially substituted ought not to vary too much (Newman & Choo, 2005).

Oxide	**Per cent Content**
CaO	60% - 67%
SiO_2	17% - 25%
Al_2O_3	3% - 8%
Fe_2O_3	0.5% - 6%
MgO	0.1% - 4%
SO_3	1.3% - 3%
Alkalis (K_2O, Na_2O)	0.4% - 1.3%

Table 2: Chemical properties of Cement

2.4.1 Manufacture of Portland cement

The raw materials required for manufacture of Portland cement are calcareous materials, such as limestone or chalk, and argillaceous material such as shale or clay. Cement factories are established where these raw materials are available in plenty.

The process of manufacture of cement consists of grinding the raw materials, mixing them intimately in certain proportions depending upon their purity and composition and burning them in a kiln at a temperature of about 1300^{o}C to 1500°C, at which temperature, the material sinters and partially fuses to form nodular shaped clinker. The clinker is cooled and ground to fine powder with addition of about 3 to 5% of gypsum. The product formed by using this procedure is Portland cement (Shetty, 2000).

2.5 Chemical properties of Chicken Egg Shells

By composition, chicken egg shells contain 95% calcium carbonate. This is the same compound found in limestone. The rest contains elements such as magnesium, aluminium, phosphorous, zinc, iron and uranic acid. All these elements are not biodegradable and therefore their performance in concrete with respect to time ought not to vary.

Element/ Compound	Per Cent Content
$CaCaO_3$	95%
Aluminium	1% -2%
Zinc	0.4% - 0.9%
Iron	0.6% - 1%
Uranic Acid	0.2% - 0.4%
Phosphorous	0.5% - 0.8%

Table 3: Chemical properties of Chicken Egg Shells

2.6 Aggregates

Aggregates constitute roughly 70%-80% of concrete. It is therefore imperative that their characteristics be addressed. Being that they constitute such a large percentage of the concrete, the types of aggregates used will naturally affect the characteristics of the concrete they are used in making. Additionally, they play an important role in determining the cost of production of concrete. Therefore, aggregates give body to the concrete, affect the economy of production and reduce shrinkage in concrete.

2.6.1 Selection of Aggregates

Size

The largest maximum size of aggregate practicable to handle under a given set of conditions should be used. Using the largest possible maximum size will result in

(i) reduction of the cement content
(ii) reduction in water requirement
(iii) reduction of drying shrinkage

However, the maximum size of aggregate that can be used in any given condition may be limited by the following conditions:

(i) Thickness of section
(ii) Spacing of reinforcement
(iii) Clear cover
(iv) Mixing, handling and placing techniques

Shape

With regards to economy in cement requirement for a given water/cement ratio, rounded aggregates are preferable to angular aggregates. On the other hand, the additional cement required for angular aggregate is offset by the higher strengths and greater durability as a result of the interlocking texture of the hardened concrete and higher bond characteristic between aggregate and cement paste.

Flat particles in concrete aggregates will have particularly objectionable influence on the workability, cement requirement, strength and durability. Generally, excessively flaky aggregates make very poor concrete (Alexander & Mindness, 2005).

Classification	Description	Examples
Rounded	Fully water worn or completely shaped by attrition	River or seashore gravels; desert, seashore and windblown sands
Irregular or Partly Rounded	Naturally irregular or partly rounded by attrition, having rounded edges	
Angular	Possessing well-defined edges formed at the intersection of roughly planar faces	Crushed rocks of all types; talus; screes
Flaky	Material, usually angular, of which the thickness is small relative to the width and/or length	Laminated rocks

Table 4: Classification of Aggregates

Texture

Surface texture depends on hardness, grain size, pore structure, structure of the rock, and the degree to which forces acting on the particle surface have smoothed or roughened it. Dense, fine-grained materials will generally have smooth fracture surfaces. The adhesion between cement paste and aggregate is influenced by several factors in addition to the physical and mechanical properties.

As surface smoothness increases, contact area decreases, hence a highly polished particle will have less bonding area with the concrete than a rough particle of the same volume. A smooth particle will require a thinner layer of paste to lubricate its movements relative to other aggregate particles. It will permit denser packing for equal workability requiring lower paste content than rough particles (Alexander & Mindness, 2005).

Strength

Concrete is obtained through individual pieces of aggregate bound together by cementing material; its properties are based primarily on the quality of the cement paste. This strength is dependant also on the bond between the cement paste and the aggregate. If either the strength of the paste or the bond between the paste and aggregate is low, a concrete of poor quality will be obtained irrespective of the strength of the rock or aggregate. But when cement paste of good quality is provided and its bond with the aggregate is satisfactory, then the mechanical properties of the rock or aggregate will influence the strength of concrete. Thus, for making strong concrete, strong aggregates are an essential requirement (Alexander & Mindness, 2005).

Modulus of Elasticity

The modulus of elasticity of an aggregate depends on its composition, texture and structure. It influences shrinkage and elastic behaviour and to very small extent creep of concrete (Alexander & Mindness, 2005).

Chapter Three

3.0 Methodology

The methodology involved collection of egg shells from the surrounding areas. Due to the smell associated with raw egg shells, the shells of eggs that had been boiled were preferred in order to solve this problem. Egg shells that had been collected from eggs that had not been boiled were placed in hot water to kill of the decaying remains of the eggs. This also had the effect of separating the egg remains of the egg white and yolk in order to reduce the amount of impurities in the collected samples.

3.1 Materials

3.1.1. Preparation of the Egg Shell powder

Fineness

The fineness of the egg shell powder affects the surface area for reaction when mixed with water in the presence of other aggregates. The finer the specimen, the greater the surface area for reaction. As it was meant to be a partial replacement for cement, the fineness sought was that close to cement. Experimentally, it takes a cement particle of roughly 1 µm diameter one day to fully react with water. However, if all the cement is of this size, it would set too quickly meaning the concrete would not be workable. Particles with diameters of about 10 µm would take roughly 30 days to fully react with water. This is almost the time required for the 28 day strength test on cubes and cylinders, as they have achieved 99% of their strength by this point. Particles larger than 50µm will probably never react with water. Therefore, when crushing the sample specimen, it was ensured that it was done to achieve particle sizes between 5µm and 15µm. This would give an average that would be workable for the tests (Newman & Choo, 2005).

Cleanliness

The sample has to be devoid of materials that may compromise the integrity of the results obtained. Eggs have a thin white organic membrane that is attached to the shell. This would affect the reaction with water. This membrane was removed through sieving with a fine sieve. The shells were first broken down into small particles, the size of fine aggregates. They could pass through the 5mm sieve totally but were retained by the 0.6mm sieve. As the membrane does not break, it was possible to sieve it out. Although it was the membrane that needed to be removed, any other contaminants were also sieved out during this process. Although they may not have necessarily have reacted, they potentially limit the surface area for reaction of the egg shells as a binder.

3.1.2. Preparation of Aggregates

The aggregates have to be prepared so that they are fit for making the concrete. Both the fine and coarse aggregates were batched individually to ensure they could be taken care of as per their requirements. Additionally, it proved useful in ensuring ease during collection in the making of the actual concrete. It was possible to measure the quantities of each material to be used with relative ease and accuracy.

3.1.3. Grading of Aggregates

Grading of aggregates refers to their separation in terms of their size from the largest to the smallest. This was done by passing the aggregates through standard sieves, as specified by BS 410 (1986). Grading is done to ensure the proportion of aggregates is adequate in terms of their sizes and proportions in the concrete. Part of the strength gain in concrete is due to the interlocking of aggregate particles. It is therefore important that the proportions are gotten right in order to avoid voids in the concrete, and consequently compromise on its strength.

An aggregate with a high proportion of large aggregates is referred to as coarse, typically unable to pass through a 5mm sieve. Aggregates passing through the 5mm sieve but unable to pass through the 0.3mm sieve are referred to as fine aggregates.

Coarse Aggregates

Coarse aggregates are important in concrete as a structural element. Through interlocking action, they form a bond that is not easily broken once held together by enough cement of good quality. In order to save on the economy of producing concrete, the maximum size coarse aggregates may be used. This will help with adding to the volume of the concrete, at a cheaper cost than cement, which is the most expensive, and fine aggregates which are also pricier. There are however limits to which the coarse aggregate may be used in order to maintain the quality of the concrete produced. According to BS 882: 1992, these are the limits which coarse aggregates are to be used, based on sieve analysis.

Sieve Size (mm)		**Percentage Passing**	
	Lower Limit	Upper Limit	Actual % Passing
50	100	100	100
37.5	90	100	95
20	35	70	54
14	25	55	39
10	10	40	12
5	0	5	0
2.36	0	0	0

Table 5: Grading of Coarse Aggregates

Fine Aggregates

Fine aggregates play two roles in concrete. The first is helping with filling in the voids once the coarse aggregates have interlocked. They therefore provide strength to the concrete prepared through reduction of voids, which would be areas of weakness. Similarly, they reduce the possibility of shrinkage and creep in the concrete through the same action. Lastly, they also add to the volume of the concrete at a much cheaper rate per unit volume than cement. There are limits to which fine aggregates may be used in the production of concrete with the view of maintaining the strength and quality produced. They are prescribed by BS 882: 1992.

Sieve Size (mm)		Percentage Passing	
	Lower Limit	Upper Limit	Actual % Passing
10	100	100	100
5	89	100	96
2.36	60	100	93
1.18	30	100	72
0.6	15	100	36
0.3	5	70	10
0.15	0	15	0

Table 6: Grading of Fine Aggregates

3.2 Laboratory Tests

3.2.1 Slump Test

The slump test is done to measure the workability of the concrete. Through it, it is possible to know whether the water/cement ratio is okay. Concrete is poured into a cone as below.

Figure 1: Slump Test Apparatus

The concrete is poured as it is being compacted. Once the cone is removed, the concrete mass should remain standing. Collapse is a sign that the water to cement ratio is not okay, with the water being too much. There is however a small deflection as the mass falls. The difference in height between the initial height of the mould and the fallen level is referred to as the slump.

Preparation of Concrete Samples

Once concrete was found to be of good consistency, samples were prepared with substitution with the values of 0%, 5%, 10% and 15%. The concrete was placed in cubes of 150mm x 150mm dimensions and cylinders of 150mm diameter and 300mm heights. The samples prepared were for crushing after 7 days and 28 days, with the samples marked to ensure they were tested on time.

Curing was done by completely submerging the samples in water one day after casting. Curing promotes cement hydration by keeping the samples saturated. After curing, the cement paste ought to have hydrated and the by products are what will exist in the concrete, giving it its characteristic strength.

3.2.2 Hydrometer Analysis

(1) Apply meniscus correction to the actual hydrometer reading.

(2) From Table 1, obtain the effective hydrometer depth L in cm (for meniscus corrected reading).

(3) For known Gs of the soil, obtain the value of K from Table 2.

(4) Calculate the equivalent particle diameter by using the following formula:

$$D = K\sqrt{L/T}$$

Where t is in minutes, and D is given in mm.

(5) Determine the temperature correction *CT* from Table 3.

(6) Determine correction factor "*a*" from Table 4 using Gs.

(7) Calculate corrected hydrometer reading as follows:

$$Rc = R_{ACTUAL} - \text{zero correction} + C_T$$

(8) Calculate per cent finer as follows:

$$P = \left(Rc\ x\,\frac{a}{Ws}\right) x\ 100$$

Where Ws is the weight of the sample in grams.

(9) Adjusted per cent fines as follows:

$$PA = P\ x\,\frac{F200}{100}$$

F200 = % finer of #200 sieve as a per cent

(10) Plot a graph of the grain size curve D versus the adjusted per cent finer.

Chapter Four

4.0 Results, Analysis and Discussion

4.0.1 Sieve Analysis of Aggregates

4.0.1.1 Sieve analysis of Fine Aggregates

	Lab Results		
	Sieve Size (mm)	**Weight Retained (g)**	**Weight Passing (g)**
	10	0	1156
	5	46	1110
	2.36	35	1075
	1.18	243	832
	0.6	416	416
	0.3	300	116
	0.15	116	0
Total		1156	

Table 7: Sieve analysis of Fine Aggregates

4.0.1.2 Sieve Analysis of Coarse Aggregates

	Lab Results		
	Sieve Sizes (mm)	**Weight Retained (g)**	**Weight Passing (g)**
	50	0	9854
	37.5	493	9361
	20	4040	5321
	14	1478	3843
	10	2661	1182
	5	1182	0
	2.36		0
Total		9854	

Table 8: Sieve Analysis of Coarse Aggregates

4.0.2 Tests on Concrete

4.0.2.1 Slump Test

% Replacement of Cement	Slump (mm)
0%	32
5%	30
10%	27
15%	33

Table 9: Slump Test Results

Figure 2: Slump Test

4.0.2.2 Cube Crushing Results

%Replacement	Gauge Reading (KN)

	7 day	28 day
0%	378	594
5%	387	610
10%	409.5	630
15%	371	563

Table 10: Cube Crushing Results

4.0.2.3 Cylinder Crushing Results

%Replacement	Gauge Reading (KN)	
	7 day	**28 day**
0%	109	168
5%	112	172
10%	114	176
15%	101	155

Table 11: Cylinder Crushing Results

4.1 Analysis

4.1.1 Grading Limits for Fine Aggregates

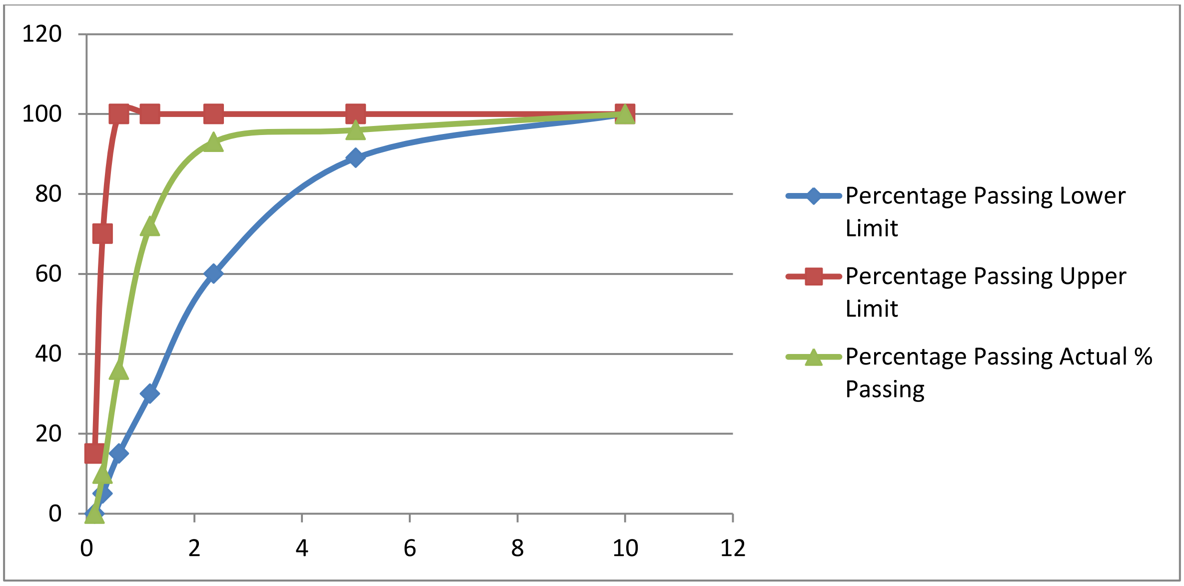

Figure 3: Grading Limits for Fine Aggregates

The S-curve for the fine aggregates fell within the allowable limits. The aggregate was therefore expected to perform adequately.

4.1.2 Grading Limits for Coarse Aggregates

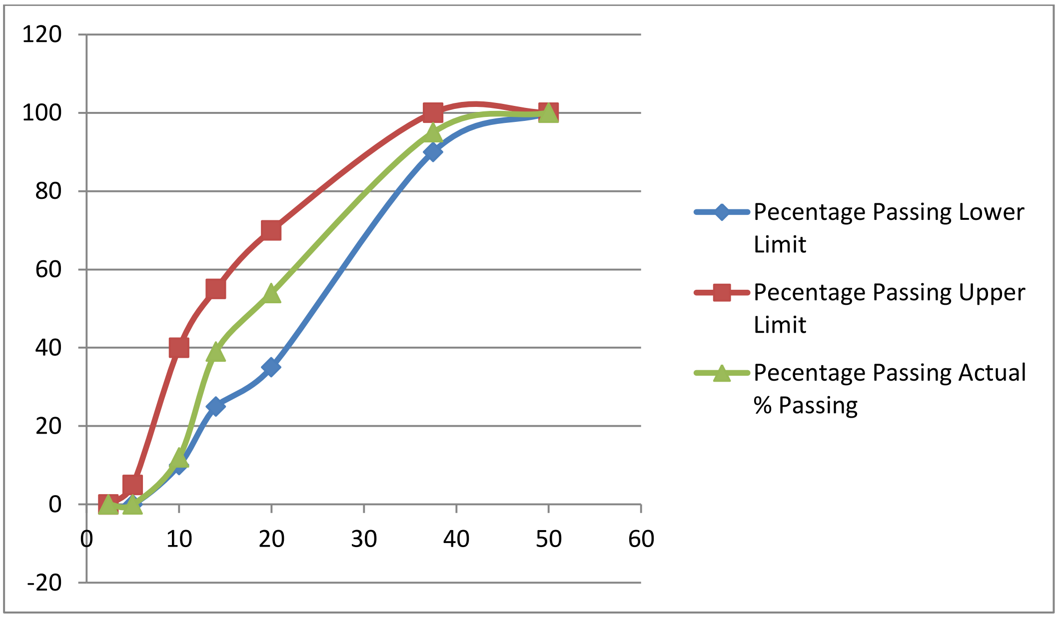

Figure 4: Grading Limits for Coarse Aggregates

The S-curve for the coarse aggregates fell within the allowable limits. The aggregate was therefore expected to perform adequately.

4.1.3 Hydrometer Analysis

Date	Time	Time Elapsed (min)	Temp (°C)	Actual Hydrometer Reading R_a	Hydrometer Correction for Meniscus	L	K	D (mm)	Ct	a	Corrected	% Finer P
22/01/2016												
	2:12	0	25	55	6.5	71	0.1326	0	1.3	1.018		
	2:13	1	25	47	5.7	86	0.1326	0.03	1.3	1.018	42.3	86
	2:14	2	25	42	5.2	91	0.1326	0.028	1.3	1.018	37.3	76
	2:16	4	25	40	5	96	0.1326	0.02	1.3	1.018	35.3	72
	2:20	8	25	37	4.7	101	0.1326	0.014	1.3	1.018	32.3	66
	2:28	16	25	32	4.2	109	0.1326	0.01	1.3	1.018	27.3	56
	2:46	34	25	28	3.8	115	0.1326	0.007	1.3	1.018	23.3	48
	4:14	136	25	22	3.2	125	0.1356	0.004	1.3	1.018	16.7	34
	3:18	1518	25	15	2.5	137	0.1366	0.001	1.3	1.018	9.4	20

Table 12: Hydrometer Analysis Results

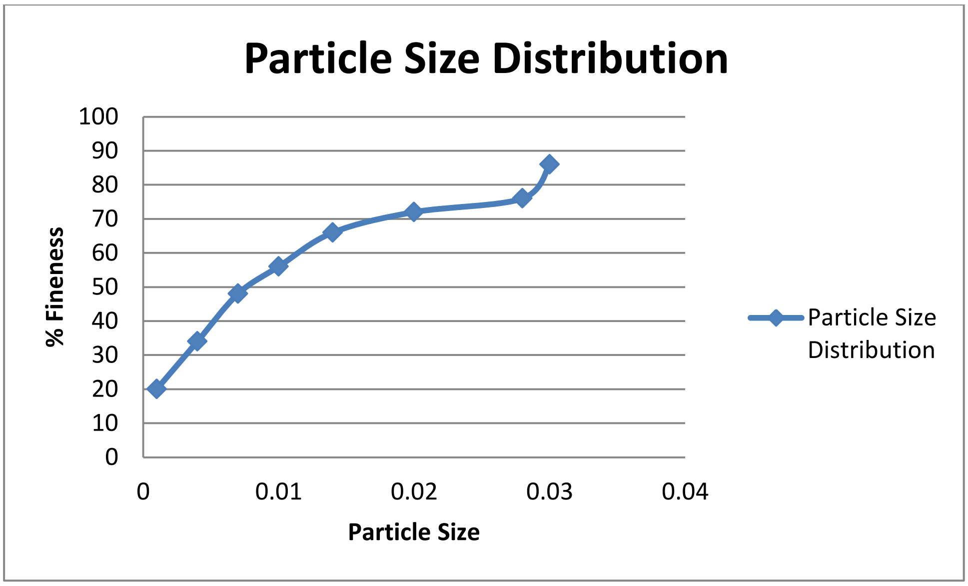

Figure 5: Particle Size Distribution

4.1.4 Cube Crushing Test

% Replacement	Strength Obtained (N/mm^2)	
	7 day	**28 day**
0%	16.8	26.4
5%	17.2	27.1
10%	18.2	28
15%	16.5	25

Table 13: Results, Cube crushing tests

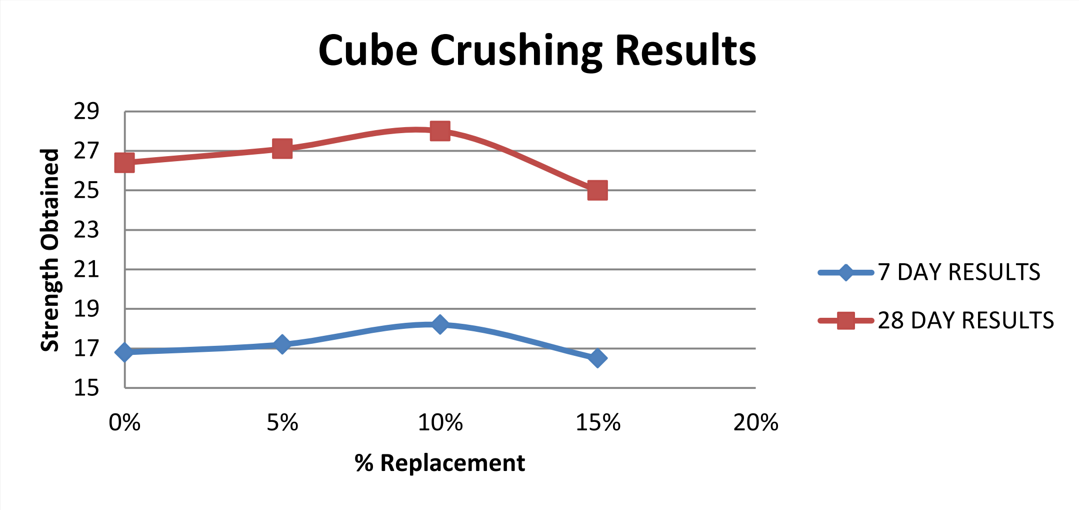

Figure 6: Results, Cube Crushing Tests

4.1.5 Cylinder Crushing Test

% Replacement	Strength Obtained (N/mm^2)	
	7 day	**28 day**
0%	1.55	2.37
5%	1.54	2.44
10%	1.62	2.5
15%	1.43	2.2

Table 14: Results, Cylinder Crushing Tests

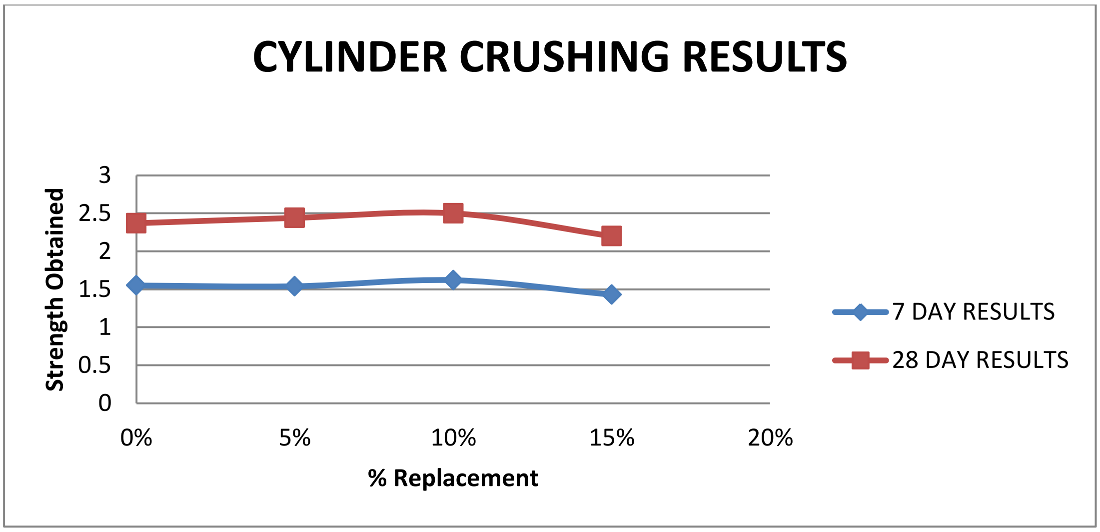

Figure 7: Results, Cylinder Crushing Tests

4.3 Discussion

4.3.1 Aggregates

The way particles of aggregate fit together in the mix, as influenced by the gradation, shape, and surface texture, has an important effect on the workability and finishing characteristic of fresh concrete, consequently on the properties of hardened concrete. Ideal grading curves have been proposed to ensure the mixture of the aggregates is in good proportions. Good gradation is one of the most important factors for producing workable concrete of sufficient strength.

Secondly, if concrete is viewed as a two phase material, paste phase and aggregate phase, it is the paste phase which is vulnerable to all ills of concrete. The paste is more permeable than many of the mineral aggregates. It is the paste that is susceptible to deterioration by reacting with aggressive chemicals. Thus, the lesser the quantity of the paste, the better will be the concrete. This objective can be achieved by having well graded aggregates. Hence, the importance of good grading.

According to Young, proportioning based on the surface area of aggregate to be wetted is ideal. Other things being equal, the concrete made from aggregate grading having least surface area will require least water which will consequently be the strongest.

Abrams on the other hand, uses a parameter known as “fineness modulus” for arriving at satisfactory grading. He argues that any sieve analysis curve of aggregate that will give the same fineness modulus will require the same quantity of water to produce a mix of the same plasticity and gives concrete of the same strength, so long as it is not too coarse for the quantity of cement used. The fineness modulus is an index of the coarseness or fineness of an aggregate sample, but, because different grading can give the same fineness modulus, it does not define the grading.

The quality of our aggregates having being satisfactory according to the theory proposed by Abrams and used in preparation of S curves ought to perform satisfactorily. This can be seen through the results of the slump test where the workability of the concrete was okay. Furthermore, the strengths obtained by the concrete were sufficient for all the cases except when the cement was replaced by 15% ratio. This illustrates proper interlocking of the aggregates in order to achieve the minimum strengths required of class 25 concrete.

4.3.4 Hydrometer Analysis

The results show that over 50% of the sample had a diameter of less than 10µm. cement particle sizes range from diameters of 5µm to 50µm. For cement, the time for hydration for particles with diameters of 10µm is roughly 28 days. Therefore, this shows that the crushing was done to the right size to provide for a margin of error almost similar to that of cement.

4.3.3 Crushing Tests

The strength of concrete is an important structural factor. This is the value Engineers use in their design process to ensure any structure is stable. The tests conducted showed the samples achieved the required strengths. At 10% replacement, the strength was significantly higher in both compression and tension. The replacement of cement with crushed egg shells was therefore successful.

The strength achieved may however have been affected by the smaller particle sizes than there would normally be in cement. This increased the surface area for hydration meaning the samples had more bonding. The binder in this case may have worked “too well”. This only represents 10% of the overall binder having roughly 50% of particles as too fine. This is 5% of the total binder. The significance of the smaller particle sizes may therefore be negligible and the assumption made that all the binder had normal particle size distribution.

%Replacement	Slump (mm)	28 day Cube Compressive Strength	% Variation in 28 day Compressive Strength	28 day Tensile Strength	% Variation in 28 day Tensile Strength
0%	32	26.4	100%	2.37	100%
5%	30	27.1	102.65%	2.44	103%
10%	27	28	106.06%	2.5	105.50%
15%	33	25	94.69%	2.2	92.83%

Table 15: Analysis of Strength Variation with Percentage Replacement

Chapter Five

5.0 Conclusion

It is possible to replace cement with up to 10% chicken egg shell powder and attain sufficient strength.

5.1 Recommendations

With these results, I would recommend the use of chicken egg shells as a partial replacement for cement in concrete. The cost of cement is already too expensive and even 10% savings would go some way in lowering construction costs.

When collecting the egg shells, the areas with the most waste were supermarkets, hotels and bakeries. If the collection were to be done at one place, the collected waste would be quantified and it would be possible to see if it is viable to use them commercially. Having enough quantities is the only thing that would limit this research. However, with other potential replacement options such as wood ash and fly ash, if all are collected then cement would be replaced by a variety of options which would then be commercially viable.

Lastly, it is worth researching on the possibility of replacing cement with more than one material. Using materials such as wood as, fly ash and crushed egg shells in different proportions might also prove just as viable.

Appendices

Appendix 1: Sieve Analysis

Objective

(i) To determine the particle size distribution of aggregates to be used

(ii) To draw grading curves for the aggregates specified

Procedure

1. The test sieves were arranged from top to bottom in order of decreasing aperture sizes with pan and lid to form a sieving column.

2. The aggregate sample was then poured into the sieving column and shaken thoroughly manually.

3. The sieves were removed one by one starting with the largest aperture sizes (top most), and each sieve shaken manually ensuring no material is lost. All the material which passed each sieve was returned into the column before continuing with the operation with that sieve.

4. The retained material was weighed for the sieve with the largest aperture size and its weight recorded.

5. The same operation was carried out for all the sieves in the column and their weights recorded.

6. The screened material that remained in the pan was weighed and its weight recorded.

Calculations

1. Record the various masses on a test data sheet.

2. Calculate the mass retained on each sieve as a percentage of the original dry mass.

3. Calculate the cumulative percentage of the original dry mass passing each sieve down to the smallest aperture sieve.

Appendix 2: Mix Design

Mix parameters

Concrete is normally specified by a system of proportions, example 1:2:4 (proportions of cement: fine aggregates: coarse aggregates either by mass or volume. For this project, after a mix proportion has been adopted, the percentage replacement levels of 0%, 5%, 10%, and 15% of cement by crushed egg shells shall be adopted.

Strength margin

As a result of the variability of concrete in production it is necessary to design the mix to have a mean strength greater than the specified characteristic strength by an amount termed the margin. Thus

$$fm = fc + ks$$

Where f_m = the target mean strength

f_c = the specified characteristic strength

k_s = the margin, which is the product of:

s = the standard deviation

k = a constant

K is derived from normal distribution and increases as the proportion of defectives is decreased, thus

K for 10% defectives = 1.28

K for 5% defectives = 1.64

K for 2.5 defectives = 1.96

K for 1% defectives = 2.33

For 5% defective level specified in BS 5328, k=1.64 and thus

$$fm = fc + 1.64s$$

3.6.3 Stages in mix design

a. Stage 1: selection of the target water/ cement ratio

b. Stage 2: selection of the free-water content; depends upon the type and maximum size of the aggregate to give a concrete of the specified slump.

c. Stage 3: Determination of the cement content

Cement content = free-water content / (free-water to cement ratio)

d. Stage 4: determination of the total aggregate content

Total aggregate content (saturated and surface dry) = D – C – W

Where

D = the wet density of concrete (kg/m3)

C = the cement content (kg/m3)

W = the free-water content (kg/m3)

e. Stage 5: Selection of the fine and the coarse aggregate contents

Fine aggregates content = total aggregate content x proportion of fines

Coarse aggregate content = total aggregate content – fine aggregate content

Appendix 3: Slump Test

Apparatus

a) A standard mould which is a frustum of a cone complying with BS 1881 – 102: 1983.

b) A standard flat base plate preferably steel.

c) A standard tamping rod.

d) Standard graduated steel rule from 0 to 300mm at 5mm intervals.

e) A scoop approximately 100mm wide

Procedure

a) The inside surfaces of the mould was cleaned and oiled to prevent adherence of fresh concrete on the surfaces.

b) The mould was then placed on the base plate and firmly held.

c) The cone was then filled with fresh concrete in three layer with each layer compacted with 25 strokes of the tamping rod.

d) After filling the mould, the top surface was struck off by means of rolling action of the tamping rod.

e) Immediately after filling, the cone was then slowly and carefully lifted.

f) Immediately after removal of the mould the slump of the unsupported concrete was then measured and recorded.

Appendix 4: Hydrometer Analysis

Equipment:

Mixer, 152H Hydrometer, Sedimentation cylinder, Control cylinder, Thermometer, Beaker, Timing device.

Procedure:

(1) Take the sample from the bottom pan of the sieve set, place it into a beaker, and add 125 mL of the dispersing agent (sodium hexametaphosphate (40 g/L)) solution. Stir the mixture until sample is thoroughly wet. Let the sample soak for at least ten minutes.

(2) While the sample is soaking, add 125mL of dispersing agent into the control cylinder and fill it with distilled water to the mark. Take the reading at the top of the meniscus formed by the hydrometer stem and the control solution. A reading less than zero is recorded as a negative (-) correction and a reading between zero and sixty is recorded as a positive (+) correction. This reading is called the zero correction. The meniscus correction is the difference between the top of the meniscus and the level of the solution in the control jar (Usually about +1). Shake the control cylinder in such a way that the contents are mixed thoroughly. Insert the hydrometer and thermometer into the control cylinder and note the zero correction and temperature respectively.

(3) Transfer the sample slurry into a mixer by adding more distilled water, if necessary, until mixing cup is at least half full. Then mix the solution for a period of two minutes.

(4) Immediately transfer the sample slurry into the empty sedimentation cylinder. Add distilled water up to the mark.

(5) Cover the open end of the cylinder with a stopper and secure it with the palm of your hand. Then turn the cylinder upside down and back upright for a period of one minute. (The cylinder should be inverted approximately 30 times during the minute.)

(6) Set the cylinder down and record the time. Remove the stopper from the cylinder. After an elapsed time of one minute and forty seconds, very slowly and carefully insert the hydrometer for the first reading.

(Note: It should take about ten seconds to insert or remove the hydrometer to minimize any disturbance, and the release of the hydrometer should be made as close to the reading depth as possible to avoid excessive bobbing).

(7) The reading is taken by observing the top of the meniscus formed by the suspension and the hydrometer stem. The hydrometer is removed slowly and placed back into the control

cylinder. Very gently spin it in control cylinder to remove any particles that may have adhered.

(8) Take hydrometer readings after elapsed time of 2 and 5, 8, 15, 30, 60 minutes and 24 hours

Table 2. Values of **k** for Use in Equation for Computing Diameter of Particle in Hydrometer Analysis

Temperature °C	Specific Gravity of Soil Particles								
	2.45	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
16	0.01510	0.01505	0.01481	0.01457	0.01435	0.01414	0.0394	0.01374	0.01356
17	0.01511	0.01486	0.01462	0.01439	0.01417	0.01396	0.01376	0.01356	0.01338
18	0.01492	0.01467	0.01443	0.01421	0.01399	0.01378	0.01359	0.01339	0.01321
19	0.01474	0.01449	0.01425	0.01403	0.01382	0.01361	0.01342	0.01323	0.01305
20	0.01456	0.01431	0.01408	0.01386	0.01365	0.01344	0.01325	0.01307	0.01289
21	0.01438	0.01414	0.01391	0.01369	0.01348	0.01328	0.01309	0.01291	0.01273
22	0.01421	0.01397	0.01374	0.01353	0.01332	0.01312	0.01294	0.01276	0.01258
23	0.01404	0.01381	0.01358	0.01337	0.01317	0.01297	0.01279	0.01261	0.01243
24	0.01388	0.01365	0.01342	0.01321	0.01301	0.01282	0.01264	0.01246	0.01229
25	0.01372	0.01349	0.01327	0.01306	0.01286	0.01267	0.01249	0.01232	0.01215
26	0.01357	0.01334	0.01312	0.01291	0.01272	0.01253	0.01235	0.01218	0.01201
27	0.01342	0.01319	0.01297	0.01277	0.01258	0.01239	0.01221	0.01204	0.01188
28	0.01327	0.01304	0.01283	0.01264	0.01244	0.01255	0.01208	0.01191	0.01175
29	0.01312	0.01290	0.01269	0.01269	0.01230	0.01212	0.01195	0.01178	0.01162
30	0.01298	0.01276	0.01256	0.01236	0.01217	0.01199	0.01182	0.01165	0.01149

Table 16: K value for Hydrometer Analysis

Table 3. Temperature Correction Factors C_T

Temperature °C	factor C_T
15	1.10
16	-0.90
17	-0.70
18	-0.50
19	-0.30
20	0.00
21	+0.20
22	+0.40
23	+0.70
24	+1.00
25	+1.30
26	+1.65
27	+2.00
28	+2.50
29	+3.05
30	+3.80

Table 17: Temperature Correction for Hydrometer Analysis

Table 4. Correction Factors *a* for Unit Weight of Solids

Unit Weight of Soil Solids, g/cm^3	Correction factor a
2.85	0.96
2.80	0.97
2.75	0.98
2.70	0.99
2.65	1.00
2.60	1.01
2.55	1.02
2.50	1.04

Table 18: Correction Factors for Unit Weight of Solids

Lab Results

Hydrometer Reading	**Effective Depth (cm)**	**Hydrometer Reading**	**Effective Depth (cm)**
0	16.3	31	11.2
1	16.1	32	11.1
2	16	33	10.9
3	15.8	34	10.7
4	15.6	35	10.6
5	15.5	36	10.4
6	15.3	37	10.2
7	15.2	38	10.1
8	15	39	9.9
9	14.8	40	9.7
10	14.7	41	9.6
11	14.5	42	9.4
12	14.3	43	9.2
13	14.2	44	9.1
14	14	45	8.9
15	13.8	46	8.8
16	13.7	47	8.6

17	13.5	48	8.4
18	13.3	49	8.3
19	13.2	50	8.1
20	13	52	7.9
21	12.9	52	7.8
22	12.7	53	7.6
23	12.5	54	7.4
24	12.4	55	7.3
25	12.2	56	7.1
26	12	57	7
27	11.9	58	6.8
28	11.7	59	6.6
29	11.5	60	6.5
30	11.4		

Table 19: Lab Results, Hydrometer Analysis

References

1. Hawkins, P., Tennis, P. and Detwiler, R (2003). The use of limestone in Portland cement: a state-of-the-art review, EB227, Portland Cement Association, Skokie, IL, 44.
2. BS 410
3. BS 882: 1992
4. Shetty, M.S (2000). Concrete Technology, Theory and Practice.
5. Newman, J., Choo, B. S (2003). Advanced Concrete Technology, Testing and Quality.
6. Alexander, M., Mindness, S (2005). Aggregates in Concrete, Modern Concrete Technology.