VOL. 10 NO. 4,
NOVEMBER, 2025
E-ISSN 3026-9210
P-ISSN 3026-815X

African Scholar Publications & Research International
www.africanscholarpub.com

Journal of Built Env. & Geological Research (JBEGR)

Optimization of Compressive Strength of Periwinkle Shell Concrete Using Scheffe's Model

B. A. Abbas; A. Ibrahim; & A. T. Andyar
Department of Civil Engineering Federal University of Technology, Minna
Corresponding Author: andyartamen71@futminna.edu.ng
DOI: https://doi.org/10.70382/ajbegr.v10i4.052

Abstract

This study investigates the optimization of compressive strength of periwinkle shell concrete using scheffe's model. Physical properties of the aggregates such as specific gravity, bulk density, and sieve analysis were determined. Specific gravities of fine and coarse aggregates were 2.62 and 2.64 respectively. The bulk densities were 1745kg/m^3 and 1660kg/m^3 respectively. From the sieve analysis test, the sand belonged to zone 2 and well graded with coefficient of gradation of 1.04. Ninety 150mm x 150mm x 150mm cube specimens were produced for the compressive strength test. Mode was fitted to data obtained on the compressive strength and mathematical model was developed based on Scheffe's model. The formulated model was tested for adequacy at 95% level of confidence using t-statistic and was found to be adequate. The compressive strength of concrete was observed to decrease with increase in the percentage replacement of periwinkle shells (PS). After 28 days of water curing, the concrete gave an average optimum compressive strength value of 22.84N/mm^2 corresponding to a mix proportion of 1, 0.1, 1, 1.9 (cement, periwinkle shell, sand, granite) at a water-cement ratio of 0.4. This compressive strength value obtained at 5% replacement is within the recommended value required for low strength concrete works.

Keywords: Optimization; Concrete, periwinlke shell, Aggregates, Cement, Optimization; Replacement

Introduction

Background of the Study

Concrete is a composite material made up of aggregate (fine and coarse) bonded together with a fluid cement that cures overtime (Bamigboye *et al.,* 2016). Concrete is a constituent construction material that its

standard cannot be compromised for cost reduction. Concrete is the second most used substance in the world after water and is the most widely used building material (Azhagarsamy, 2017). Its usage worldwide, ton to ton is twice that of steel, wood, plastic and aluminum combined. When concrete is mixed with dry Portland cement and water, the mixture forms a fluid slurry that is easily poured and molded into shape.

The cement reacts with the water through a process called concrete hydration that hardens over several hours to form a hard matrix that binds the materials together into a durable stone-like materials that has many uses. The hydration process is exothermic, which means ambient temperature plays a significant role in how long it takes concrete to set. Often, additives (such as pozzolans or superplasticizers) are included in the mixture to improve the physical properties of the wet mix, delay or properties of the wet mix, delay or accelerate the curing time, or otherwise change the finished material. Aggregates are described as coarse aggregate if particles are retained on a screen with 5 mm apertures or 4 mm apertures; otherwise, they are described as fine aggregate or sand if they pass through them. (Neville and Brooks, 2005)

Aggregates provide about 75 per cent of the body of concrete and hence their influence is extremely important. They should therefore meet certain requirements if the concrete is to be workable, strong, durable, and economical. The aggregates must be of proper shape (either rounded or approximately cubical), clean, strong and well graded; and should possess chemical stability and in many cases, exhibit abrasion resistance and resistance to freezing and thawing (Neville, 1981]). There are three major reasons why aggregates are mixed with cement paste to form concrete rather than using cement paste alone. The first and oldest reason is that aggregate is cheaper than cement, so its use extends the mix and reduces costs. Secondly, aggregate reduces shrinkage and creep, giving better volume stability. Thirdly, aggregate gives greater durability to concrete.

The coconut shell cement composite is compactible, and pre- treatment is not required. One side of the coconut shell has smooth surface resulting in better workability of coconut shell aggregate concrete (CSAC).

Periwinkle shells are small greenish blue marine snail with spiral conical shell and round aperture. It is mostly found in riverine areas like south-south and south–west part of Nigeria. According to Alhaji (2016) periwinkle shell can be used as a partial replacement of gravel especially in places where gravel is in short supply and periwinkle shells are in abundance.

Palm kernel shell is the hard fibrous material that enclose the nut or seed of palm kernel fruit. It is obtained as residual waste from the cracking of the palm kernel and extraction of the nut in the mill and constitute about 34.5 percent of a single ripe fresh palm kernel fruit.

Palm kernel can be processed into various dimension grades to suit a specific application such as light weight aggregate for concrete and filling specifically, bulk density of the palm kernel shell at 740kg/m^3 is similar to those of other light weight concrete material indicating that the shell could be used as light weight coarse aggregate. The qualities are relatively low weight and natural size, relatively hardness and organic origin and non- toxic effect on the concrete. Several Nigeria studies have reported that most building constructed with palm kernel shell concrete have an apparent good record of service of more than 30 years.

However, Gibigaye and Godonou (2018) in their study, maintained that most mixed designs method for palm kernel shell concrete that satisfy the requirement of technical specification

for structural light weight concrete were based on trial and error or empirical method. This is because, mix design base on the established construction method for normal and light weight structural concrete have been unsuccessful based on this, they investigated a trial mix proportional of structural light weight concrete using palm kernel shell (PKS) as coarse aggregate. They reported the optimal mix proportion to the C:S :PKS in weight of 1:1.60: 0.96 and 1: 1.53: 0.99 with a cement content of 450kg/m^3 and W/C of 0.45, which resulted in attaining the appropriate values for workability (≥20mm), and density compressive strength (≥15mpa), recommended by the American Concrete Institute (ACI) and British code for structural light weight concrete. The use of palm kernel shell in cement concrete could be indeed serves as a sustainable means of converting this abundant waste to more beneficial function, especially at the rural palm oil processing location in Africa. This could further reduce the cost of constructing houses especially at the location where the conventional concrete is costly.

This study is concerned with the application of Scheffe's model in optimizing the compressive strength of concrete using periwinkle shell as partial replacement of coarse aggregate. This will involve the formulation of mathematical models and the determination from the formulated mathematical models, the mix proportions that would predict and optimize the compressive strength of periwinkle shell coarse aggregate (PSCA) -concrete. It is believed that research into the compressive strength of PSCA-concrete will enhance its maximum utilization.

Problem Statement

In Nigeria, the cost of conventional concrete production is rapidly increasing day by day. This makes it difficult for low-income earners to have a roof over their head, hence a need to embark on the research into the possibility of checking the suitability of alternative local materials. Against this background, Olufemi *et al.* (2009) worked on the effectiveness of periwinkle shell as partial replacement of coarse aggregate in concrete production, also Gibigaye and Godonou (2018), conducted research on effectiveness of palm kernel shell as partial replacement of coarse aggregate in concrete production. Alhaji (2016) conducted research on periwinkle, palm kernel and Coconut shell respectively to determine their effectiveness in the strength of concrete.

The aforementioned research does not apply scheffe's model to optimize the compressive strength of periwinkle shell concrete. It is against this background that this research aims at applying scheffe's mathematical model to optimize the compressive strength of concrete produced by partial replacement of coarse aggregate with periwinkle to address the above research gab.

Aim

The aim of this study is to optimize the compressive strength of periwinkle shell concrete using scheffe's model.

Objectives

The objectives are to:

i. Determine the physical properties of aggregates.
ii. To determine the workability of fresh concrete.
iii. Determine the compressive strength of periwinkle shell-coarse aggregate concrete, when PS is used as partial replacement and the optimum content of PS in the mix.
iv. Formulate a mathematical model that will adequately predict the compressive strength of PSCA- concrete.

Concrete

Concrete is a construction material composed of cement, fine aggregates (sand) and coarse aggregates mixed with water which hardens with time. Portland cement is the commonly used type of cement for production of concrete. Concrete technology deals with study of properties of concrete and its practical applications.

In a building construction, concrete is used for the construction of foundations, columns, beams, slabs and other load bearing elements.

There are different types of binding material is used other than cement such as lime for lime concrete and bitumen for asphalt concrete which is used for road construction.

Various types of cements are used for concrete works which have different properties and applications. Some of the types of cement are Portland Pozzolana Cement (PPC), rapid hardening cement, Sulphate resistant cement etc.

Materials are mixed in specific proportions to obtain the required strength. Strength of mix is specified as M5, MIO, M15, M20, M25, M30 etc., where M signifies Mix and 5, 10, 15 etc. as their strength in kN/m^2. In United States, concrete strength is specified in PSI which is Pounds per Square Inch.

Water cement ratio plays an important role which influences various properties such as workability, strength and durability. Adequate water cement ratio is required for production of workable concrete.

When water is mixed with materials, cement reacts with water and hydration reaction starts. This reaction helps ingredients to form a hard matrix that binds the materials together into a durable stone-like material.

Concrete can be casted in any shape. Since it is a plastic material in fresh state, various shapes and sizes of forms or formworks are used to provide different shapes. Various structural members such as beams, slabs, footings, columns, and lintels are constructed with concrete.

There are different types of admixtures which are used to provide concrete with certain desired properties. Admixtures or additives such as pozzolans or super plasticizers are included in the mixture of concrete to improve the physical properties of the wet mix or the finished material.

Various types of concrete are manufactured these days for construction of buildings and structures. These have special properties and features which improve quality of construction as per requirement.

Components of concrete

Components of concrete are cement, sand, aggregates and water. Mixture of Portland cement and water is called as paste. So, concrete can be called as a mixture of paste, sand and aggregates. Sometimes rocks are used instead of aggregates.

The cement paste coats the surface of the fine and coarse aggregates when mixed thoroughly and binds them. Soon after mixing the components, hydration reaction starts which provides strength and a rock-solid concrete is obtained.

Grade of concrete

Grade of concrete denotes its strength required for construction. For example, M30 grade signifies that compressive strength required for construction is 30MPa. The first letter in grade "M" is the mix and 30 is the required strength in MPa. Based on various laboratory tests, grade of concrete is presented in mix proportions. For example, for M30 grade, the mix proportion is presented as 1:1:2, where the first "1" is the ratio of cement, second "1" is the ratio of sand, and 2 is the ratio of coarse aggregate based on volume or weight of materials.

The compressive strength of concrete is measured with concrete cube or cylinders by civil engineers at construction site. Cube or cylinders are made during casting of structural member and after hardening it is cured for 28 days. Then compressive strength test is conducted in accordance with BS EN 12390-3 (2002) to determine the strength.

Common grades of concrete are Ml5, M20, M25 and M30. For plain cement concrete works, M15 is generally Ml5 is used. For reinforced concrete construction minimum M20 grade of concrete are used.

Grading of concrete

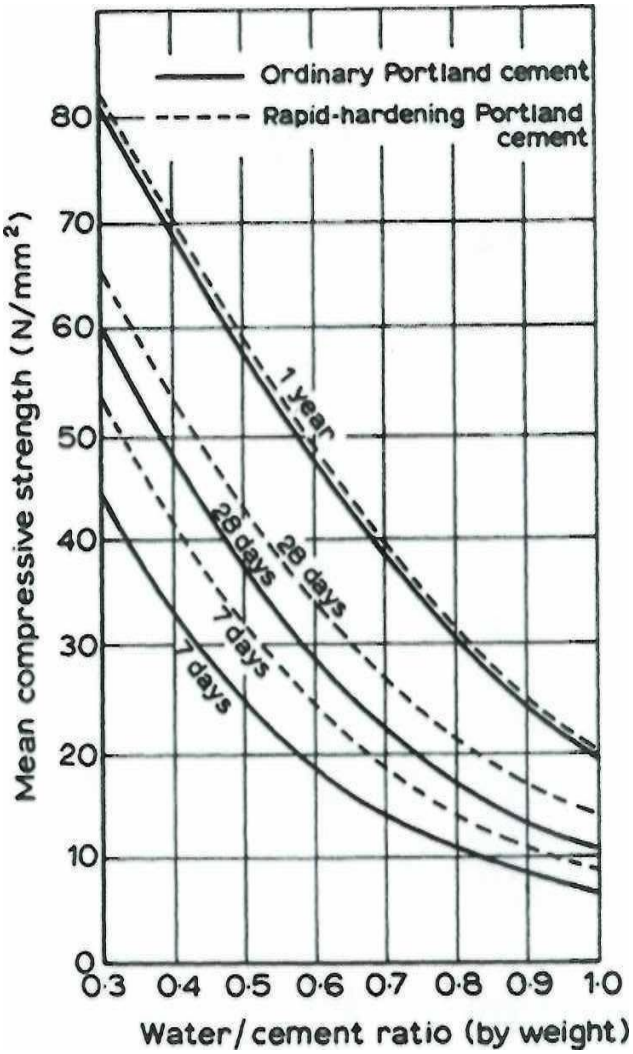
Concrete grades or strength classes denotes the compressive strength of concrete which is taken as the 28 days crushing strength of concrete cubes or cylinders (Leon and Ramirez, 2010). Grade of concrete is also defined as the minimum strength the concrete must possess after 28 days of construction with proper quality control. Grade of concrete is denoted by prefixing M to the desired strength in MPa. For example, for a grade of concrete with 25MPa strength, it will be denoted by M25, where M stands for Mix. Grade of concrete construction is selected based on structural design requirements. There are two types of concrete mixes, nominal mix and design mix.

Nominal mix concrete is those which are generally used for small scale construction and small residential buildings where concrete consumption is not high. Nominal mix takes care of factor of safety against various quality control problems generally occurring during concrete construction. Nominal mixes for grades of concrete such as M15, M20, and M25 are generally used for small scale construction.

Compressive strength of concrete

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of

concrete are qualitatively related to its compressive strength. (Neville and brooks, 2010).
The compressive strength of concrete is the most common measure for judging the quality of concrete. In the UK. the characteristic strength of concrete is based on the 28-day cube strength; that is, the crushing strength of standard 150 mm cubes at an age of 28 days after mixing; 100 mm cubes may be used if the nominal maximum size of the aggregate does not exceed 25 mm. The Strength of hardened concrete is measured by the compression test. The compression strength of concrete is a measure of the concrete's ability to resist loads which tend to compress it. The compressive strength of concrete is measured by crushing cylindrical or cubic concrete specimens in compression testing machine.
The strength of concrete is primarily dependent on the free water/cement ratio, that is the ratio of the weight of the free mixing water to that of the cement in the mixture. Other things being equal, the lower the w/c ratio the higher is the strength of the concrete.



(*Source:* Teychenne *et al.*, 1997).

Figure 1: Variation of compressive strength of concrete with water/cement ratio.

Aggregates

Aggregates are the major constituent of concrete and influence the properties and performance of both the freshly mixed and hardened concrete. Aggregates occupy between 70% and 80% of concrete volume (León and Ramírez, 2010). The knowledge of aggregates, which constitute the major volume in concrete, is important in understanding concrete generally (Neville and Brooks, 2010).

Effects of aggregates on concrete

Aggregate in Fresh and Plastic Concrete: When concrete is freshly mixed, the aggregates are suspended in the cement–water–air bubble paste. The behavior of fresh concrete, such as fluidity, cohesiveness, and rheological behavior, is largely influenced by the amount, type, surface texture, and size gradation of the aggregate (Hu and Wang, 2011). The grading or particle size distribution of aggregates affects significantly some characteristics of concrete like packing density, voids content, workability, segregation, and other characteristics of concrete (Vishalakshi *et al*., 2018). In addition to reducing the cost, aggregate in concrete can reduce the shrinkage and creep of cement paste.

Classification of aggregates

According to Mandal *et al*. (2023), aggregates can be divided into several categories according to different criteria,

(a) In accordance with size, aggregates are classified into coarse and fine aggregates.

Coarse aggregate: These are the aggregates that are retained on 4.75 mm sieve.

Fine aggregate (sand): Fine aggregates comprise of particles finer than 4.75 mm in mean diameter. They form a part of the cement mortar and act as fillers between the coarse aggregates.

b) In accordance with source, aggregates are classified into natural, and artificial aggregates.

Natural Aggregates: These are aggregates obtained from natural deposits without any change in the nature of the aggregate.

Artificial Aggregates**:** These are man-made aggregates, resulting from products or by-products of industry.

(c) In accordance with unit weight, aggregates are classified into the following types.

Ultra-lightweight aggregate: The unit weight of such aggregates is less than 500 kg/m3.

Lightweight aggregate: The unit weight of this class of aggregates is between 500 and 1120 kg/m^3. Aggregates in this category include cinder, blast-furnace slag, volcanic pumice, and expanded clay.

Normal-weight aggregate**:** Aggregates with unit weight of 1520–1680 kg/m^3 are classified as normal-weight aggregates. Sand, gravel, and crushed rock which are the most widely used aggregates in concrete belong to this category.

Heavy-weight aggregate**:** Aggregates with unit weight greater than 2100 kg/m^3 are classified as heavy-weight aggregates. This group of aggregates are obtained from iron ore, crashed steel pieces, and magnesite limonite.

(e) In accordance with the external characteristics such as the shape and texture of the aggregate, they are classified as rounded, irregular, flaky, angular, elongated (Neville and Brooks, 2010).

Characterization of aggregates

Aggregates are usually characterized by shape, size, particle size distribution, surface texture, specific gravity, bulk density, soundness, fineness, impact value, crushing value, water absorption, and abrasion value.

Periwinkle shell as aggregates

Periwinkles are a group of marine snails. Their shells are typically mottled gray, white, and black and taper to a straight sided or rounded cone with an obtuse point as shown in below. Periwinkles inhabit the littoral zone, the region between low and high tides. Although they must live near the ocean and spend part of their time underwater, they prefer to be partially exposed to air. In the riverine areas of Nigeria, periwinkles are extremely useful. Apart from the fact that the snails are been consumed as food, their shells are also useful for, soil stabilization, concrete production, beads production, poultry birds' feeds, decorations and so on. The reasons favouring the extensive usage of periwinkle shells as concrete materials are; the shells are hard, apart from being hard, they are generally light materials suitable for the riverine, they are readily available in sizeable quantity, they have good bonding properties with cement and sand and are less expensive when compared to crushed stones (granites).

Optimization techniques

Optimizing a concrete mixture involves finding a balance of components that minimizes costs while meeting performance criteria like workability, strength, and durability (Hossain *et al*., 2025).

Optimization of concrete mixture involves using a statistical concept to fit empirical models to the experimental concrete property data (Osadebe, 2013). Optimization is the act of obtaining the best result under any given circumstance. The goal of all such decisions is either to minimize the effort required or to maximize the desired benefit, since the effort required, or the benefit desired in any practical situation can be expressed as a function of certain decision variables. In concrete mixture optimization, the engineer finds the maximum or minimum value of a multivariable function and the constraints on the decision variables must be satisfied.

The concrete property of interest is a function of the proportions of the component materials, such as, water-cement ratio, cement, fine and coarse aggregates and sometimes, the proportion of the supplementary cementing materials in concrete. Studies have been carried out using optimization techniques to optimize the concrete properties (Osadebe, 2003); Scheffe, 1958).

Materials

The materials utilized in this study are Ordinary Portland Cement (OPC), sharp river sand, Granite, periwinkle shell and water.

Cement: The cement used as the binding agent was OPC brand of cement 42.5Rwith properties conforming to BS EN 197-1 (2011) sourced from Minna.

***Water*:** clean potable water conforming to BS EN 1008, (2002), was used for mixing and curing the concrete.

***Coarse aggregate*:** Crushed granite of igneous rock with maximum size of 20 conforming to BS EN 12620-5 (2002) with a density of 1660 was used for the study.

Fine aggregate: Locally available river sand conforming to grading of BS 882: (1992) with a density of 1745, fineness modulus of 3.4, specific gravity of 2.64, coefficient of uniformity of 2.17, and coefficient of curvature of 1.04 was sourced from Chanchaga river in Minna and used for the study.



Figure 2: Periwinkle shell used for the study

***Periwinkle shell*:** Sourced from Bwari market Abuja was used for the study.

Methods

Concrete mix design

Concrete mix design was carried out using the British Method for design of normal weight concrete made with Portland cement produced by the Department of Environment (DOE) (Teychenne *et al.*, 1997).

Specimen preparation

Concrete cube specimens were prepared and tested in accordance with BS EN 12390-3 (BS EN 12390-3, 2002) to evaluate mechanical properties of the concrete. The batching was done by weight with crushed stone replacement levels of 5, 10, 15, 20, and 25% periwinkle shells and tested for workability in accordance with EN 12350-2 (2019).

Formulation of simplex lattice design

Simplex is a factor space or a polygon. The simplest simplex is a straight line; others could be a plane, tetrahedron or any other imaginary solids whose dimension is above three. Periwinkle Shell (PS) Crushed granite (CA) - concrete is a five-component mixture consisting of water, cement, periwinkle shell, sand, and crushed granite rock. This was analyzed using a five-dimensional simplex lattice (pentahedron).

Scheffe (1958) introduced polynomial regression to model the response, called (q,n) polynomial which must be of low degree (n)

where q = number of components

n = degree of polynomial

if n=1: $f(x)\sum_{i=1}^{q}\beta i\ xi$ (4.1)

if n= 2: $f(x)\sum_{i=1}^{q}\beta i\ xi + \sum_{1\leq i\leq j\leq q}\ \beta ij\ Xi\ Xj$ (4.2)

if n=3: f(x) $\sum_{1=1}^{q} \beta i\, xi \sum_{i\le i\le j\le q}^{q} \beta ij\, Xi\, Xj + \sum_{i\le i\le j\le q}^{q} \beta_{iij}\, X_i\, X_j\, X_k)$ (4.3)

The number of coefficient k in a (q.n) lattice is given by c_q^n + n – 1.

where

$k = \frac{q(q+1)\ldots(q+n-1)}{n!}$

Hence, for the five-parameter case, $k = \frac{5(5+1)}{2} = 15$

For the five-component mixture with two degrees of reaction, the number of coefficients is 15, and the diagrammatic expression of the criteria in Scheffe's proposition is shown in Figure 3.

Table 1: Compressive strength of concrete cubes obtained from the experiment and model

Points	Compressive Strength (N/mm2)			Mean compressive strength (N/mm2)	Experiment Predicted Compressive strength (N/mm2)
	Trial 1	Trial 2	Trial 3		
Y1	27.20	26.5	25.47	26.39	22.84
Y2	22.27	21.75	23.60	22.54	22.54
Y3	21.37	22.13	20.25	21.25	21.25
Y4	20.69	21.09	21.43	21.07	21.07
Y5	20.57	21.17	21.93	20.89	20.89
Y12	24.98	25.25	25.07	25.10	25.10
Y13	24.00	25.42	23.33	24.25	24.25
Y14	21.06	21.28	21.14	21.16	21.16
Y15	22.72	22.11	21.14	22.09	22.09
Y23	21.09	21.00	20.94	21.01	21.01
Y24	20.35	22.25	23.46	22.02	22.02
Y25	20.78	19.29	21.04	20.37	20.37
Y34	21.87	19.47	19.14	20.16	20.16
Y35	20.30	22.12	21.27	21.23	21.23
Y45	20.05	20.55	20.45	20.35	20.35

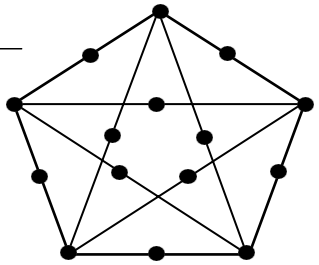


Figure 3: A (5,2) Pentahedron simplex lattice

The effects of different percentage replacements of granite with PS on the compressive strength, and workability of concrete are shown in Figures 4, and 5 respectively.

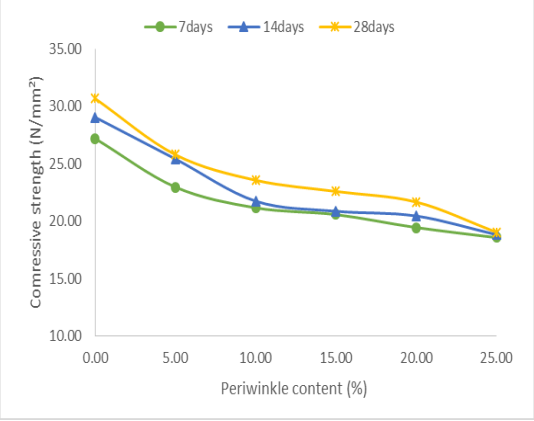


Figure 4: Relationship between compressive strength and PS content

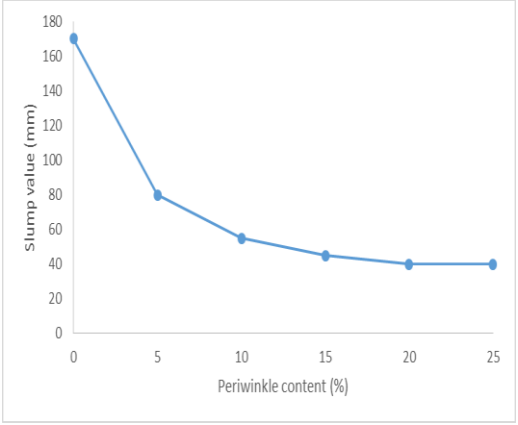


Figure 5: Slump value and PS content

Accuracy test of the model

Adequacy test for second degree polynomial was done using statistical student's t-test at 95% accuracy level. The compressive strength at the control points were used for the test. The following two hypotheses were tested using statistical student's t-test.

The test is carried out and presented in Table 2 using the following relationships:

Y_E = Responses (Compressive Strength) from experiment

Y_P = Response (Compressive Strength) from the second-degree polynomial equation

N = Number of observations

D = Difference of Y_E and Y_P

$M_D = \frac{\Sigma D}{N}$ mean of difference of Y_E and Y_P

$S^2 = \frac{\Sigma(MD-D)2}{N-1}$ = variance of difference of M_D and D

$t = \frac{MD*N0.5}{S} = t_{calculated}$ value

Table 2: Statistical student's t-test for the model

Point	Y_E	Y_P	$D=Y_E-Y_P$	M_D-D	$(M_D-D)^2$
C1	23.45	22.84	0.61	-0.04	0.002
C2	22.25	22.16	0.09	-0.09	0.008
C3	23.34	25.36	-2.02	2.02	4.080
C4	22.19	21.86	0.33	-0.33	0.109
C5	21.5	22.85	-1.35	1.35	1.823
C12	24.02	20.57	3.45	-3.45	11.903
C13	36.51	38.56	-2.05	2.05	4.203
C14	21.69	21.13	0.56	0.56	0.314
C15	21.95	21.09	0.86	-0.86	0.740
C23	21.92	20.47	1.45	-1.45	2.103
C24	28.17	26.1	2.07	-2.07	4.285
C25	26.74	25.4	1.34	-1.34	1.796
C34	22.1	20.88	1.22	-1.22	1.488
C35	21.6	20.34	1.26	-1.26	1.588
C45	17.71	17.05	0.66	-0.66	0.436
		Σ_D =	8.48	$\Sigma(M_D-D)^2$ =	34.874
		Two- tailed t-Test			

From table 2,

$\sum D = 8.48$

N = 15

$D = \frac{\sum D}{N} = \frac{8.48}{15} = 0.57$

$S^2 = \frac{\sum(YE-YP)^{\wedge}2}{N-1} = 2.49$

$S = \sqrt{2.49} = 1.25$

Actual value of total variation in t-test

$t = \frac{D*N^{\wedge}0.5}{S} = 1.76$

allowable total variation in t-test with degree of freedom = N-1 = 15 and 5% significant for two-tailed test 1-0.975

Allowable total variation in t-test = $t_{(0.975,14)} = 2.14$ (obtainable from statistical table).

From Table 2, the $t_{calculated}$ is 1.76. The value obtained from standard statistical t-distribution table of 2.14 is greater than the $t_{calculated}$ value of 1.76.

This means that the difference between two set of cubes compressive strength is less than the allowable difference. Hence null hypothesis is accepted, and alternate hypothesis is rejected. Therefore, the regression equation is adequate for the prediction of compressive strength of PSCA concrete.

Constituent materials of concrete

The effect of partial replacement of coarse aggregate with periwinkle shell on the compressive strengthof concrete is as shown in Fig1. It can be observed that compressive strength decreases with increases in the percentage replacement of coarse aggregate with periwinkle shell.

The reduced value of the compressive strength may be due to lower specific gravity value of periwinkle shell compared to that of coarse aggregate. The blending of the two materials caused a reduction in strength value of the product since specific gravity is strength related. The reduced compressive strength value may also be because periwinkle shell has fewer binding properties compared to crushed granite. After 28 days of water curing, the concrete gave an average optimum compressive strength value of 22.84 N/mm^2 corresponding to a mix proportion of 1,0.1,1,1.9, (cement, periwinkle shell, sand, granite) at a water-cement ratio of 0.4.

This compressive strength value obtained at 5% replacement is within the recommended value required for plain concrete works, lean concrete, simple foundations, masonry walls and other simple construction works in low-cost housing construction (Deodhar, 2009).

The 2.64 specific gravity value for sand agrees with Shirley (1975), that the specific gravities of normal density aggregates lie between 2.5 and 3.0. The results of the sieve analysis when compared with the grading limits for fine aggregates as recommended by ASTM C136 – 06 (2009) show that the sand used belong to zone 2.

Analysis of prediction models

The compressive strength test results are presented in Table 3.2. A model based on Scheffe's technique was formulated for the compressive strength. The compressive strength model was tested for adequacy using Student's t-test. The null hypothesis is accepted for the compressive strength model based on the student's t-test indicating that the model is adequate. The optimal value of the compressive strength, which can be predicted byScheffe's model is 22.84 N/mm^2.

The optimal value of compressive strength being 22.84N/mm^2 is above the minimum value of 15 N/mm^2 recommended for construction of non-load bearing walls and mass concrete foundations as earlier suggested by Deodhar (2009) on similar concrete predictions.

Conclusion

i. The results of the study show that periwinkle shell can be used to replace crushed granite partially for concrete works.
ii. The workability of concrete containing periwinkle shell reduces with increase in the content of periwinkle shell.
iii. Compressive strength of concrete containing periwinkle shell increases with age and reduces with percentage replacement of periwinkle shell.
iv. On comparison of the predicated and the experimental value of the compressive strength shows that the model equation below is adequate for predicting compressive strength of concrete made with partial replacement of crushed granite at 5% replacement level after 28days curing. The Scheffe's based model for the prediction and optimization of compressive strength of periwinkle shell concrete determined is given by the expression:

$$Y = 26.39X1 + 22.54X2 + 21.25X3 + 21.07X4 + 20.89X5 + 2.54X1X2 + 1.72X1X3 - 10.28X1X4 - 5.6X1X5 - 3.54X2X3 + 0.86X2X4 - 5.38X2X5 - 4X3X4 + 0.64X3X5 - 2.5X4X5$$

Recommendations

Based on the results obtained from this study, the following recommendations are made:

- The mathematical model developed in this study can be used as design codes and standards for optimal design of PSCA concrete mix ratios.
- The model developed in this study can be used for optimization of any compressive strength of concrete made from cement, periwinkle shell, sand, granite and water.
- Further research can be carried out to ascertain the accuracy of the formulated model using higher order polynomials.

Contribution to knowledge

The study established that the optimal compressive strength of PSCA concrete using Scheffe's model is 22.84 N/mm^2 at 5% replacement of coarse aggregate with periwinkle shell, which is acceptable for plain concrete works, simple foundations and other construction works.

References

Alhaji B. (2016). Statiscal modelling of mechanical property of concrete made from natural aggregate from Bida environs. PHD thesis submitted to civil engineering, Federal university of Technology Minna.

ASTM C136 - 06. (2009). *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*. www.astm.org,

Azhagarsamy S., Sumaiya A.M, &Thilagavathi k. (2017). Effect of Quarry Dust on high performance concrete. International Research Journal of Engineering and Technology (IRJET),1223-1226. B, 20, 344 -360.

Bamigboye G, A, Anthony N, Unwanabasi E. U, Yajudeen O. O and Adekunle O. (2016). Assessment of strength characteristic

of concrete made from locally sourced gravel from south-south Nigeria.British Journal of applied Science & Technology, ISSN:2231-0843

Bdeir, L. M. H. (2012). Study Some Mechanical Properties of Mortar with Sawdust as a Partially Replacement of Sand. Anbar Journal for Engineering Sciences, 5(1), 22-30.

Benin city: B. Eng. project civil Engineering department University of Benin

British Standards Institution, BS 1881: Part 116 (1983) Method for determination of Compressive Strength of Concrete Cubes. London, BSI.

BS 882. (1992). *Specification for aggregates from natural sources for concrete*. British Standards Institution.

BS EN 1008. (2002). *Mixing water for concrete-Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*.

BS EN 12390-3. (2002). *Testing Hardened Concrete—Part 3 Compressive Strength of Test Specimens. - References - Scientific Research Publishing*. https://www.scirp.org/reference/ReferencesPapers?ReferenceID=1884343

BS EN 12390-5. (2019). *Testing hardened concrete. Part 5, Flexural strength of test specimens*. BSI.

BS EN 12620:2002 +A1:2008. (2008). *Aggregates for concrete*. British Standards Institution.

BS EN 197-1. (2011). *Cement Part 1 Composition, Specifications and Conformity Criteria for Common Cements. British Standard Institute, London. - References - Scientific Research Publishing*. https://www.scirp.org/reference/referencespapers?referenceid=2517588

Dauda A.M. Akinmusura J.O. Dauda O.A. Durotoye T.O.,Ogundipe K.E. Oyesomi. K. O (2018). Geotechnical properties of lateritic soil stabililized with periwinkle shells powder International Journal Civil Engineering Technology pp2014-2025.

Deodhar S. V. (2009); Civil Engineering Materials 6th Edition, Market, Naisarak, Delhi, India. ISBN81-7409-163.7

EN 12350-2. (2019). *Testing fresh concrete (Part 2 Slump test)*.

Gibigaye M, Godonou GF (2018), structured mixture proportioning for oil palm kernel shell concrete, construction materials 2017;219-224.

Hossain, Md. Anwar, Umme Sarmeen Akhtar, Md. Sagirul Islam, Mohammad Golam Mostafa, Imdadul Haque, Gorungo Ray, and Tanvir Ahmed (2025). "Optimization of Locally Sourced Concrete Mix Design Using RSM and ANN for Enhanced Strength and Durability." *International Research Journal of Pure and Applied Chemistry* 26 (3): 46–64. https://doi.org/10.9734/irjpac/2025/v26i3916.

Hu, J., & Wang, K. (2011). Effect of coarse aggregate characteristics on concrete rheology. *Construction and Building Materials*, *25*(3), 1196–1204. https://doi.org/10.1016/J.CONBUILDMAT.2010.09.035

León, P. M., & Ramírez, F. (2010). Morphological characterization of concrete aggregates by means of image analysis. *Revista Ingeneria de Construction*, *25*(2), 215–240. www.ing.puc.cl/ric

Neville A. M. (1981); Properties of Concrete, 3rd edition, Pitman publishing Limited London, pp. 154.

Neville A. M., Brooks J. J. (2005). Concrete Technology, Longman Group UK. Ltd, Longman House, Burnt Mill England.

Neville, A. M., & Brooks, J. J. (2010). *Concrete Technology* (Second Edition). Pearson Education Limited.

Mandal, S., Anand, V., Agarwala, S. K., & Waikar, M. L. (2023). *Concrete Technology: Theory and Practice (Based on Model Curriculum of AICTE)*. All India Council for Technical Education (AICTE).

Olufemi I.A. and Manaseh J. (2009), Suitability of Periwinkle Shell as Partial Replacement for River Gravel in Concrete, Leonardo Electronic Journal of Practices and Technologies, pp.59- 66.

Olutoge F. A., Buari T. A. & Adeleke J. S. (2013). Characteristics Strength and Durability of Groundnut Shell Ash Blended Cement Concrete in Sulphate Environments. International Journal of Scientific & Engineering Research, Vol 4.

Osadebe, N.N. (2003). Generalized mathematical modeling of compressive strength of normal concrete as multi-variate function of the properties of its constituent components. A paper delivered at Faculty of Engineering, University of Nigeria, Nsukka.

Scheffe, H. (1958). Experiments with mixtures. *Journal of Royal Statistical Society Series*

Shirley D. E. (1975). Introduction to Concrete. London: Cement and concrete.

Teychenne, D. C., Franklin, R. E., & Erntroy, H. C. (1997). *Design of normal concrete mixes* (Second Edition). Building Research Establishment.

Vishalakshi, K. P., Revathi, V., & Sivamurthy Reddy, S. (2018). Effect of type of coarse aggregate on the strength properties and fracture energy of normal and high strength concrete. *Engineering Fracture Mechanics*, *194*, 52–60. https://doi.org/10.1016/J.ENGFRACMECH.2018.02.029