# Cost – Benefit Evaluation of Using Periwinkle Shells Produce [PSP] as Partial Replacement for Rigid [Concrete] Pavement Conventional Raw Materials

K. C. Nwachukwu[1*]; O. Edike[2]; U. C. Onwuegbuchulem[3]; N. M. Ihekweme[4]; O. E. Nwosu[5]; C. A. O. Udokporo[6]; B. C. Kings- Nwachukwu[7]

[1,5,6]Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria.
[2]Department of Civil Engineering, Nigeria Maritime University, Okerekendo, Delta State, Nigeria.
[3]Department of Building, Federal University of Technology, Owerri, Imo State, Nigeria.
[4]Department of Quantity Surveying, Federal University of Technology, Owerri, Imo State, Nigeria.
[7]Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria

Corresponding Author: K. C. Nwachukwu[1*]

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**Abstract: Nowadays that the cost of concrete conventional raw materials such as Cement[C], Fine Aggregate[FA] and Course Aggregate [CA] are on the increasing side, there is no doubt that the cost of constructing 1km of rigid pavement will equally go higher. This work seeks to highlight the advantages of using Periwinkle Shells Produce [PSP] in partial replacements of Cement[C], FA and CA in a typical rigid [concrete] road pavement. PSP include the Periwinkle Shells Ash [PSA], Periwinkle Shells Ash for FA [PSAF] and Periwinkle Shells [PS] in its ungrounded form for partial replacements of cement, FA and CA respectively. The compressive strengths of Periwinkle Shells Produce Concrete [PSPC] were determined through ten trial mixes using Kings- HDEMD [K-H] Model. In the development of the mix ratios, only 20 per cent (%) of cement, FA, and CA were replaced with PSA, PSAF and PS respectively using conventional mix ratio of 1:2: 4 where twenty (20) concrete cubes were cast for the ten (10) trial mixes. Thereafter, using the newly introduced Kings- SCBOQ [K-S] Model, the cost of constructing 1 km of rigid concrete road pavement using PSPC concrete was evaluated in comparison with the cost of constructing 1km of the same road project using concrete made of conventional raw materials. The result of the comparison shows that for 1km concrete road project , despite the fact that the compressive strength of PSPC is slightly over 19 MPa, its cost- benefit is highly overwhelming, in the absence of Reinforcement Cost Function [RCF] on the build up of both cost analyses . Whereas it costs between 350 million naira to 1billion naira to construct 1km of concrete road pavement on a typical Nigeria road project, with the use of PSPC, it can cause between 300 million naira to 350 million naira. This implies that concrete roads pavement built using PSPC can sustain multi level traffic designed for Nigerian roads because of its safety, aesthetics, economic and durability satisfaction. Thus, all stakeholders in the Environmental, Building and Construction industries, as well as the Government agencies and Research institutions are advised to support this present innovation for sustainability of durable, affordable and environmentally friendly concrete road projects.**

***Keywords:*** *PSP, PSPC, Rigid/Concrete Pavement, Cement, Compressive Strength [CS], Kings- HDEMD [K-H] Model, Mixture Design, Kings- SCBOQ [K-S] Model, Low Cost Concrete Road Projects.*

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## I. INTRODUCTION

The present Nigerian government under the current minister of works has been desirous to construct more of concrete roads (Rigid Pavements) as compared to flexible road pavements. This is due their quest to provide strong, durable and long lasting road network across the country. But due to limited budget, the economic and affordability criteria

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of this decision may not be always fulfilled. This work is therefore aimed at providing a balance between durability and affordability satisfaction of Rigid (concrete) Road Pavement in a typical Nigerian Road Network.

Flexible Pavement and Rigid Pavement are two basic types of Road pavement found in Nigeria. The choice on which type to select for construction is a function of fund availability , durability preference, political will, public interest, nature of soil , terrain, and other environmental considerations. According to Lees (2021), rigid pavement consists of one layer and flexible pavement is typically made up of multiple layers. Figure 1 provides a right view of basic difference between rigid and flexible pavement in terms of number of layers. In a nutshell, Rigid (Concrete) roads provide durable, low- maintenance alternative to flexible (Bituminous) pavements. They are used where very heavy vehicular loading, long lifespan or zero re-surfacing matters more than initial cost. Usually, rigid or concrete roads have 25- 40 years lifespan, very low maintenance, high initial cost, and high load capacity. It is best for industrial roads, port and airport access, urban arterials, multi-storey- residential gated colonies, etc. on the other hands, flexible (bituminous) roads have 10-15 years design life, periodic overlay every 5-7 years as well as lower initial cost. It is best for rural roads under normal traffic, state inter village links, residential colonies. This is to say that both rigid and flexible pavements have their various advantages and disadvantages, even though rigid pavement seems to be preferred when choice selection judgment is based on a 30 year life cycle. Therefore, in other to overcome the demerits of rigid pavement which may include high initial cost, the use of inexpensive innovative constructions materials such as PSP to partially replace Concrete Conventional Raw Materials [CCRM] can be a welcome idea. This work therefore provides a platform on how the initial cost of rigid roads can be reduced through partial replacements of Cement[C], FA and CA using PSP which include PSA, PSAF and PS.

In general, concrete is a homogeneous mixture of cement, sand (as FA), gravel or granite (as CA) and water . More about Concrete, Cement and their importance, as well as the choice of using shells as partial replacement for cement have been done extensively by the works of Oyenuga (2008), Syal and Goel (2007), Neville (1990) and Nwachukwu and others (2025 d,e & f). The special property of PSPC to be investigated in this present study is the concrete's compressive strength. By definition, this mechanical property of concrete is the strength of hardened concrete measured by the compression test or the Universal Testing Machine [UTM]. See the works of Nwachukwu and others (2025b).

For the PSPC Mixture Design, the Kings –HDEMD [K-H] Model used in this work has provided a platform for the development of mix ratios. Before the introduction of the K-H Model, Shacklock (1974) and Jackson and Dhir (1996) have outlined the objectives of mix design. See Nwachukwu and others (2025b). Though Hughes (1971), ACI- 211(1994) and DOE (1988) had proposed empirical mix design procedures that seems to be more complex and time consuming because of the involvement of a lot of trial mixes and complex statistical calculations before the desired strength of the concrete can be reached, Nwachukwu and others (2025b) had developed the method called Handy Developed Empirical Mixture Design [HDEMD] method, which is modified now as Kings –HDEMD [K-H]. The seven components for PSPC mixture design are: Water, Cement, PSA, Fine Aggregate [FA], PSAF, Coarse Aggregate [CA] and PS.

On Concrete Cost Estimation, the Civil Engineering Standard Method Of Measurement [CESMM] and other Cost Estimation materials have been providing adequate guide on cost analysis. But no one can resist the newly introduced cost estimation model in this present work because of its handy and simplified way of estimating the cost of concrete work in the concrete road project. The K-H Model will be used in the cost- benefit evaluation of PSPC road project in comparison with Concrete Using Conventional Raw Materials [CCRM].

The present work evaluates the Cost – Benefit of using Periwinkle Shells Produce [PSP] as Partial Replacement for Rigid [Concrete] Pavement Conventional Raw Materials. Owing to the peculiar nature of the subject matter, many authors have done some work or the other relating to it but none has been able to address the subject matter sufficiently. Take for instance, on the use of PS, PSA, Snail Shells (SS), Egg Shells (ES), ESA, SSA, Mussel Shells (MS), MSA and other Mollusks Shells and Ashes in the environmental , construction and allied industries, Agbede and Manasseh (2009) investigated the suitability of Periwinkle Shell as partial replacement for river gravel in concrete. Oyedepoo (2016) has examined the evaluation of the properties of lightweight concrete using Periwinkle Shells as a partial replacement for coarse aggregate..Elamah and others (2021) accessed the strength characterization of periwinkle polymer concrete. Soneye and others (2016) carried out a research on the study of Periwinkle Shells as fine and course aggregate in concrete works. Abdullah and Sara (2015) carried out an assessment of periwinkle shells ash as composite materials for particle board production. Offiong and Akpan (2017) carried out an assessment of physico-chemical properties of Periwinkle Shell ash as partial replacement for cement in concrete.. Adeala and Olaoye (2019) have investigated the Structural Properties of Snail Shell Ash Concrete (SSAC). Zaid and Ghorpade (2014) have carried out an Experimental Investigation of Snail Shell Ash (SSA) as Partial Replacement of Ordinary Portland Cement in Concrete. Alla and Asadi (2022) carried out an Experimental investigation and Microstructural behaviour of un-calcined and calcined snail shell powder cement mortar. Alla and Asadi (2021) examined the Mechanical Strength, Durability and Microstructure in an Experimental Investigation of Snail Shell-Based Cement Mortar and Nnochiri and others (2018) investigated the Effects Of Snail Shell Ash On Lime Stabilized Lateritic Soil.. Mtallib and Rabiu (2009) investigated the effects of Eggshells Ash [ESA] on the setting time of cement. Syammaun and others (2023) assessed the performance of Eggshells ash as sustainable bitumen modifier. Bamigboye and others (2021) have investigated the prospects and challenges pertaining to the sustainable use of

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seashells as binder in concrete production. Peceno and others (2019) investigated the substitution of coarse aggregates with mollusc-shells waste in acoustic-absorbing concrete. Adewuyi and others (2015) examined the utilization of mollusc shells for concrete production for sustainable environment. Mohammad and others (2017) carried out a review on seashells ash as partial cement replacement. Gonzalez and others (2015) investigated the effects of seashell aggregates in concrete properties.. Gigante and others (2020) investigated the evaluation of Mussel Shells powder as reinforcement for PLA-based biocomposites. Melo and others (2019) carried out an extensive work on high- density polyethylene/mollusc shell –waste composites, effects of particle size and coupling agent on morphology, mechanical and thermal properties.. On the application of environmentally friendly techniques to ensure partial replacement of cement for cement, concrete and overall building optimization and pollution free environment, the works of Ugwuanyi and others ( 2018), Mmonwuba and others (2023), Mmonwuba and Bonaventure(2025), Ishaya and others (2016), Ogunjiofor and others (2023a), Ogunjiofor and others (2023b) and Ogunjiofor and others (2023c) still play important role in sustenance of green and clean environment. On works done using optimization model in concrete mixtures, recent works have shown that many researchers have applied Scheffe's and Kings- Scheffe's method to carry out one form of optimization work or the other, in the determination of concrete mechanical properties such as compressive strength, flexural strength and split tensile strength . For example, Nwakonobi and Osadebe (2008) have used Scheffe's model to optimize the mix proportion of Clay- Rice Husk Cement Mixture for Animal Building. Ezeh and Ibearugbulem (2009) have applied Scheffe's model to optimize the compressive cube strength of River Stone Aggregate Concrete. Scheffe's model was used by Ezeh and others (2010a) to optimize the compressive strength of cement- sawdust Ash Sandcrete Block. Again Ezeh and others (2010b) optimized the aggregate composition of laterite/ sand hollow block using Scheffe's simplex method. The works of Ibearugbulem (2006) and Okere (2006) were based on the use of Scheffe' model in the optimization of compressive strength of Perwinkle Shell-Granite Aggregate Concrete and optimization of the Modulus of Rupture of Concrete respectively. Mbadike and Osadebe (2013) applied Scheffe's (4,2) model to optimize the compressive strength of Laterite Concrete. Egamana and Sule (2017) carried out an optimization work on the compressive strength of periwinkle shell aggregate concrete Obam (2009) developed a mathematical model for the optimization of strength of concrete using shear modulus of Rice Husk Ash as a case study. The work of Obam (2006) was based on four component mixtures, that is Scheffe's (4,2) and Scheffe's (4,3) where comparison was made between second degree model and third degree model. Nwachukwu and others (2017) developed and employed Scheffe's Second Degree Polynomial model to optimize the compressive strength of Glass Fibre Reinforced Concrete (GFRC). Also, Nwachukwu and others (2022a) developed and used Scheffe's Third Degree Polynomial model, Scheffe's (5,3) to optimize the compressive strength of GFRC where they compared the results with their previous work, Nwachukwu and others (2017). Nwachukwu and others (2022c) used Scheffe's (5,2) optimization model to optimize the compressive strength of Polypropylene Fibre Reinforced Concrete (PFRC). Again, Nwachukwu and others (2022d) applied Scheffe's (5,2) mathematical model to optimize the compressive strength of Nylon Fibre Reinforced Concrete (NFRC). Nwachukwu and others (2022b) applied Scheffe's (5,2) mathematical model to optimize the compressive strength of Steel Fibre Reinforced Concrete (SFRC). Furthermore, Nwachukwu and others (2022e) used Scheffe's Third Degree Regression model, Scheffe's (5,3) to optimize the compressive strength of PFRC. Nwachukwu and others (2022f) applied Modified Scheffe's Third Degree Polynomial model to optimize the compressive strength of NFRC. Again, Nwachukwu and others (2022g) applied Scheffe's Third Degree Model to optimize the compressive strength of SFRC. In what is termed as introduction of six component mixture and its Scheffe's formulation ,Nwachukwu and others (2022h) developed and used Scheffe's (6,2) Model to optimize the compressive strength of Hybrid- Polypropylene – Steel Fibre Reinforced Concrete ( HPSFRC). Nwachukwu and others (2022 i) applied Scheffe's (6,2) model to optimize the Compressive Strength of Concrete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA). Nwachukwu and others (2022j) applied Scheffe's (6,2) model in the Optimization of Compressive Strength of Hybrid Polypropylene – Nylon Fibre Reinforced Concrete (HPNFRC) .Nwachukwu and others (2022k) applied the use of Scheffe's Second Degree Polynomial Model to optimize the compressive strength of Mussel Shell Fibre Reinforced Concrete (MSFRC). Nwachukwu and others (2022l) carried out an optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Periwinkle Shells Ash (PSA) Using Scheffe's Second Degree Model. Nwachukwu and others (2023a) applied Scheffe's Third Degree Regression Model to optimize the compressive strength of Hybrid-Polypropylene- Steel Fibre Reinforced Concrete (HPSFRC). Nwachukwu and others (2023b) applied Scheffe's (6,3) Model in the Optimization Of Compressive Strength of Concete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA). Nwachukwu and others (2023c) applied Scheffe's (6,2) model to optimize the Flexural Strength And Split Tensile Strength Of Hybrid Polypropylene Steel Fibre Reinforced Concrete (HPSFRC). Nwachukwu and others (2023d) made use of Scheffe's Second Degree Model In The Optimization Of Compressive Strength Of Asbestos Fibre Reinforced Concrete (AFRC). Nwachukwu and others (2023e) used optimization techniques in the Flexural Strength And Split Tensile Strength determination of Hybrid Polypropylene - Steel Fibre Reinforced Concrete (HPSFRC). Nwachukwu and others (2023f) applied Scheffe's Optimization model in the evaluation of Flexural Strength And Split Tensile Strength Of Plastic Fibre Reinforced Concrete (PLFRC). Nwachukwu and Opara (2023) in their paper presented at the Conference Proceedings of the Nigeria Society of Engineers, demonstrated the use of Snail Shells Ash (SSA) in the partial replacement of cement using Scheffe's (5,2) optimization model. Nwachukwu and others (2024a) applied the use of Scheffe's (6,2) model to evaluate the optimum flexural and

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split tensile strengths of Periwinkle Shells Ash (PSA)- Mussel Shells Ash (MSA)- Cement Concrete (PMCC). Nwachukwu and others (2024b) applied the use of Scheffe's (6,2) model to evaluate the optimum compressive strength of Periwinkle Shells Ash (PSA)- Snail Shells Ash (SSA)- Cement Concrete (PSCC). Nwachukwu and others (2024c) applied Scheffe's (5,2) model to evaluate the compressive strength of Plastic Fibre Reinforced Concrete [PLFRC]. Nwachukwu and others (2024d) applied the use of Scheffe's Third Degree Model to optimize the compressive strength of HPNFRC. Nwachukwu and others (2024e) applied the use of Scheffe's Third Degree Regression Model to optimize the compressive strength of MSFRC. Nwachukwu and Okodugha (2024a) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of NFRC. Again, Nwachukwu and others (2024f) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of PFRC. Nwachukwu and Okodugha (2024b) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of GFRC. Furthermore, Nwachukwu and Okodugha (2024c) made use of Scheffe's (5,2) Model to optimize the flexural strength and split tensile strength of SFRC. Nwachukwu and Okodugha (2024d) applied the use of Scheffe's Second Degree Model to optimize the flexural strength and split tensile strength of AFRC. Nwachukwu and others (2024g) applied the use of Kings -Scheffe's (6,2) Modified Model to optimize the flexural strength and split tensile strength of HNSFRC, Nwachukwu and others (2024h) applied the use of Kings - Scheffe's (6,2) Modified Model to optimize the compressive strength of HNSFRC. Nwachukwu and others (2024i) applied the use of Kings- Scheffe's (6,2) Model to optimize the flexural strength and split tensile strength of HPNFRC. Nwachukwu and others (2025a) investigated the compressive strength of PMCC using Kings- Scheffe's (6,2) Model. On the use of HDEMD method, Nwachukwu and others (2025b) evaluated the Compressive Strength of PSA-ESA-Cement Concrete [PECC] Using Handy Developed Empirical [HDE] Mixture Design Method. Nwachukwu and others (2025c) evaluated the Flexural Strength of PSA-ESA-Cement Concrete [PECC] Using HDEDM method. Nwachukwu and others (2025d) evaluated the Compressive Strengths of Concretes made with FUTO Otamiri River in comparison with those made with potable borehole water using HDEMD. Nwachukwu and others (2025e) investigated the Split Tensile Strength Of PSA- ESA- Cement Concrete [PECC] Using Handy Developed Empirical Mixture Design [HDEMD]. Finally, Nwachukwu and others (2025 f), applied the Use Of Kings- HDEMD [K-H] Model In The Flexural Strength [FS] Investigation Of PSA- SSA- Cement Concrete [PSCC]. On cost estimation, the necessity for a precise preliminary estimate has prompted several studies. Some authors have ended up into constructing models relying on machine learning (ML) algorithms to predict the initial assessment of road, building, bridge, or other construction projects while some have explored and used CNN-DAE algorithm for economic cost predictions. The following works: Abed and Hasan (2022); Akinradewo and others.(2020); Lees (2021); Mirkovic and Mirkovic (2026); Ojo (2019); the US Department Of Transportation (2023); Yang .(2025) as well as Zhang.(2025), all have contributed to literature as far as estimation of construction work is concerned. Furthermore, Ogungbile and others (2018) on their own have developed cost models to predict the preliminary estimates of road projects in Nigeria at the early state using parametric estimating techniques. Based on the works reviewed so far, it can be envisaged that no work has been done on the subject matter: Cost – Benefit Evaluation Of Using Periwinkle Shells Produce [PSP] As Partial Replacement For Rigid [Concrete] Pavement Conventional Raw Materials. Henceforth, the need for this present research work, where K-H Model will be employed to determine the compressive strength of PSPC and the newly introduced K-S Model will be utilized in evaluating the Cost- Benefit of using the PSPC for Low Cost Concrete Road Projects.

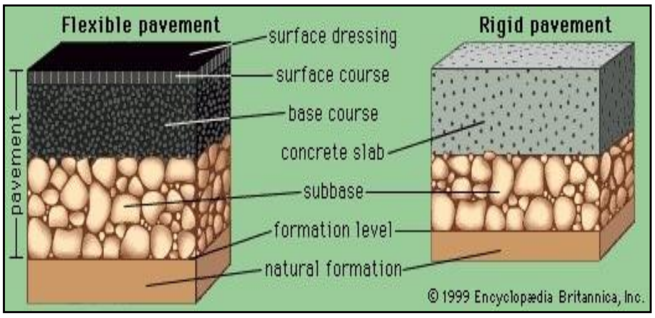


Fig 1 Types of Pavement [Lees (2021)]

## II. METHODOLOGY

➢ *Material for PSPC- CS Mixture*

In this recent research work, the component PSPC materials under compressive strength investigations are: Water/Cement(W/C) ratio, Cement (C), PSA, FA, PSAF, CA and PS. The water is procured from potable clean water source and was applied in accordance with ASTM C1602/C1602M-22 (2022). The cement that is a brand of Ordinary Portland Cement that conforms to British Standard Institution, BS 12 (1978) was procured from local distributors. Sand as FA of suitable size was also purchased from the local distributor. Granite as a CA was purchased from a local stone market. Both FA and CA were procured and prepared in accordance with ASTM C33/C33M-18 (2018). The PS used in this work was procured as a waste in an aquaculture industry markets and was washed and sundried for few days. After sufficient drying, some of the ungrounded PS were reserved for use as partial replacement for CA while others were calcined in a Gallenkamp Muffle Furnace at sufficient high temperature. The calcined PS samples were allowed to cool in a deciccator and then grinded using a ceramic mortar and pestle into Very Fine Powder [VFP]. Some of the VFP as Ash were preserved as PSAF for partial replacement for FA while the rest were sieved through a BS sieve of 75 microns as PSA for partial replacement for Cement(C) and were kept in air tight containers for use in the PSPC mixtures for compressive strength investigation. In the large scale production of PSA and PSAF, large quantities of PS were taken to Muffle furnace with large capacities and were grinded with Machines that have large capacities.

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➢ *Theoritical Framework for Models in this Work*

- *K-H Model Theoritical Background*

K- H Model is Kings- Handy Developed Empirical Mixture Design [HDEMD] Model developed by Nwachukwu and Others (2025b) for Handy Development of Mix Ratios and Prompt Measurement of Quantities of Materials in the Laboratory.

✓ *Adopted Mix Ratio for PSPC - CS Mixture Design*

The adopted mix ratio for this work is 1:2:4. The different water/ cement (W/C) ratios adopted are 0.50, 0.58, 0.60, 0.63, 0.68, 0.70, 0.73, 0.75, 0.80, 0.85.

✓ *Conventional Mix Ratios for Partial Replacement of Cement, FA and CA in PSPC- CS Mixture*

Using W/C ratio of 0.5, we have new conventional mix ratio as : 0.5:1:2:4.

Then replacing only 20% of conventional Cement, FA and CA with PSA, PSAF and PS respectively, we have:

C: PSA: FA: PSAF: CA: PS = 0.5: 0.8: 0.2: 1.6: 0.4: 3.2: 0.8. The rest are shown in Table 1.

✓ *Measurement of Quantities of PSPC- CS Materials at the Laboratory*

Mathematically, from the works of Nwachukwu and others (2024a), Measured Quantity, $M^Q$ of PSPC – CS Mixture is given by Eqn.(1).

$$M^Q = \frac{X}{T} * W \tag{1}$$

Where, X = Individual mix ratio at each point.

T = Sum of mix ratios at each point

And W = Average weight of Concrete cube/beam/cylinder

For the Compressive Strength concrete cube mould of 15cm*15cm*15cm, Average W from experience = 8kg

Using point 1 mix ratios, we have: W/C: C: PSA: FA: PSAF: CA: PS = 0.5: 0.8: 0.2: 1.6: 0.4: 3.2: 0.8.

T= 7.5, W = 8Kg

For $X_1$ = 0.5, using Eqn. (1), $Q_I$ = 0.53 etc, and the measured quantity for point mix ratios equals

$Q_I : Q_2: Q_3: Q_4: Q_5: Q_6 : Q_7$ = 0.53: 0.86:0.21:1.71: 0.43: 3.42 : 0.86

For the 10 different trial mix ratios, the measured quantities are displayed in Table 1.

- *K-S Model Theoritical Build UP*

K- S Model is Kings- Simplified Concrete Bill of Quantity [SCBOQ] Model which is being developed in this present work by the corresponding author, Engr. Dr. Apostle Kingsley Chibuzor Nwachukwu for Handy Estimation of Cost of Concrete Work for 1 km of Concrete Road Project. In this Model, the Concrete Cost Function [$CC^F$] is given by Eqn.(2).

$$CC^F = \frac{X\,G\,V\,R_i}{T\,Y_i} \tag{2}$$

Where, X = Each concrete component mix ratio

T = Sum of mix ratios for concrete combined components

G = Approximate weight of $1m^3$ of Concrete (Kg)

V = Total volume of concrete needed in 1km of concrete road project ($m^3$) = L * W* t

L = Length of 1 km of concrete road = 1km = 1000m

W = Width of the road (m)

T = Thickness of the Road (m)

$R_i$ = Unit price of each concrete component from the Build-up Rate .

And $Y_i$ = 50kg = General guide for 1 bag of each concrete component. That is Cement, FA, CA, PSA, PSAF, etc where i could be Cement component, FA, CA, etc.

➢ *Methods*

- *Methods for PSPC- CS*

✓ *PSPC Specimen Preparation/Batching/Curing for Compressive Strenght [CS] Test*

The specimen used for the compressive strength is concrete cube. They were cast in steel mould measuring 150mm*150mm*150mm. The mould and its base were damped together during concrete casting to prevent leakage of mortar and then thin engine oil was applied to the inner surface of the moulds to make for easy removal of the cubes. Batching of all the constituent material was done by weight using a weighing balance of 50kg capacity based on the adopted mix ratios and water cement ratios as depicted in Table 1. The measured actual quantities of PSPC are as shown in Table 1. For the ten trial tests, a total number of 10 mix ratios were to be used to produce 20 PSPC prototype concrete cubes. Curing commenced 24hours when the specimens were removed from the moulds and were placed in clean water in the curing tank for curing. After 28 days of curing the specimens were taken out of the curing tank for the PSPC compressive strength test.

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✓ *PSPC Compressive Strenght Test Procedure/Calculation*

Compressive strength testing was done in accordance with BS 1881 – Part 116 (1983) - Method of Determination of Compressive Strength of concrete cube and ACI (1989) guideline. Two samples were crushed for each mix ratio. In each case, the compressive strength was calculated using Eqn.(3) as:

$$\text{Compressive Strength (MPa), CS} = \frac{\text{Average failure Load, P}}{\text{Cross- sectional Area, A}} \quad (3)$$

- *Methods for PSPC Cost – Benefit Evaluation Using [K-S] Model*

Here, the method for evaluating the Cost- Benefit using the K-S Model involves determining the quantity of works, building up of rate and evaluating the total cost function.

✓ *Important Terms/ K-S Model Formular*

- *Quantity Determination:*

Using the K-S Model, the quantity, Z (kg) of concrete work is determined using Eqn. (4)

$$Z = \frac{XGV}{T} \quad (4)$$

- *Building up of Rate:*

For each concrete component, the build- up rate, $R_i$ sometime is the unit price of that commodity and some times , a cumulative of all the expenses incurred during procurement of the material. For instance, $R_i$ for PSA may include the cost of procurement of the PS, the cost of calcinations and grinding, as well as the cost of sieving. Every unit price is calculated per price of 50kg of any of the concrete component. That is 50kg bag of cement, 50kg bag of sand, 50kg bag of PSA , etc.

- *Determination of Number of Bags of Items Needed:*

Number of Bags of Items Needed, N is determined using Eqn. (5)

$$N = \frac{Z}{Y_i} \quad (5)$$

Where $Y_i$ = 50kg = General guide for 1 bag of each concrete component

- *Determination of Cost Function for Each Concrete Component*

This is determined using either Eqn.(6) or Eqn.(2)

$$CC^F = N\,R_i \quad (6)$$

- *Determination of Total Cost Function for All Concrete Components*

This is the overall sum of the cost of all concrete components. This is demonstrated in Table 2.

✓ *Summarized Procedures for K-S Model:*

- Determine V = Volume of concrete needed in 1km of road project = LW t
- Evaluate the mix proportion using conventional mix ratio such as 1:2:4 without incorporating W/C ratio. Here , X is component mix ratio.

For CCRM [Concrete Using Conventional Raw Materials], X = C: FA: CA = 1:2:4

For PSPC, X = C: PSA: FA: PSAF: CA: PS = 0.8: 0.2: 1.6: 0.4: 3.2: 0.8.

- Determine G = Approximate weight of $1m^3$ of concrete. Weight of $1m^3$ of concrete ranges between 2300kg and 2500kg. This work adopts 2450kg.
- Determine T = Sum of all Mix ratios
- Then Z for each concrete compnent is computed using Eqn. (4)
- Build up rate, $R_i$ for each component is determined
- Using $Y_i$ = 50kg as a general guide for 1 bag of each concrete component, determine the number of bags needed in each component using Eqn.(5).
- Finally, determine each component cost function using Eqn.(2). Then sum of the each component cost function is the overall cost of the project. The summarized procedure is shown in Table 2.

## III. RESULTS AND DISCUSSIONS

➢ *Result Presentation*

- *$28^{th}$ Day Compressive Strenght Test Result of PSPC Based on K-H Model*

The results of the compressive strength of PSPC, together with the mix ratio and measured quantity of PSPC in the Laboratory are shown in Table 1

Table 1 Presentation of Results of Compressive Strength of PSPC, the Mixture Design Mix Ratio and the Measured Quantity of PSPC at the Laboratory

| | | | | |
|---|---|---|---|---|
| | | **AIM: PSPC-COMPRESSIVE STRENGHT[CS] – MIXTU** | **• DIMESION OF MOULD: 150X150X150MM**<br>**• APPROXIMATE. WEIGHT OF CAST CS CONCRETE CUBE, W: 8KG** | **• MEASURED QTY OF PSPC MATERIAL AT LAB, MQ:**<br>**• $M^Q = \frac{X\,W}{T}$ [KG]**<br>**• X = INDIVIDUAL MIX RATIO**<br>**• T = SUM OF MIX RATIOS** |
| | | | **• AREA, A : 22500MM²** | |

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| | | RE DESIGN | • WEIGHING BAL.: 50KG | | | | | | | | • DATE OF CRUSHING: AUGUST , 2025. | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | REPLICATE | CODING | MIX RATIO BASED ON 1:2:4 | | | | | | | | MEASURED QTY AT LAB, $M^Q$ [KG] | | | | | | | P [KN] | CS [MPA] $=\frac{P}{A}$ | AV CS [MPA] |
| | | | $X_1$ W/C | $X_2$ C | $X_3$ PSA | $X_4$ FA | $X_5$ PSAF | $X_6$ CA | $X_7$ PS | TOTAL | $Q_1$ W/C | $Q_2$ C | $Q_3$ PSA | $Q_4$ FA | $Q_5$ PSAF | $Q_6$ CA | $Q_7$ PS | | | |
| 1. | A | PSPC/$A_1$/CS | 0.50 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.50 | 0.53 | 0.86 | 0.21 | 1.71 | 0.43 | 3.42 | 0.86 | 270 | 12.00 | 12.43 |
| | B | PSPC/$B_1$/CS | 0.50 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.50 | 0.53 | 0.86 | 0.21 | 1.71 | 0.43 | 3.42 | 0.86 | 289 | 12.86 | |
| 2. | A | PSPC/$A_2$/CS | 0.58 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.58 | 0.61 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 449 | 19.96 | 19.98 |
| | B | PSPC/$B_2$/CS | 0.58 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.58 | 0.61 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 450 | 20.00 | |
| 3. | A | PSPC/$A_3$/CS | 0.60 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.60 | 0.63 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 384 | 17.04 | 17.02 |
| | B | PSPC/$B_3$/CS | 0.60 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.60 | 0.63 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 383 | 17.04 | |
| 4. | A | PSPC/$A_4$/CS | 0.63 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.63 | 0.66 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 377 | 16.75 | 16.75 |
| | B | PSPC/$B_4$/CS | 0.63 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.63 | 0.66 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 379 | 16.75 | |
| 5. | A | PSPC/$A_5$/CS | 0.68 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.68 | 0.71 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 403 | 17.90 | 17.60 |
| | B | PSPC/$B_5$/CS | 0.68 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.68 | 0.71 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 389 | 17.30 | |
| 6. | A | PSPC/$A_6$/CS | 0.70 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.70 | 0.73 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 421 | 18.71 | 18.71 |
| | B | PSPC/$B_6$/CS | 0.70 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.70 | 0.73 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 421 | 18.71 | |
| 7. | A | PSPC/$A_7$/CS | 0.73 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.73 | 0.76 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 365 | 16.22 | 16.22 |
| | B | PECC/$B_7$/CS | 0.73 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.73 | 0.76 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 365 | 16.22 | |
| 8. | A | PSPC/$A_8$/CS | 0.75 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.75 | 0.77 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 426 | 18.92 | 18.92 |
| | B | PSPC/$B_8$/CS | 0.75 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.75 | 0.77 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 426 | 18.92 | |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9. | A | PECC/$A_9$/CS | 0.80 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.80 | 0.82 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 396 | 17.61 | 17.63 |
| | B | PSPC/$B_9$/CS | 0.80 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.80 | 0.82 | 0.84 | 0.21 | 1.68 | 0.42 | 3.36 | 0.84 | 397 | 1765 | |
| 10. | A | PSPC/$A_{10}$/CS | 0.85 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.85 | 0.87 | 0.82 | 0.20 | 1.63 | 0.40 | 3.26 | 0.82 | 344 | 15.30 | 15.26 |
| | B | PSPC/$B_{10}$/CS | 0.85 | 0.80 | 0.20 | 1.60 | 0.40 | 3.20 | 0.80 | 7.85 | 0.87 | 0.82 | 0.20 | 1.63 | 0.40 | 3.36 | 0.82 | 342 | 15.22 | |
| TOTAL | | | | | | | | | | | | | | | | | | | | |

- *Result of Cost – Benefit Analysis of Using PSPC for 1km of Concrete Road Project Compared with Concrete Using Conventional Raw Materials [CCRM]*

Table 2 displays the results of the Cost – Benefit Analysis between PSPC and CCRM based on 1km of concrete road of width, 7.5m and thickness, 200mm.

Table 2 Result of Cost – Benefit Evaluation of Using PSPC for 1km of Concrete Road Project Compared with CCRM Based on K-S Model

| **S/N** | | **Quantity** $Z(Kg) = \frac{XGV}{T}$ | | **No. Of Bags** $N = \frac{Z}{Y_i}$ | | **Rate** $R_i$ | **Concrete Cost Function (#)** $CC^F = N R_i$ **Or From Eqn. (2)** | | **Difference (#)** |
|---|---|---|---|---|---|---|---|---|---|
| | | **PSPC** | **CCRM** | **PSPC** | **CCRM** | | **PSPC** | **CCRM** | |
| 1. | Cement Cost Function [$CEC^F$] | 420,000 | 525,000 | 8,400 | 10,500 | 12,000 | 100,800,000 | 126,000,000 | |
| 2. | PSA Cost Function [$PSAC^F$] | 105,000 | - | 2,100 | - | 1,500 | 3,150,000 | - | |
| 3. | FA Cost Function [$FAC^F$] | 840,000 | 1.050,000 | 16,800 | 21,000 | 3000 | 50,400,000 | 63,000,000 | |
| 4. | PSAF Cost Function [$PSAFC^F$] | 210,000 | - | 4200 | - | 1500 | 6,300,000 | - | |
| 5. | CA Cost Function [$CAC^F$] | 1,680,000 | 2,100,000 | 33,600 | 42,000 | 4000 | 134,400,000 | 168,000,000 | |
| 6. | PS Cost Function [$PSC^F$] | 420,000 | - | 8400 | - | 1000 | 8,400,000 | - | |
| SUM | | | | | | | 303,450,000 | 352,009,000 | 48,550,000 |

- *Result Discussions*

From the Strength perspective, the maximum compressive strength of PSPC evaluated using K-H Model is 19.98 MPa for the 28th day result. The maximum value is close to 20 MPa, which is the minimum value specified by the American Concrete Institute [ACI] for the compressive strength of good concrete .From the Cost- Benefit Analysis using K-S Model, the difference between the estimated cost of constructing 1km of concrete road using PSPC or CCRM is 48,550,000 naira. This implies that for 10 km of concrete road project, over 4 billion naira can be saved together with the benefit that comes from partial replacement of sand (FA) with PFAF as there is a reduction in excavation processes through which sand is produced. Both results are in good agreement with safety, economic, aesthetics and environmental satisfactions.

## IV. CONCLUSION

So far in this research work, the K-H and K-S Models have been presented respectively in the evaluation of

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compressive strength of PSPC as well as Cost-Benefit Evaluation of PSCS and CCRM in concrete road projects.

The Kings- HDEMD [K-H] Model offers advantages in the mixture design as well as quick computation of the quantities of PSPC materials required in the laboratory. The Kings- SCBOQ [K-S] Model is the newly introduced Cost Estimation Model which offers simplified handy approach in estimating the cost of concrete works. In a nutshell, PSPC is a concrete mixture where Concrete Conventional Raw Materials [CCRM] which include Cement, FA , and CA can be partially replaced with alternative less expensive innovative Periwinkle Shells Produce [PSP]. This arrangement offers low cost concrete production. It has also been demonstrated that the use of PSP (which include PS, PSA and PSAF) can help reduce global environmental pollution. The PS that would have caused a menace to the environment are procured almost free of charge and harnessed as construction material for the benefit of mankind. The results of the compressive strength are as stated in Table 1 and in the result discussion section. Similarly in Table 2, the result of the cost –benefit analysis are displayed. The results using both models produced good concrete and favorable economic advantage that PSPC would possess in the construction of 1km of concrete road project. Thus, all stakeholders in the construction industries as well as environmental engineering sectors are advised to cooperate with this innovation for sustainability of durable low cost concrete road construction and affordable housing for satisfactory pollution control measures.

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