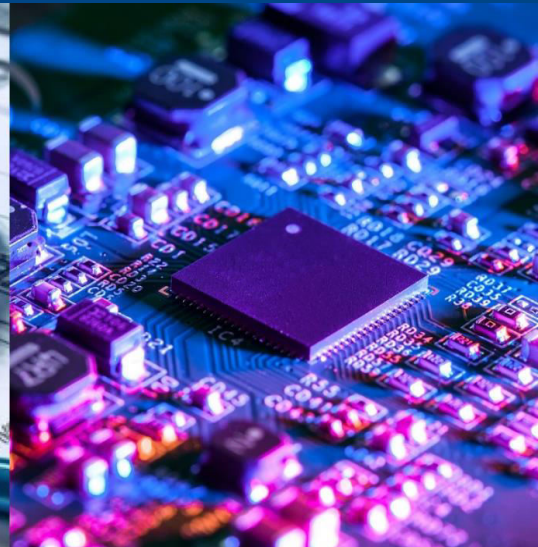




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Split Tensile Strength [STS] Property Investigation of SSA - ESA- Cement Concrete [SECC] Using Kings- HDEMD [K-H] Model

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ABSTRACT: Disaster Risk Reduction is one of the United Nations Sustainable Development Goal [SDG-11] agenda in Nigeria by 2030. Based on this, Hydraulic Structures in the form of Dams, etc are built to tackle issues of Flooding from Climate Change. Because Hydraulic Structures are constructed to provide their services without interruption during their design life span, efforts are always made to check both Serviceability Limit States [SLS] and Ultimate Limit State[ULS] Functions during the Conceptual Design and Construction Stages of the project. Cracking is one of the SLS phenomena. Splitting Tensile strength [STS] is an important index to determine the capacity of crack resistance in concrete design. This work is therefore aimed at evaluating the STS of SECC in a typical Hydraulic Structures Construction [HSC] Setting using Kings- Handy Developed Empirical Mixture Design (HDEMD) Model [K-H Model]. SECC is a concrete mixture where expensive cement is partially replaced with two combined innovative inexpensive materials of Snail Shells Ash [SSA] and Egg Shells Ash [ESA]. In the development of the mix ratios using K-H Model, only 60 per cent (%) of cement is replaced with the mix proportion of SSA- ESA kept in 50% - 50% . Using conventional mix ratio of 1:2: 4, ten (10) different mix trials at different Water – Cement (W/C) ratio were generated and used to cast twenty (20) concrete cylinders and the Split Tensile Strength of SECC were evaluated at each trial mix. The 28th day maximum SECC-STs is **2.48 MPa**, while the minimum value is obtained as **1.27 MPa**. Thus, the SECC- STS values can sustain construction of light-weight , water retaining some heavy-weight structures at the best economic, aesthetic, safety and environmentally friendly advantages. Therefore concerted efforts should be put together by all stakeholders in the Civil/ Environmental Engineering/Water Resources Engineering/Construction Industries in order to improve upon this innovation of partial replacement of conventional expensive construction raw materials with less expensive innovative and environmentally friendly ones in line with SDG- 3, 9 & 11 agenda

KEYWORDS: Split Tensile Strength [STS], SSA –ESA Cement Concrete [SECC], Hydraulic Structures/Dam, K-H Model, SLS, ULS, Cracking, United Nations/ SDG.

I. INTRODUCTION

Sustainable Development Goals [SDG-3,9 & II] can be summarized as Improved Health/Living, Innovation and Disaster Risk Reduction Agenda. This work captures these three agenda. The construction of Hydraulic Structure provides relief to the community and helps in reducing flood disaster that can affect human as result of climate change. More also, the use of Shells Ash to partially replace cement towards amelioration of Construction Cost Function is one of the key indicator to actualize the Innovation strategy of the SDG. Global Reports on Climate and SDG Synergy, Dams, Hydraulic Structures, and flooding can be reviewed through the following works: United Nation (2023,2024 and 2026), SDG -3,9 and 11 (2015),_Echendu, (2020), Aladekomo (2022), The Prism Cement (2026) as well as Felder, and others (2021).



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Serviceability Limit States [SLS] are those in which the behaviour of the structure is unsatisfactory, and include Excessive Deflection, Cracking, Excessive Vibration and Excessive Permanent Deformation. Cracks whether in building or in Civil Engineering project are most common problem that occur in any type of concrete structure. It has the tendency of making a structure not to realize its designed objective. Since Hydraulic Structures [HS] are constructed to provide steady services, any interruption during their design life can cause serious problem to the environment. To this end, SLS and ULS [Ultimate Limit State, which include collapse of the structure] criteria need to be adequately checked during the design stage. Similarly during construction stage, since model and prototype of HS are designed to be similitude geometrically, dynamically and kinematically, a scaled modeling of the HS prototype needs to be constructed and the specimen subjected for STS test. Splitting Tensile Test [STS] of Concrete is therefore necessary in order to determine the load at which the concrete members may crack. The Split Tensile Strength Test is used to measure the tensile strength of concrete, which is important because concrete is weak in tension. The test helps estimate load conditions to prevent cracking, which is vital for structural continuity and corrosion prevention. In a nutshell, STS is a crucial mechanical property for the function, safety and durability of all concrete structures. Additional works on STS, SLS, ULS and Cracking are documented through the works of Rajabather (2016), Pavate (2023), Ashokkumar (2026), Luo and others (2022), as well as Pise and others (2021).

Concrete is one of the most important construction materials used in most Hydraulic Structures Construction. Cement is an important component of concrete. It acts as the binding agent in concrete, holding aggregates and sand together to form a solid mass. High-quality cement ensures proper bonding, durability, and resistance to cracking. The combination of cement and aggregates creates strong concrete capable of supporting the massive loads experienced in Dam structures. 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 and 2026). For the SECC-STS Mixture Design, the **Kings –HDEMD [K-H]** Model used in this work provides a platform for the development of mix ratios. Before then, Shacklock (1974) and Jackson and Dhir (1996) have discussed 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 which seems to be more complex and time consuming because of several 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. This model is now modified as **Kings –HDEMD [K-H]**. The six components for SECC-STS Mixture Design are: Water, Cement, SSA, ESA, Fine Aggregate [FA] and Coarse Aggregate [CA]

The present work is aimed at investigating the Split Tensile Strength Property of SSA - ESA- Cement Concrete [SECC] Using **Kings- HDEMD [K-H]** Model. This subject matter has its peculiarity and hence has attracted many authors reviews from the world's literature. Despite many background of contributions from different authors through related works, no sufficient work has been on the subject matter. For instance, on the use of Snail Shells (SS), Egg Shells (ES), ESA, SSA, PS, PSA, Mussel Shells (MS), MSA and other Mollusks Shells and Ashes in the environmental, water resources, construction and allied industries, 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 Rabi (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. 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 coarse 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. Bamigboye and others (2021) have investigated the prospects and challenges pertaining to the sustainable use of seashells as binder in concrete production. Peceno and others (2019) investigated the substitution of coarse



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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. Ezech 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 Ezech and others (2010a) to optimize the compressive strength of cement- sawdust Ash Sandcrete Block. Again Ezech 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 (GFRF). Also, Nwachukwu and others (2022a) developed and used Scheffe's Third Degree Polynomial model, Scheffe's (5,3) to optimize the compressive strength of GFRF 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 (NFRF). 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 NFRF. 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 (HPNFRF) .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



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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 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 HDEMD 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]. 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]. Finally, Nwachukwu and others (2026) applied K-H Model to determine the compressive strength of PSPC in the work titled 'Cost – Benefit Evaluation Of Using Periwinkle Shells Produce [PSP] As Partial Replacement For Rigid [Concrete] Pavement Conventional Raw Materials'. Based on the works reviewed so far, it can be envisaged that no work has been done on the subject matter: **Split Tensile Strength[STS] Property Investigation Of SSA - ESA- Cement Concrete [SECC] Using Kings- HDEMD [K-H] Model..** Henceforth, the need for this present research work.

II. METHODOLOGY

2.1. MATERIALS FOR SECC- STS MIXTURE

In this present SECC research work, the component materials under STS investigation are : Water, Cement, SSA, ESA, Fine and Coarse Aggregates. As usual, water used for the work was procured from potable clean water source and was applied in accordance with ASTM C1602/C1602M-22 (2022). Cement as a brand of Ordinary Portland Cement that conforms to British Standard Institution BS 12 (1978) was procured from local distributors. Fine aggregate was purchased from the local distributor. Again, Granite as a Coarse Aggregate was purchased from a local stone market. Both fine and coarse aggregates were procured and prepared in accordance with ASTM C33/C33M-18 (2018). The SS and ES used in this work were procured as a waste in an aquaculture industry markets and were washed and sundried for few days. After sufficient drying, the SS and ES were then calcined in a Gallenkamp Muffle Furnace at sufficient high temperature of 600°C before allowing to cool in a deciccator. Thereafter, the SS and ES were then grinded into very fine powder [VFP] as SSA and ESA respectively using a ceramic mortar and pestle. The resulted PSA and ESA were later sieved through a BS sieve of 75 microns and kept in air tight container for use in the SECC mixtures for Split Tensile Strength investigations..



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2.2. K-H MODEL FUNDAMENTAL THEORY FOR SECC-STs MIXTURE DESIGN

The K-H Model stands for Kings- Handy Developed Empirical Mixture Design [HDEMD] Model which is a mixture design model developed by Nwachukwu and Others (2025b) for Handy Development of Mix Ratios and Measurement of Quantities of Materials in the Laboratory. Below are the fundamentals:

2.2.1. ADOPTED MIX RATIO FOR SECC - STs MIXTURE DESIGN

The adopted mix ratio used in this work is **1:2:4**. The different water/ cement ratios adopted are **0.5, 0.53, 0.6, 0.63, 0.68, 0.7, 0.73, 0.75, 0.80, 0.85**

2.2.2. EVALUATION OF CONVENTIONAL MIX RATIOS FOR PARTIAL REPLACEMENT OF SECC-STs COMPONENTS

Using W/C ratio of 0.5, we can evaluate the new conventional mix ratio as : **0.5:1:2:4**. Then replacing only 60% of conventional cement and using SSA: ESA in the ratio of 50%: 50% of the replaceable cement, we have: **W/C: C: SSA: ESA: FA: CA = 0.5: 0.4: 0.3: 0.3: 2: 4**. The rest are shown in Table 1.

2.2.3. MEASUREMENT OF QUANTITIES OF SECC- STs MATERIALS AT THE LABORATORY.

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

$$M^Q = \frac{\sum X}{T} * W \quad (1)$$

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 Split Tensile Strength concrete cylinder mould of 150mm*300 mm, Average W from experience = 12.5kg

Using point 1 mix ratios, we have now have : **0.5: 0.4: 0.3: 0.3: 2: 4**.

T= 7.5, W = 12.5

For $X_1 = 0.5$, using Eqn. (1), $Q_1 = 0.83$ etc, and the measured quantities for point mix ratios equals

$Q_1 : Q_2 : Q_3 : Q_4 : Q_5 : Q_6 = 0.83 : 0.67 : 0.50 : 0.50 : 3.33 : 6.67$ for instance.

Then, for the ten (10) different trial mix ratios, the measured quantities are shown in Table 1.

2.3. METHOD FOR SECC - SPLIT TENSILE STRENGTH TEST [STS]

2.3.1. SECC SPECIMEN PREPARATION / BATCHING/ CURING FOR SPLIT TENSILE STRENGTH TEST[STS]

The specimen for the Split Tensile Strength is Concrete Cylindrical specimen measuring diameter 150 mm and length 300 mm. They were cast with plastic fibres and the specimen was loaded for ultimate compressive load under Universal Testing Machine (UTM) for each mix. 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 shown in Table 1. The measured actual quantities of SECC- STs are as shown in Table 1. For the ten experimental tests, a total number of 10 mix ratios were to be used to produce 20 SECC replicate concrete cylinders. Twenty-four (24) hours after casting, the specimens were removed from the moulds and were placed in clean water tank for curing. After 28 days of curing the concrete specimens were taken out of the curing tank for the SECC Split Tensile Strength [STS] test.

2.3.2. SECC - STs TEST PROCEDURE/CALCULATION

The cylindrical STs test was carried out using the universal testing machine in accordance with BS

EN 12390-6:2009 and ASTM C 496/ C 496 M-17 (2017). Two samples were crushed for each mix ratio and the Split Tensile Strength of each specimen/sample was then calculated using Eqn. (2)

$$F_t = \frac{2P}{\pi D L} \quad (2)$$

Where, F_t = Split Tensile Strength (MPa) ,P = maximum applied load (that is Load at failure, N) ; D = diameter of the cylindrical specimen (Dia. Of cylinder, mm); and L = Length of the specimen (Length of cylinder, mm).



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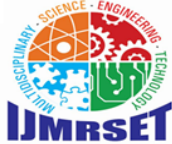
III. PRESENTATION AND DISCUSSION OF SECC-STTS RESULTS

3.1. PRESENTATION OF SECC- STS RESULTS

The results of the Split Tensile Strength of SECC, together with the mix ratios and measured quantities of SECC- STS are shown in Table 1

Table 1: Presentation Of Results Of Split Tensile Strength Of SECC, The Mixture Design Mix Ratios And The Measured Quantities Of SECC- STS

S/ N	R E P L I C A T E	CODING	TITLE: SECC LABORATORY EXPERIMENTS FOR 2025/2026/CIE/FUTO/FINAL YEAR PROJECT STUDENTS UNDER ENGR. DR. APOSTLE KINGSLEY CHIBUZOR NWACHUKWU							• DIMENSION OF MOULD: 150 mm * 300mm • APPROXIMATE. WEIGHT OF CAST STS CONCRETE CYLINDER, W: 12.5 KG						• MEASURED QTY OF SECC- STS MATERIAL AT LAB, MQ: $M^Q = \frac{XW}{T}$ • X = INDIVIDUAL MIX RATIO • T = SUM OF MIX RATIOS	
			AIM: SECC- SPLIT TENSILE STRENGTH [STS] DETERMINATION USING K-H MODEL							• D = 150mm; L= 300mm • WEIGHING BAL.: 50KG						• DATE OF CASTING: FRIDAY, JULY 31, 2026. • DATE OF CRUSHING: FRIDAY, AUGUST 28, 2026.	
			MIX RATIO BASED ON 1:2:4							MEASURED QTY AT LAB, M ^Q [KG]						F _t [MP A] SEE EQ N(2)	AV .F _t [M PA]
			X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	TO TA L [T]	Q ₁	Q ₂	Q ₃	Q ₄	Q ₅	Q ₆		
			W/ C	C	S S A	E S A	F A	C A		W/ C	C	S S A	E S A	FA	CA		
1.	A	SECC/A ₁ /S TS	0.50	0.4	0.3	0.3	2.0	4.0	7.5	0.83	0.67	0.50	0.50	3.33	6.67	1.26	1.27
	B	SECC/B ₁ /S TS	0.50	0.4	0.3	0.3	2.0	4.0	7.5	0.83	0.67	0.50	0.50	3.33	6.67	1.28	
2.	A	SECC/A ₂ /S TS	0.53	0.4	0.3	0.3	2.0	4.0	7.53	0.88	0.66	0.50	0.50	3.32	6.64	2.48	2.48
	B	SECC/B ₂ /S TS	0.53	0.4	0.3	0.3	2.0	4.0	7.53	0.88	0.66	0.50	0.50	3.32	6.64	2.48	
3.	A	SECC/A ₃ /S TS	0.60	0.4	0.3	0.3	2.0	4.0	7.6	0.99	0.66	0.49	0.49	3.29	6.58	2.36	2.33
	B	SECC/B ₃ /S TS	0.60	0.4	0.3	0.3	2.0	4.0	7.6	0.99	0.66	0.49	0.49	3.29	6.58	2.30	
4.	A	SECC/A ₄ /S TS	0.63	0.4	0.3	0.3	2.0	4.0	7.63	1.03	0.66	0.50	0.50	3.28	6.55	2.12	2.12
	B	SECC/B ₄ /S TS	0.63	0.4	0.3	0.3	2.0	4.0	7.63	1.03	0.66	0.50	0.50	3.28	6.55	2.12	
5.	A	SECC/A ₅ /S TS	0.68	0.4	0.3	0.3	2.0	4.0	7.68	1.11	0.55	0.49	0.49	3.30	6.60	2.11	2.11
	B	SECC/B ₅ /S	0.68	0.4	0.3	0.3	2.0	4.0	7.68	1.11	0.55	0.49	0.49	3.30	6.60	2.11	



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		TS		4	3	3	0	0				49	49		0		
6.	A	SECC/A ₆ /S TS	0.70	0. 4	0. 3	0. 3	2. 0	4. 0	7.7	1.12	0.65	0. 49	0. 49	3.25	6.4 9	1.69	1.6 7
	B	SECC/B ₆ /S TS	0.70	0. 4	0. 3	0. 3	2. 0	4. 0	7.7	1.12	0.65	0. 49	0. 49	3.25	6.4 9	1.65	
7.	A	SECC/A ₇ /S TS	0.73	0. 4	0. 3	0. 3	2. 0	4. 0	7.73	1.18	0.65	0. 49	0. 49	3.23	6.4 6	1.98	1.9 8
	B	SECC/B ₇ /S TS	0.73	0. 4	0. 3	0. 3	2. 0	4. 0	7.73	1.18	0.65	0. 49	0. 49	3.23	6.4 6	1.98	
8.	A	SECC/A ₈ /S TS	0.75	0. 4	0. 3	0. 3	2. 0	4. 0	7.75	1.21	0.65	0. 48	0. 48	3.23	6.4 5	2.00	2.0 0
	B	SECC/B ₈ /S TS	0.75	0. 4	0. 3	0. 3	2. 0	4. 0	7.75	1.21	0.65	0. 48	0. 48	3.23	6.4 5	2.00	
9.	A	SECC/A ₉ /S TS	0.80	0. 4	0. 3	0. 3	2. 0	4. 0	7.80	1.28	0.64	0. 48	0. 48	3.21	6.4 1	2.22	2.4 4
	B	SECC/B ₉ /S TS	0.80	0. 4	0. 3	0. 3	2. 0	4. 0	7.80	1.28	0.64	0. 48	0. 48	3.21	6.4 1	2.26	
10	A	SECC/A ₁₀ /S TS	0.85	0. 4	0. 3	0. 3	2. 0	4. 0	7.85	1.35	0.64	0. 48	0. 48	3.18	6.3 6	1.90	1.8 8
	B	SECC/B ₁₀ /S TS	0.85	0. 4	0. 3	0. 3	2. 0	4. 0	7.85	1.35	0.64	0. 48	0. 48	3.18	6.3 6	1.86	
T O T A L										21.9 6	13.0 6	26 .1 2	26 .1 2	65.2 4	13 0.4 8		

3.2. DISCUSSION OF SECC-STS RESULTS

The maximum Split Tensile Strength [STS] of SECC evaluated based on K-H Model is **2.48 MPa** for the 28th day result. The corresponding mix ratio is **0.53: 0.40: 0.30:0.30:2.00:4.00** and the measured quantities at the laboratory are in the ratio : **0.88: 0.66 : 0.50 : 0.50: 3.32 : 6.64** for Water/Cement Ratio, Cement, SSA, ESA, Fine Aggregate and Coarse Aggregate respectively. Similarly, the minimum Split Tensile Strength of SECC determined is **1.27 MPa** for the 28th day result with the corresponding mix ratio of **0.50: 0.40: 0.30:0.30:2.00:4.00** and measured quantities at the laboratory as : **0.83: 0.67 : 0.50: 0.50 : 3.33 : 6.67** for Water/Cement Ratio, Cement, SSA, ESA, Fine Aggregate and Coarse Aggregate respectively. The obtained range of values of STS are ideal to control cracking.

IV. CONCLUSION

So far in this research work, **Split Tensile Strengths [STS]** of concrete made through partial replacement of cement with SSA and ESA have been evaluated using **K-H Model**. The results of the STS are as stated in Table 1 and in the result discussion section. The new model offers numerous advantages which include the ability of the engineer to easily know the quantities of materials to be procured for Split Tensile Strength determination by merely looking at the total measured quantities at a glance. Therefore, all stakeholders in the Civil/Water Resources/ Environmental Engineering/Construction Industry are advised collaborate and cooperate to this innovation of partial replacement of conventional expensive construction raw materials with less expensive innovative and environmentally friendly ones like SS and ES for the sustainability of Low Cost Hydraulic Structures Construction, Effective Pollution Control Measures and Flood Mitigations in line with Sustainable Development Goals (SDG -3 , 9 and 11) agenda in Nigeria by 2030.

REFERENCES

[1] Abdullahi, I. and Sara, S.G.(2015): Assessment of periwinkle shell ash as composite materials for particle board production, International conference on African Development Issue



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

- [2] ACI Committee 544. (1989): "Measurement of Properties of Fibre Reinforced Concrete, (ACI 544.2R-89)"; American Concrete Institute, Detroit, Michigan, USA.
- [3] ACI Committee 211. (1994): "Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1R-91)"; American Concrete Institute, ACI Manual of Concrete Practice, Detroit, Michigan, USA.
- [4] Adeala, A.J and Olaoye J.O .(2019): Structural Properties Of Snail Shell Ash Concrete (SSAC); Journal of Emerging Technologies and Innovative Research (JETIR), Vol.6, No. 12.
- [5] Adewuyi, A.P, Franklin, S.O. and Ibrahim, K. A..(2015): "Utilization of Mollusc Shells for Concrete Production for Sustainable Environment; International Journal of Scientific and Engineering Research, Vol.6.No.9. Pp. 201-208.
- [6] Agbede, O.I and Manasseh, J.(2009): " Suitability of Periwinkle Shell as Partial Replacement for River Gravel in Concrete; Leonardo Electronic Journal of Practices and Technologies, Vol. 15. Pp.59- 66..
- [7].Aladekomo, J.(2022): Types of Hydraulic Structures Explained: Dams, Culverts, Bridges, Drains and Weirs, Available online at <https://jayadvisorscare.water.blog/2022/10/26/hydraulic-structures>.
- [8] Alla, S.and Asadi, S.S.(2021): " Experimental Investigation of Snail Shell Based Cement Mortar: Mechanical Strength, Durability and Microstructure, Available at Research gate.
- [9] Alla, S and Asadi , S. S.(2022) ; Experimental investigation and microstructural behavior of un-calcined and calcined snail shell powder cement mortar; Journal of Building Pathology and Rehabilitation, Vol. 7, No. 1.
- [10].Ashokkumar,V.(2026): Split Tensile Strength Of Concrete, Available online at https://www.academia.edu/28732492/Split_Tensile_Strength_Of_Concrete
- [11] ASTM C33/C33M-18 (2018); Standard Specification for Concrete Aggregates. ASTM International: West Conshohocken, PA, USA.
- [12].ASTM C496/C496M-17 (2017); Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens. ASTM International: West Conshohocken, PA, USA.
- [13].ASTM C1602/C1602M-22 (2022); Standard Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete. ASTM International: West Conshohocken, PA, USA.
- [14].Bamigboye, G.O, Nwogu, A.I., Odetoyan, A.O, Kareem, M. Enabulele, D.O. and Bassey, D.E.(2021): "Sustainable Use of Seashells as Binder in Concrete Production: Prospects and Challenges" Journal of Building Engineering, Vol. 34
- [15].British/European code -BS EN 12390-6 (2009): Testing concrete - Split tensile strength of test specimens. BSI - London.
- [16] British Standards Institution, BS 12 (1978): Ordinary and Rapid – Hardening Portland cement; London.
- [17] Department of Environment, DOE(1988): Design of Normal Concrete Mixes , HMSO, London.
- [18].Echendu, A..J.(2020): The impact of flooding on Nigeria's sustainable development goals (SDGs), Journal of Ecosystem Health and Sustainability ,Vol.6, No. 1
- [19] Egamana, S and Sule, S.(2017): Optimization of compressive strength of periwinkle shell aggregate concrete, Nigerian Journal of Technology (NIJOTECH), Vol. 36, No. 1, Pp.32- 38.
- [20] Elamah, D ., Akhigbe, P, Fadele, S.O.and Ivarah, V.I.(2021): "Strength characterization of periwinkle shell polymer concrete, the International journal of engineering and science (IJES) , Vol. 10, No. 8, Pp.52- 61.
- [21] Ezech, J.C.& Ibearugbulam, O.M. (2009): "Application of Scheffe's Model in Optimization of Compressive Cube Strength of River Stone Aggregate Concrete"; *International Journal of Natural and Applied Sciences*; Vol. 5, No. 4, Pp 303 – 308 .
- [22] Ezech, J.C., Ibearugbulam, O.M.& Anyaogu, L. (2010a): "Optimization of Compressive Strength of Cement-Sawdust Ash Sandcrete Block using Scheffe's Mathematical Model"; *Journal of Applied Engineering Research*. Vol.4, No.4, Pp 487–494.
- [23] Ezech, J.C., Ibearugbulam, O.M.& Anya, U. C (2010b): "Optimization of aggregate composition of laterite/sand hollow Block Using Scheffe's Simplex Method"; *International Journal of Engineering*, Vol.4, No.4, Pp. 471 – 478.
- [24]. Felder, S., Erpicum, S., Mulligan, S. , Valero, D. , Zhu, D., and Crookston, B.(2021): Hydraulic structures at a crossroads towards the Sustainable Development Goals, IAHR White Paper Series 2.
- [25].Gigante, V., Cinelli, P, Righetti, M.C., Sandroni, M, Tognotti, L, Seggiani, M and Lazzeri, A.(2020): "Evaluation of Mussel Shell Powder As Reinforcement for PLA-Based Biocomposites, *International Journal of Molecular Sciences*, Vol.21, Pp. 1-16.
- [26] Gonzalez, B., Carro, D., Martinez, C. and Seara-Paz, S.(2015): "Effects of Seashell Aggregates in Concrete Properties, *AJCE Special issue*, Vol.33, No.2, Pp. 376-382.
- [27] Hughes, B.P. (1971): The Economic Utilization of Concrete Materials, Proceedings of the Symposium on Advances in Concrete , Concrete Society, London



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

- [28] Ibearugbulam, O.M. (2006): "Mathematical Model for Optimization of Compressive Strength of Periwinkle Shell-Granite Aggregate Concrete"; *M.Eng. Thesis*, Federal University of Technology, Owerri, Nigeria.
- [29] Ishaya, A., Oyemogun, I.M., Arinze, A. and Abah, J.C. (2016): Properties of Concrete Produced With Waste Bottle Caps As Partial Replacement Of Coarse Aggregate and Orange Leaves Powder As Plasticizer, *Journal of Civil Engineering and Environmental Research*, Vol.8, No.7, Pp. 22 – 44.
- [30] Jackson, N. and Dhir, R.K. (1996): *Civil Engineering Materials*, 5th Edition, Palgrave, New York.
- [31] Luo, T., Pan, X., Tang, L., Sun, O., and Pan, J. (2022): Research on Splitting-Tensile Properties and Failure Mechanism of Steel-Fiber-Reinforced Concrete Based on DIC and AE Techniques, *Materials*, Vol. 15, No. 20, Available online at <https://www.mdpi.com/1996-1944/15/20/7>
- [32] Mbadike, E. M. and Osadebe, N.N. (2013): Application Of Scheffe's Model In Optimization Of Compressive Strength Of Laterite Concrete; *Journal of Civil Engineering And Construction Technology*, Vol.4, No.9, Pp.265- 274.
- [33] Melo, P.M.A., Macedo, O.B., Barbosa, G.P., Ueki, M.M, and Silva, L.B. (2019): "High-Density Polyethylene/Mollusc Shell- Waste Composites: Effects of Particle Size and Coupling Agent on Morphology, Mechanical and Thermal Properties, *Journal of Materials Research and Technology*, Vol.8, No. 2 Pp. 1915-1925.
- [34] Mmonwuba, N. C., and Bonaventure, C. (2025): Enhancing Concrete Performance in Marine Environments: Insights into Seawater Effects and Cement Optimization. *IPS Journal of Physical Sciences*, 2(1), 12–19. <https://doi.org/10.54117/ijps.v2i1.4>
- [35] Mmonwuba, N.C, Ore, David Chekwube and Okoye Stella-Maris Chibuzor (2023): Bioremediation and Phytoremediation of Petroleum Contaminated Soil ; *Journal of Energy Research and Reviews* , Vol.15, No.4, Pp.34-44, DOI: 10.9734/jenrr/2023/v15i4322
- [36] Mohammad, W.A.S., Othman, N.H., Ibrahim, M.H.W. Rahim, M.A, Shahidam, S, and Rahman, R.A. (2017): "A Review on Seashells Ash as Partial Cement Replacement; *IOP Conference Series : Materials Science and Engineering*, Vol.271.
- [37] Mtallic, M.O.A. And Rabi, A. (2009): Effects of Eggshells Ash [ESA] on the Setting Time of Cement, Available on Researchgate.
- [38] Neville, A.M. (1990): *Properties of Concrete*; 3rd edition, Pitman, England.
- [39] Nnochiri, E. S., Ogundipe, O. M., & Emeka, H. O. (2018): Effects Of Snail Shell Ash On Lime Stabilized Lateritic Soil. *Malaysian Journal of Civil Engineering*, Vol. 30, No.2.
- [40] Nwachukwu, K.C., Okafor, M., Thomas, B., Oputa, A.A., Okodugha, D.A. and Osaigbovo, M.E. (2017): "An Improved Model For The Optimization Of The Compressive Strength Of Glass Fibre Reinforced Concrete (GFRP) Using Scheffe's Second Degree Polynomials"; *Research Journal's Journal of Civil Engineering*, Vol. 3, No. 2
- [41] Nwachukwu, K. C., Njoku, K.O., Okorie, P. O., Akosubo, I.S., Uzoukwu, C. S., Ihemegbulem, E.O. and Igbojiaku, A.U (2022a): "Comparison Between Scheffe's Second Degree (5,2) And Third Degree (5,3) Polynomial Models In The Optimization Of Compressive Strength Of Glass Fibre Reinforced Concrete (GFRP)"; *American Journal of Computing and Engineering (AJCE)*, Vol. 5, No. 1, Pp 1– 23.
- [42] Nwachukwu, K.C., Okodugha, D.A., Uzoukwu, C. S., Igbojiaku, A.U. and Okafor, M. (2022b): "Application Of Scheffe's Second Degree Mathematical Model For The Optimization Of Compressive Strength Of Steel Fibre Reinforced Concrete (SFRC)"; *International Journal of Advances in Engineering and Management (IJAEM)* , Vol. 4, No. 3.
- [43] Nwachukwu, K.C., Okorie, P.O., Ihemegbulem, E.O., Kemebiye Dimaro, Uzoukwu, C. S., and Maduagwu, J.C.. (2022c): "The Use Of Scheffe's Model For The Optimization Of Compressive Strength Of Polypropylene Fibre Reinforced Concrete (PFRC)"; *International Journal of Innovative Science and Research Technology (IJSRT)*, Vol. 7, No. 1
- [44] Nwachukwu, K.C., Ozioko, H.O., Okorie, P.O, and Uzoukwu, C. S. (2022d): "Application Of Scheffe's Mathematical Model For The Optimization Of Compressive Strength Of Nylon Fibre Reinforced Concrete (NFRC)"; *International Journal of Advances in Engineering and Management (IJAEM)* , Vol. 4, No. 2, Pp 850-862
- [45] Nwachukwu, K. C., Okodugha, D.A., Igbojiaku, A.U., Attah, U.G. And Ihemegbulem, E.O. (2022e): Application Of Scheffe's Third Degree Regression Model For The Optimization Of Compressive Strength Of Polypropylene Fibre Reinforced Concrete (PFRC); *International Journal Of Advance Research And Innovative Ideas In Education (IJARIE)* , Vol. 8, No. 2.
- [46] Nwachukwu, K. C., Okodugha, D.A., Edike, O., Okafor, M.. And Attah, U.G. (2022f): Application Of Modified Scheffe's Third Degree Polynomial Model For The Optimization Of Compressive Strength Of Nylon Fibre Reinforced Concrete (NFRC); *International Journal of Trend In Scientific Research And Development (IJTSRD)* , Vol. 6, No. 3.
- [47] Nwachukwu, K.C., Okodugha, D.A, Akosubo, I.S. and Atulomah, F.K (2022g): Optimization of Compressive



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Strength of Steel Fibre Reinforced Concrete (SFRC) Using Scheffe's Third-Degree Regression Model; Iconic Research And Engineering Journals (IRE), Vol. 5, No. 11.

[48] Nwachukwu, K.C., Onwuegbuchulem, U.C., Atulomah, F.K. and Ihemegbulem, E.O. (2022h): Optimization of Hybrid- Polypropylene- Steel Fibre Reinforced Concrete (HPSFRC) ; Iconic Research And Engineering Journals (IRE), Vol. 5, No. 12

[49] Nwachukwu, K.C., Thomas, B., Oguaghamba, O., Onwuegbuchulem, U.C., Igbojiaku, A.U., Atulomah, F.K and Okafor, M. (2022i): Optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA) Using Scheffe's Second Degree Model; international Journal of Engineering Inventions (IJEI), Vol. 11, No. 8, Pp. 40-50.

[50] Nwachukwu, K.C., Oguaghamba, O., Akosubo, I.S., Atulomah, F.K. and Igbojiaku, A.U. (2022j): Optimization of Compressive Strength of Hybrid Polypropylene – Nylon Fibre Reinforced Concrete (HPNFRC); International Journal Of Advanced Research And Innovative Ideas In Education (IJARIIE), Vol. 8, No. 5. Pp. 376 -392.

[51] Nwachukwu, K.C., Edike, O., Oguaghamba, O., Onwuegbuchulem, U.C and Egbulonu, B.A. (2022k): The Application Of Scheffe's Model For The Optimization Of Mussel Shells Fibre Reinforced Concrete (MSFRC); International Journal of Engineering Inventions (IJEI), Vol. 11, No. 9. Pp. 47- 57

[52]. Nwachukwu, K.C., Ozioko, H.O., Akosubo, I.S., Oguaghamba, O., Okafor, M., Onyechere, I.C. and Ikpa, P.N (2022l): Optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Periwinkle Shells Ash (PSA) Using Scheffe's Second Degree Model; Paper presented at the Proceedings of the 1ST International Conference on Advances in cement and concrete research (ICACCR-2022) Organized by Ladoke Akintola University of Technology (LAUTECH), Nigeria. Theme: Cement and Concrete Innovative Materials For Sustainable Development.

[53]. Nwachukwu, K.C and Opara, H.E. (2023): Maximizing And Exploring The Benefits Of Using Latest Innovative Materials (LIM) And Low Cost Automation (LCA) For The Rapid Economic Growth Of The Cement Manufacturing Industry; Paper presented at the Conference Proceedings of the Nigeria Society of Engineers (Abuja 2023), Nov. 27 – Dec. 1, 2023.

[54] Nwachukwu, K.C., Ozioko, H. O., Mama, B.O., Oguaghamba, O., and Atulomah, F.K. (2023a): The Application of Scheffe's Third Degree Regression Model In The Optimization Of Compressive Strength of Hybrid- Polypropylene- Steel Fibre Reinforced Concrete (HPSFRC); International Journal of Research and Analytical Reviews (IJRAR), Vol. , No. Pp.

[55]. Nwachukwu, K.C., Oguaghamba, O., Ozioko, H. O. and Mama, B.O. (2023b): Optimization Of Compressive Strength of Concrete Made With Partial Replacement Of Cement With Cassava Peel Ash (CPA) and Rice Husk Ash (RHA) Using Scheffe's (6,3) Model; International Journal of Trend In Scientific Research and Development (IJTSRD), Vol. 7, No. 2, Pp. 737-754

[56] Nwachukwu, K. C., Mathew, C.C., Mama, B.O., Oguaghamba, O. And Uzoukwu, C.S. (2023c): Optimization Of Flexural Strength And Split Tensile Strength Of Hybrid Polypropylene Steel Fibre Reinforced Concrete (HPSFRC) : International Journal Of Advance Research And Innovative Ideas In Education (IJARIIE), Vol. , No.

[57] Nwachukwu, K. C., Oguaghamba, O., Akosubo, I.S., Egbulonu, B.A., Okafor, M. and Mathew, C.C. (2023d): The Use Of Scheffe's Second Degree Model In The Optimization Of Compressive Strength Of Asbestos Fibre Reinforced Concrete (AFRC); Research Inventy: International Journal of Engineering and Science (IJES), Vol. , .

[58]. Nwachukwu, K.C., Nnegha, A.R., Senator, W.U., Okere, C.P., Nmecha, T.M., Obi, C.G., Etukudoh, E.E. and Ezeike, U.C. (2024a): Determination Of Optimized Flexural And Split Tensile Strengths Of PSA-MSA- Cement Concrete (PMCC) Using Scheffe's (6, 2) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 5, Pp.

[59]. Nwachukwu, K. C., Anyachi, C.M., Njoku, I.C., Olinya, I.A., Nkama, J., Egbara, T.E., Anike, V.A., Nwabueze, C.S and Ejiofor, H.C. (2024b): Investigation Of Compressive Strength Property Of PSA - SSA-Cement Concrete (PSCC) Using Scheffe's (6, 2) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 6, Pp.

[60]. Nwachukwu, K. C., Edike, O., Mathew, C.C., Mama, B.O. and Oguaghamba, O. (2024c): Evaluation Of Compressive Strength Property Of Plastic Fibre Reinforced Concrete (PLFRC) Based On Scheffe's Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 6, Pp.

[61]. Nwachukwu, K. C., Edike, O., Mathew, C.C., Oguaghamba, O. and Mama, B.O. (2024d): Investigation of Compressive Strength Property of Hybrid Polypropylene - Nylon Fibre Reinforced Concrete (HPNFRC) Based on Scheffe's (6,3) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 6, Pp. 4020-4039



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

- [62].Nwachukwu, K. C., Nwachukwu, A.N., Njoku, C.F. , Uzoukwu, C.S., Ozioko, H.O. and Mathew, C.C.,(2024e): Application Of Scheffe's (5,3) Model In The Compressive Strength Determination Of Mussel Shells Fibre Reinforced Concrete (MSFRC); Goya Journal, Vol. 17, No. 6.
- [63].Nwachukwu, K. C. and Okodugha, D.A.(2024a): Application Of Scheffe's (5,2) Optimization Model In The Flexural And Split Tensile Strengths Determination Of Nylon Fibre Reinforced Concrete [NFRFC]; International Journal of Progressive Research In Engineering Management And Science [IJPREMS], Vol. 4, No. 8, Pp. 628- 642
- [64].Nwachukwu, K. C., Okodugha, D.A. and Atulomah, F.K.(2024f): Investigation of Flexural and Split Tensile Strengths Properties of Polypropylene Fibre Reinforced Concrete [PFRC] Based on Scheffe's Optimization Model International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 8, Pp. 2606- 2620
- [65].Nwachukwu, K. C., Okodugha, D.A., Njoku, C.F. and Nwachukwu, A.N. (2024g): Flexural And Split Tensile Strengths Evaluation Of Hybrid Nylon- Steel Fibre Reinforced Concrete [HNSFRC] Based On Kings - Scheffe's (6,2) Optimization Model.;International Journal of Advanced Research in Education and Technology[IJARETY], Vol. 11, No. 5, Pp. 2304-2322.
- [66].Nwachukwu, K. C., Okodugha, D.A and Njoku, C.F.(2024h): Optimized Compressive Strength Determination of Hybrid Nylon –Steel Fibre Reinforced Concrete [HNSFRC] Using Kings - Scheffe's Binary Mixture; International Journal of Advanced Research in Education and Technology[IJARETY], Vol.11, No. 5, Pp. 2323-2338..
- [67].Nwachukwu, K. C. and Okodugha, D.A.(2024b): Evaluation of Flexural and Split Tensile Strengths of Glass Fibre Reinforced Concrete [GFRFC] using Scheffe's Optimization Model; International Journal of Advanced Research in Education and Technology[IJARETY], Vol. 11, No. 4, Pp. 1301-1316.
- [68].Nwachukwu, K. C. and Okodugha, D.A.(2024c): Flexural And Split Tensile Strengths Investigation Of Steel Fibre Reinforced Concrete [SFRC] Using Scheffe' S (5,2) Optimization Model; International Journal of Progressive Research In Engineering Management And Science [IJPREMS], Vol. 4, No. 9, Pp. 1116- 1131
- [69].Nwachukwu, K. C. and Okodugha, D.A.(2024d): Flexural and Split Tensile Strengths Evaluation of Asbestos Fibre Reinforced Concrete [AFRC] Based on Scheffe's (5,2) Model; International Journal of Research Publication and Reviews [IJRPR], Vol. 5, No. 10, Pp. 160- 175.
- [70].Nwachukwu, K.C, Okodugha, D.A, Edike, O, Njoku , C.F , Uzoukwu. C.S. (2024i): Flexural and Split Tensile Strengths Evaluation of Hybrid Polypropylene -Nylon Fibre Reinforced Concrete [HPNFRFC] Using Kings Scheffe's Six Components – Binary Mixture, International Journal of All Research Education and Scientific Methods (IJARESM), Vol. 12, No.10.
- [71] Nwachukwu, K. C., Mmonwuba, N.C and Ogunjiofor, E.I. (2025a): Compressive Strength Investigation of PSA –MSA - Cement Concrete [PMCC] Using Kings - Scheffe's (6, 2) Model, International Journal of Advanced Research in Education and Technology [IJARETY], Vol. 12, No. 1, Pp. 1- 16
- [72] Nwachukwu, K.C., Boniface, O.V., Orji, C.O., Abanobi, A.F., Nweke, E.C, Igbokwe , S.C., Onyia, C.J and Kings- Nwachukwu, B. C. (2025b): Compressive Strength Property Investigation of PSA- ESA- Cement Concrete [PECC] Using Handy Developed Empirical [HDE] Mixture Design for Sustainable Low Cost Building, International Journal of Advanced Research in Education and Technology [IJARETY], Vol. 12, No. 4.
- [73] Nwachukwu, K. C., Ozioko, H.O., Orji, C.O., Boniface, O.V., and Kings- Nwachukwu, B. C.(2025c): Flexural Strength Determination Of PSA- ESA- Cement Concrete [PECC] Based On Handy Developed Empirical Mixture Design [HDEMD], Accepted Paper, International Journal of Advanced Research in Education and Technology [IJARETY]
- [74] Nwachukwu, K.C., Edike, O., Mmonwuba, N.C., Igbokwe , S.C., Onyia, C.J and Kings- Nwachukwu, B. C. (2025d): Evaluation Of River Otamiri In FUTO Community For Construction Works Suitability, Accepted Paper International Journal of Advanced Research in Education and Technology [IJARETY].
- [75] Nwachukwu, K. C.,Edike, O., Abanobi, A.F., Nweke, E.C. And Kings- Nwachukwu, B. C.(2025e): Split Tensile Strength Evaluation Of PSA- ESA- Cement , Concrete [PECC] Using Handy Developed Empirical Mixture Design [HDEMD] , Accepted Paper, International Journal of Advanced Research in Education and Technology [IJARETY]
- [76].Nwachukwu, K. C.,Edike, O., Ozioko, H.O., Ikpa, P.N. Onyechere, I.C. And Kings- Nwachukwu, B. C.(2025f): The Use of Kings- HDEMD [K-H] Model in the Flexural Strength [FS] Investigation of PSA- SSA- Cement Concrete [PSCC], International Journal of Advanced Research in Education and Technology [IJARETY], Vol. 12, No.5.
- [77]. Nwachukwu, K.C., Edike, O., Onwuegbuchulem, U.C., Ihekwe, N.M., Nwosu, O.E., Udokporo, C.A.O. And Kings-Nwachukwu, B.C. (2026): Cost – Benefit Evaluation Of Using Periwinkle Shells Produce [PSP] As Partial Replacement For Rigid [Concrete] Pavement Conventional Raw Materials , Accepted for Publication, International Journal of Innovative Science and Research Technology (IJSRT), Vol. 11, No. 8.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

- [78] Nwakonobi, T.U and Osadebe, N.N (2008):“Optimization Model for Mix Proportioning of Clay- Ricehusk- Cement Mixture for Animal Buildings”; *Agricultural Engineering International:the CIGR Ejournal,Manuscript BC 08007*, Vol x
- [79] Obam, S.O. (2006). The Accuracy of Scheffe’s Third Degree over Second Degree Optimization Regression Polynomials, *Nigerian Journal of Technology*, Vol. 2, No.25, Pp 1 – 10.
- [80] Obam, S.O.(2009):“A Mathematical model for Optimization of Strength of concrete : A case study forshear modulus of Rice Husk Ash Concrete.” *Journal of Industrial Engineering International I*; Vol.5, No.9,Pp 76 – 84.
- [81] Offiong , U and Akpan, G.E.(2017):Assessment of physico- chemical properties of periwinkle shell ash as partial replacement for cement in concrete , *International journal of scientific engineering and science*, Vol. 1, No. 7, Pp.33-36.
- [82].Ogunjiofor, E.I., Agbataekwe E. and Ohizu E. (2023): “Assessment of the Mechanical properties of steel fiber reinforced concrete for Low-Cost Construction ”; *American Journal of Innovation in Science and Engineering (AJISE)*, Vol. 2, Issue 1, pp. 51 – 56.
- [83].Ogunjiofor, E.I., Amete D. C. and Nwabunwanne J.C. (2023): “Structural Behaviour of Concrete Produced Using Palm Kernel Shell (PKS) as a Partial Substitute for Coarse Aggregate”; *American Journal of Innovation in Science and Engineering (AJISE)*, Vol. 2, No.1, Pp. 1 – 7.
- [84].Ogunjiofor, E.I., Onuh R. and Ojukwu K.C. (2023): “Compressive Strength Development of Concrete Produced with Partial Replacement of Fine Aggregate with Crushed Glass” *World Wide Journal of Multidisciplinary Research and Development (WWJMRD)*, Vol. 9, No.1, Pp. 91 – 96.
- [85] Okere, C.E., (2006):“Mathematical Models for Optimization of the Modulus of rupture of concrete”; M.Eng. Thesis, Civil Engineering Department, Federal University of Technology, Owerri.
- [86] Onwuka,D.O, Okere, C.E.,Arimanwa, J.I. and Onwuka, S.U.(2011):“Prediction of Concrete Mix ratios using Modified Regression Theory, *Computer Methods in Civil Engineering*, Vol. 2. No.1 Pp.95- 107.
- [87] Oyedepoo, O.J.(2016):“Evaluation of the Properties of Lightweight Concrete Using Periwinkle Shells as Partial Replacement for Course Aggregate; *Journal of Applied Science and Management*, Vol.20, No. 3. Pp. 498-505.
- [88] Oyenuga, V.O. (2008): *Simplified Reinforced Concrete Design*, 2nd Edition, Asros Ltd, Lagos, Nigeria.
- [89].Pavate, V. (2023):CAUSES and Preventive Measures of Cracks in Residential Building, *International Journal for Research in Applied Science and Engineering Technology*, Vol.11, No. 6, Pp . 2353 – 2365.
- [90] Peceno, B., Arenas, C., Alonso-Farinas, B and Leiva, C.(2019):“ Substitution of Coarse Aggregates with Mollusc- Shells Waste in Acoustic-Absorbing Concrete; *Journal of Materials in Civil Engineering, ASCE*,Vol. 31. No.6.
- [91].Pise, N, Meshram, T., Doijad, Y., ...And Gudadhe, A. (2021) : A Brief Study on Causes of Cracks, Prevention and Pattern of Cracks on Concrete, *International Journal of Scientific Research in Science Engineering and Technology*, Available online at https://www.researchgate.net/publication/353115305_A_Brief_Study_on_Causes_of_Cracks_Prevention_and_Pattern_of_Cracks_on_Concrete?_tp=eyJjb250ZXh0Ijp7InBhZ2Z0OiJwdWJsaWNhdGlvbGlzInByZXZpb3VzUGFnZSI6bnVsbH19
- [92]. Prism Cement (2026): *Essential Construction Materials for Dam Construction Projects*, Prism Johnson Limited, India. Available online at <https://www.prismcement.com/blogs/essential-construction-materials-for-dam-building>
- [93].Rajabather, A.(2016):Investigation Of Cracks In Buildings, Conference Paper, Available online at https://www.researchgate.net/publication/319630328_INVESTIGATION_OF_CRACKS_IN_BUILDINGS#full-text
- [94] SDGs -3 (2015) : Good Health And Well Being, The United Nation Sustainable Development Goals in Nigeria by 2030, Available at <https://Nigeria.un.org/en/sdgs/3>
- [95] SDGs -9 (2015) : Industry, Innovation And Infrastructure, The United Nation Sustainable Development Goals in Nigeria by 2030, Available at <https://Nigeria.un.org/en/sdgs/9>
- [96] SDGs -11 (2015): Make Cities and Human Settlements Inclusive, Safe, Resilient and Sustainable. The United Nation Sustainable Development Goals in Nigeria by 2030, Available at <https://Nigeria.un.org/en/sdgs/11>
- [97] Shacklock, B.W. (1974): *Concrete Constituents And Mix Proportions*, The Cement and Concrete Association, London.
- [98] Soneye, T., Ede, A.N.,Bamigboye, G.O. and Olukanni, D.O.(2016):The study of periwinkle shell as fine and course aggregate in concrete works; 3rd International conference on African Development
- [99] Syal, I.C. and Goel, A.K. (2007): *Reinforced Concrete Structures*, S.Chand , India.
- [100] Syammaun, T., Husaini, Abdullah, Isya, M.and Rachman, F. (2023): Assessing the Performance of Eggshell Ash as a Sustainable Bitumen Modifier, *Science Direct*, Vol. 13.



International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

- [101]. Ugwuanyi, S.E, Mmonwuba, N. C. and Adibe, T.N (2018): “Partial Replacement of Cement with Burnt rice Husk Ash for Low Strength Concrete Production” International Journal of Innovation Engineering, Technology and Science. IJIETS, Vol. 2, No.2.
- [102]. United Nation (2023): Synergy Solutions for a World in Crisis: Tackling Climate and SDG Action Together, United Nations Department of Economic and Social Affairs (UN DESA) and United Nations Framework Convention on Climate Change (UNFCCC),
- [103]. United Nation (2024): Synergy Solutions for Climate and SDG Action: Bridging the Ambition Gap for the Future We Want, United Nations Department of Economic and Social Affairs (UN DESA) and United Nations Framework Convention on Climate Change (UNFCCC)
- [104]. United Nation (2026): Science, Technology and Innovation for the Sustainable Development Goals, United Nations Department of Economic and Social Affairs (UN DESA), New York.
- [105] Zaid, S.T. and Ghorpade, V.G.(2014): Experimental Investigation of Snail Shell Ash (SSA) as Partial Replacement of Ordinary Portland Cement in Concrete; : IJERT, Vol..3.



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