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The Application of K-H Model in the Flexural Strength [FS] Investigation of SECC in Low Cost Hydraulic Structures Construction [LCHSC]

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Abstract: **One of United Nations Sustainable Development Goal [SDG- 9] agenda in Nigeria by 2030 is focused on building Resilient Infrastructure. Thus developing quality, reliable, sustainable and resilient infrastructure such as Hydraulic Structures in the form of Bridges, Dams, etc to support Economic Development is one of the surest ways of meeting up with the SDG goals. In order to ensure and promote resilient construction, Flexural Strength [FS] testing of construction materials is important. FS is a measure of a material's resistance to deformation under bending forces and it is crucial for the Structural Integrity of most structures such as bridges, etc. This work is therefore aimed at investigating the FS of SECC using Kings- Handy Developed Empirical Mixture Design (HDEMD) Model [K-H Model]. The work centers around Bridge Structures. 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, it is assumed that only 60 per cent (%) of cement is replaced with mix proportion of SSA- ESA which is kept in 50% - 50% ratio . 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 beams and the FS of SECC were evaluated at each trial mix. The 28th day maximum SECC-FS is 8.34 MPa, while the minimum value is obtained as 3.21 MPa. As materials with high FS are more resistant to cracking and deformation, the SECC- FS values can sustain construction of light- weight , water retaining , some heavy –weight structures as well as structures that are subject to heavy load or stress such as Bridges at the best economic, aesthetic, safety and environmentally friendly advantages. There is therefore a call for collaboration by all stakeholders in the Civil/ Environmental Engineering/Water Resources Engineering/ Construction Industries to improve upon this innovation of partial replacement of conventional expensive construction raw materials with less expensive innovative and environmentally friendly ones as well as improvement in the culture of material testing in line with SDG- 3, 9 & 11 agenda.**

Keywords: **Flexural Strength [FS], SECC, Low Cost Hydraulic Structures Construction [LCHSC] , Bridge/Dam, K-H Model, Cracking/Deformation, SDG, Resilient Infrastructure.**

1. INTRODUCTION

Building Resilient Infrastructure such as Bridges, Dams, state of the art Road Network as part of the Sustainable Development Goals [SDG] improves Human lives in many aspect and hence should not be looked down upon. Resilient Infrastructure can provide solution Food Insecurity as well as reduction on the effects of climate change especially flooding. Again, the innovation of using Shells Ash to partially replace cement towards amelioration of Construction Cost Function is another key indicator to actualize the Innovation strategy of the SDG. Reviews on Climate Change and SDG Synergy, Dams, Hydraulic Structures, Bridges and flooding can be got 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).

Usually Engineering Structures deform when subjected to heavy excessive loading. This structural behavior prompted the study of Structural Analysis and Design of Structural Elements of Civil Engineering Structures such as Bridge, Dam, as well as other Hydraulic Structures. It is remarkable that the purpose of every Engineering Design is to ensure that the structure being designed does not reach both the Serviceability Limit States [SLS] and Ultimate Limit State [ULS]. SLS has to do with deflection, deformation, cracking etc of the structure while the ULS has to do with the total collapse of the structure in focus. In the field of construction, the mechanical strength test used to regulate the SLS is the Flexural Strength [FS]. It is commonly used in the Construction, Aerospace, Automotive, as well as Manufacturing industries to evaluate the performance of concrete (using ASTM C78- 22 Test Procedure), steel (using ASTM E 190 – 22 Test Procedure) and other building materials such as wood (using ASTM D 143 Test Procedure). The FS test is a widely used method for determining the ability of a material to withstand deformation under load. The results of the FS test are used to evaluate the durability and reliability of a material under various loading conditions. Additional works on FS on concrete, SLS, ULS and Cracking/Deformation are documented through the works of Rajabather (2016), Pavate (2023), Pise and others (2021) and ASTM C78- (2022) Test procedures.

FS test can be performed on variety of materials, including concrete [bridge, dam and building], steel [bridge, buildings and offshore platform] and wood structures[bridges, buildings and furniture]. This work focuses on concrete structures in the form of SECC. Concrete is one of the most important construction materials used in most Bridge 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 Bridge 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 a, b,& c). For the SECC- FS Mixture Design, the **Kings –HDEMD [K-H]** Model used in this work provides a handy 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-FS Mixture Design are: Water, Cement, SSA, ESA, Fine Aggregate [FA] and Coarse Aggregate [CA]

The Application Of K-H Model In The Flexural Strength [FS] Investigation Of SECC In Low Cost Hydraulic Structures Construction [LCHSC] is the subject matter of the present work. Before now, even though many authors have contributed to literature in many ways to topics related to the subject matter, no sufficient work has been done 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 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. 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.

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 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 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]. Nwachukwu and others (2025f), applied the Use Of Kings- HDEMD [K-H] Model In The Flexural Strength [FS] Investigation Of PSA- SSA- Cement Concrete [PSCC]. Nwachukwu and others (2026a) 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'**.** Nwachukwu and others (2026b) applied K-H Model to determine the compressive strength of SECC. Finally, Nwachukwu and others (2026c) applied K-H Model to determine the Split Tensile Strength[STS] Of SSA - ESA- Cement Concrete [SECC] **.** Based on the works reviewed so far, it can be envisaged that no work has been done on the subject matter: **The Application Of K-H Model In The Flexural Strength [FS] Investigation Of SECC In Low Cost Hydraulic Structures Construction [LCHSC]**. Henceforth, the need for this present research work**.**

2. METHODOLOGY

2.1. MATERIALS FOR SECC- FS MIXTURE

In this present SECC research work, the component materials under **FS** investigation are: Water, Cement, SSA, ESA, Fine Aggregate [FA] and Coarse Aggregates[CA]. Water used for the work was fetched 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. River Sand as FA was purchased from the local distributor. Again, 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 SS and ES used in this work were procured as a waste from 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 600^0C 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 FS investigations. In the large scale production of SSA and ESA, large quantities of SS and ES were taken to large capacity Muffle furnace and were later grinded with Machines that have large capacities

2.2. K-H MODEL FUNDAMENTAL BACKGROUND FOR SECC-FS 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 fundamental background:

2.2.1. ADOPTED MIX RATIO FOR SECC - FS 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- FS COMPONENTS

Using W/C ratio of 0.5, the new conventional mix ratio can be evaluated 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- FS 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).

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

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 Flexural Strength concrete beam mould of 150mm*150mm*600mm, Average W from experience = 30kg. Using point 1 mix ratios, we have: **0.5: 0.4: 0.3: 0.3: 2: 4.** Then, T = 7.5, W = 30. For X_1 = 0.5, using Eqn. (1), $\mathbf{Q_I = 1.95}$ etc, and the measured quantities for point 1 mix ratios equals

$\mathbf{Q_I : Q_2 : Q_3 : Q_4 : Q_5 : Q_6 = 1.95 : 1.60 : 1.20 : 1.20 : 8.00 : 16.00}$

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

2.3. METHOD FOR SECC - FLEXURAL STRENGTH [FS] TEST

2.3.1. SECC SPECIMEN PREPARATION/BATCHING/CURING FOR FLEXURAL STRENGHT [FS] TEST

In this research work, the standard size of specimen (mould) for the SECC Flexural Strength measures 150mm*150mm*600mm. The mould is of steel metal with sufficient thickness to prevent spreading or warping. The mould is constructed with the longer dimension horizontal and in such a manner as to facilitate the removal of the moulded specimen without damage. 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 SECC- FS 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 beams. 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 beam specimens were taken out of the curing tank for the SECC - FS test.

2.3.2. SECC FLEXURAL STRENGTH [FS] TEST PROCEDURE/CALCULATION

Flexural strength testing was done in accordance with BS 1881 – part 118 (1983) - Method of determination of Flexural Strength, ASTM C78/C78M-22 (2022) and ACI (1989) guideline. In this present study, two samples were crushed for each mix ratio. In each case, the Flexural Strength of each SECC specimen/sample which is expressed as the Modulus of Rupture (MOR) was then calculated to the nearest 0.05 MPa using Eqn.(2)

$$MOR = \frac{PL}{bd^2} \tag{2}$$

where b = measured width in mm of the specimen, d = measured depth in mm of the specimen at the point of failure, where L = Length in mm of the span on which the specimen was supported and P = maximum load in Newton, N applied to the specimen.

3. PRESENTATION AND DISCUSSION OF SECC- FS RESULTS

3.1. PRESENTATION OF SECC- FS RESULTS

The results of the Flexural Strength [FS] of SECC, together with the mix ratios and measured quantities of SECC- FS are shown in Table 1.

Table 1: Presentation of Results of Flexural Strengths of SECC, the Mixture Design Mix Ratios and the Measured Quantities of SECC- FS

			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 * *150mm*600mm APPROXIMATE. WEIGHT OF CAST FS CONCRETE BEAM, W: 30 KG			MEASURED QTY OF SECC- FS MATERIAL AT LAB, MQ: $M^Q = \frac{XW}{T}$ X = INDIVIDUAL MIX RATIO T = SUM OF MIX RATIOS					
			AIM: SECC- FLEXURAL STRENGHT [FS] INVESTIGATION USING K-H MODEL						WEIGHING BAL.: 50KG			DATE OF CASTING: FRIDAY, JULY 31, 2026. DATE OF CRUSHING: FRIDAY, AUGUST 28, 2026.					
S/N	REPLICATE	CODING	MIX RATIO BASED ON 1:2:4							MEASURED QTY AT LAB, M^Q [KG]						FS [MPA] SEE EQN (2)	AV. [MPA]
			X_1 W/C	X_2 C	X_3 SSA	X_4 ESA	X_5 FA	X_6 CA	TOTAL [T]	Q_1 W/C	Q_2 C	Q_3 SSA	Q_4 ESA	Q_5 FA	Q_6 CA		
1.	A	SECC/A1/FS	0.50	0.4	0.3	0.3	2.0	4.0	7.50	1.95	1.60	1.20	1.20	8.00	16.00	3.27	3.21
	B	SECC/B1/FS	0.50	0.4	0.3	0.3	2.0	4.0	7.50	1.95	1.60	1.20	1.20	8.00	16.00	3.15	
2.	A	SECC/A2/FS	0.58	0.4	0.3	0.3	2.0	4.0	7.58	2.30	1.58	1.19	1.19	7.91	15.83	8.34	8.34
	B	SECC/B2/FS	0.58	0.4	0.3	0.3	2.0	4.0	7.58	2.30	1.58	1.19	1.19	7.91	15.83	8.34	
3.	A	SECC/A3/FS	0.60	0.4	0.3	0.3	2.0	4.0	7.60	2.37	1.58	1.18	1.18	7.89	15.79	7.33	7.35
	B	SECC/B3/FS	0.60	0.4	0.3	0.3	2.0	4.0	7.60	2.37	1.58	1.18	1.18	7.89	15.79	7.37	
4.	A	SECC/A4/FS	0.63	0.4	0.3	0.3	2.0	4.0	7.63	2.48	1.57	1.18	1.18	7.99	15.94	5.55	5.55
	B	SECC/B4/FS	0.63	0.4	0.3	0.3	2.0	4.0	7.63	2.48	1.57	1.18	1.18	7.99	15.94	5.55	
5.	A	SECC/A5/FS	0.68	0.4	0.3	0.3	2.0	4.0	7.68	2.66	1.56	1.17	1.17	7.81	15.63	6.68	6.69
	B	SECC/B5/FS	0.68	0.4	0.3	0.3	2.0	4.0	7.68	2.66	1.56	1.17	1.17	7.81	15.63	6.70	
6.	A	SECC/A6/FS	0.70	0.4	0.3	0.3	2.0	4.0	7.70	2.73	1.56	1.17	1.17	7.79	15.58	4.47	4.47
	B	SECC/B6/FS	0.70	0.4	0.3	0.3	2.0	4.0	7.70	2.73	1.56	1.17	1.17	7.79	15.58	4.47	
7.	A	SECC/A7/FS	0.73	0.4	0.3	0.3	2.0	4.0	7.73	2.83	1.55	1.16	1.16	7.76	15.52	5.32	5.35
	B	SECC/B7/FS	0.73	0.4	0.3	0.3	2.0	4.0	7.73	2.83	1.55	1.16	1.16	7.76	15.52	5.38	
8.	A	SECC/A8/FS	0.75	0.4	0.3	0.3	2.0	4.0	7.75	2.90	1.55	1.16	1.16	7.74	15.48	7.78	7.78
	B	SECC/B8/FS	0.75	0.4	0.3	0.3	2.0	4.0	7.75	2.90	1.55	1.16	1.16	7.74	15.48	7.78	
9.	A	SECC/A9/FS	0.80	0.4	0.3	0.3	2.0	4.0	7.80	3.08	1.54	1.15	1.15	7.69	15.38	3.65	3.67
	B	SECC/B9/FS	0.80	0.4	0.3	0.3	2.0	4.0	7.80	3.08	1.54	1.15	1.15	7.69	15.38	3.69	
10	A	SECC/A10/FS	0.85	0.4	0.3	0.3	2.0	4.0	7.85	3.25	1.53	1.15	1.15	7.64	15.29	7.00	7.02
	B	SECC/B10/FS	0.85	0.4	0.3	0.3	2.0	4.0	7.85	3.25	1.53	1.15	1.15	7.64	15.29	7.04	
TOTAL										53.10	31.24	23.42	23.42	156.44	312.88		

3.2. DISCUSSION OF SECC- FS RESULTS

The maximum FS of SECC evaluated using **K-H** Model **is 8.34 MPa** for the 28th day result .The corresponding mix ratio is **0.58: 0.40: 0.30:0.30:2:4** and the measured quantities at the laboratory are in the ratio : **2.30: 1.58 : 1.10 : 1.10 : 7.91 : 15.80** for W/ C, Cement, SSA, ESA, FA and CA respectively. Similarly, the minimum FS of SECC evaluated **is 3.21 MPa** for the 28th day result with the corresponding mix ratio of **0.50: 0.40: 0.30:0.30:2:4** and measured quantities at the laboratory as : **1.95: 1.60 : 1.20 : 1.20 : 8.00 : 16.00** for W/C Ratio, Cement, SSA, ESA, FA and CA respectively. The high values of FS obtained is an indication that the SECC materials can resist cracking and deformation and hence suitable for use in structures that are subject to heavy loads .

4. CONCLUSION

So far in this research work, **Flexural Strengths [FS]** of concrete made through partial replacement of cement with SSA and ESA have been evaluated using **K-H Model**. The results of the FS are as stated in Table 1 and in the result discussion section. The K-H Model offers numerous advantages which include the ability of the engineer to easily know the quantities of materials to be procured for FS Investigation 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 to join hands together to adopt this innovation for the sustainability of Low Cost Hydraulic Structures Construction, Effective Pollution Control Measures and Resilient Infrastructural Provision in line with Sustainable Development Goals (SDG -3 , 9 and 11) agenda in Nigeria by 2030.

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