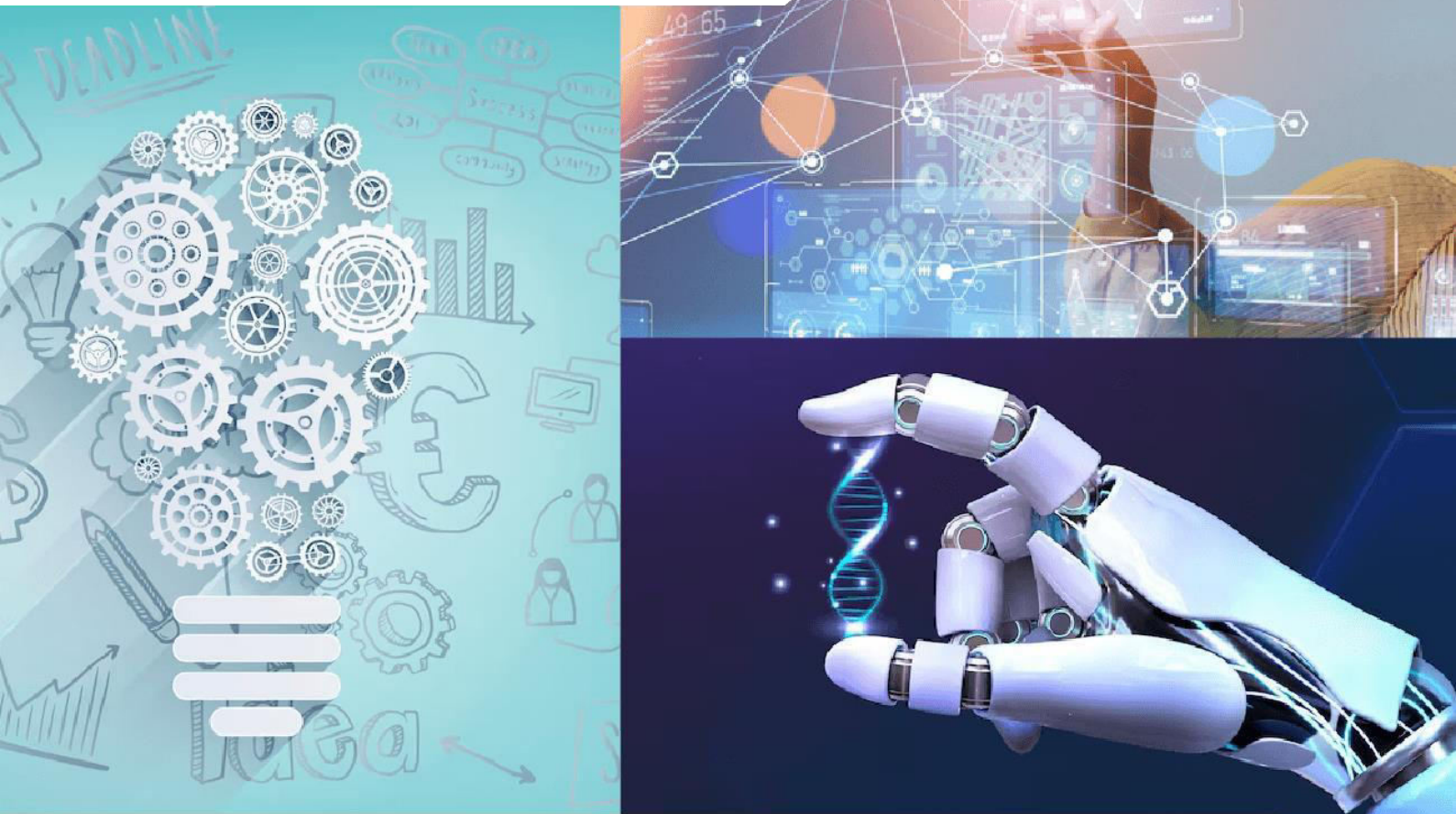




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Split Tensile Strength Evaluation of PSA- ESA- Cement Concrete [PECC] using Handy Developed Empirical Mixture Design [HDEMD]

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ABSTRACT: Shelter, we all know, is one of the three basic necessities of life. At the same time, affordable housing is one of the agenda of the Millennium Development Goal [MDG]. Achieving this feat for the downtrodden and the low income earners requires that building materials should be made affordable with the desired strengths. Owing to the fact that most costs incurred in the building projects are dawned from the costs of cement, concrete and reinforcement, it is necessary to channel our attention on how to make these expensive components of building project affordable. This work is aimed at evaluating the Split Tensile Strength [STS] Of PSA- ESA- Cement Concrete [PECC] using Handy Developed Empirical Mixture Design [HDEMD]. The splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. The innovative inexpensive materials of importance here for partial replacement of cement as a case study are Periwinkle Shells [PS] and Egg Shells [ES]. PSA is the ash form of PS while ESA is the ash form of ES. In the development of the mix ratios using HDEMD method developed by Nwachukwu and others (2025b), only 60 per cent (%) of cement is replaced with the mix proportion of PSA- ESA kept in 50% - 50% so that the mix ratio of Cement: PSA: ESA becomes 0.4: 0.3: 0.3. Using conventional mix ratio of 1:2: 4, ten (10) different mix trials at different water – cement ratios (W/C) were generated and used to cast twenty (20) concrete cylinders and the Split Tensile Strength of PECC were evaluated at each trial mix. The 28th day maximum PECC-STs is **2.53 MPa**, while the minimum value is obtained as **1.43 MPa**. Thus, the PECC-STs values can sustain construction of light-weight and some heavy-weight structures at the best economic, aesthetic, safety and environmentally friendly advantages. Thus, all stakeholders in the Civil/ Environmental Engineering/Construction are advised to cooperate to this innovation of partial replacement of conventional expensive construction raw materials with less expensive innovative and environmentally friendly ones in order to actualize the MDG agenda and for the sake of effective pollution control measures as well as sustainability of low cost and affordable housing projects.

KEYWORDS: Split Tensile Strength [STS], PECC, PSA, ESA, Concrete/ Cement, HDEMD, Mix Ratio, SDG/MDG, Low Cost And Affordable Housing..

I. INTRODUCTION

One of the Sustainable Development Goals [SDG] agenda relating to housing is that by 2030, there should be access to adequate, safe and affordable housing for all. See SDG-11.1 (2015). Affordable housing strengthens the economy, improves economic mobility, reduces poverty and has a positive impact on health outcomes. This is to say that affordable housing is a key player in achieving the SDGs globally and specifically in Nigeria. Again, one of the targets of the MDGs is to achieve a significant improvement in the lives of at least 100 million slum dwellers. In order to achieve these objectives, cost of building housings need to be reduced drastically and made affordable for the least of the world's populace. One way to reduce the cost of building projects is to incorporate alternative inexpensive innovative construction materials that can partially replace expensive conventional building materials. In this way, the use of shells such as PS and ES which are rich in calcium carbonate in cement (which is one the major component of concrete) partial replacement is a welcome idea.

Concrete, according to Oyenuga (2008), is a composite inert material comprising of a binder course (cement), mineral filter or aggregates and water. It is also a homogeneous mixture of cement, sand, gravel and water and is very strong in carrying compressive forces. According to Syal and Goel (2007) opinion, the concrete's capacity to carry compressive forces has made it to gain increasing importance as building and construction materials throughout the world. According to Neville (1990), concrete plays an important part in all building structures owing to its numerous advantages which ranges from low built in fire resistance, high compressive strength to low maintenance, etc. In order to find solution to the expensive nature of concrete due to high cost of cement and cement production as well as other building materials, recent researches have suggested the incorporation of the shells ash as binders when calcinated at suitable high temperatures. The use of PSA and ESA can improve both the economic and safety criteria of cement. The special property of PECC to be investigated in this present study is the concrete's Split Tensile Strength. By definition, Splitting Tensile Strength test on concrete cylinder is a method to determine the tensile strength of concrete. It is generally carried out to obtain the tensile strength of concrete, and the stress field in the tests is actually a biaxial stress field with compressive stress three times greater than the tensile stress. The split tensile strength test is an indirect method of testing tensile strength of concrete and is generally greater than direct tensile strength and lower than flexural strength (modulus of rupture). .

From the Mixture Design perspective, 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) proposed empirical mix design procedures that seems to be more complex and time consuming, Nwachukwu and others (2025b) has developed the method called Handy Developed Empirical Mixture Design[HDEMD] method that will be used in the development of mix ratios in this present work. The six components in the mixture design are: Water, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate.

The present research work is aimed at evaluating the Split Tensile Strength of PSA - ESA- Cement Concrete [PECC] Based On Handy Developed Empirical Mixture Design [HDEMD]. Although many researchers have done some related works, none has been able to address the subject matter sufficiently. For instance, on the use of Periwinkle Shells (PS), PSA, ES, ESA, SSA, MS, MSA and other Mollusks Shells in the construction industry, 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 uncalcined 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. Agbede and Manasseh (2009) investigated the suitability of Periwinkle Shell as partial replacement for river gravel in concrete. 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. 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. Oyedepoo (2016) has examined the evaluation of the properties of lightweight concrete using Periwinkle Shells as a partial replacement for coarse aggregate. 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. 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. 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) are all important works 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. For example, Nwakonobi and Osadebe (2008) used Scheffe's model to optimize the mix

proportion of Clay- Rice Husk Cement Mixture for Animal Building. Ezech and Ibearugbulem (2009) 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. Then the works of Ibearugbulem (2006) and Okere (2006) were based on the use of Scheffe' model in the optimization of compressive strength of Periwinkle 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 (NFRFC). 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 NFRFC. 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 use 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 (HPNFRFC). 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 Concrete 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). Finally, 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 HPNFRFC. 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 NFRFC. 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. Finally, 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. Based on the works reviewed so far, it can be envisaged that no work has been done on the subject matter: **Split Tensile Strength Evaluation Of PSA- ESA- Cement Concrete [PECC] Using Handy Developed Empirical Mixture Design [HDEMD]**. Henceforth, the need for this present research work.

II. METHODOLOGY

2.1. MATERIAL FOR PECC- STS MIXTURE

In this recent PECC research work, the component materials under investigation are : Water, Cement, PSA, ESA, Fine and Coarse Aggregates. As usual, water is 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 of sizes which range from 0.05 - 4.5mm was purchased from the local distributor. Again, Granite as a Coarse aggregate of 20mm size 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 PS 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 PS and ES were then calcined in a Gallenkamp Muffle Furnace at sufficient high temperature before allowing to cool in a decicator. Thereafter, the PS and ES were then grinded into very fine powder [VFP] as PSA 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 PECC mixtures for Split Tensile Strength evaluation..

2.2. FUNDAMENTALS IN HDEMD THEORITICAL CONCEPT IN PECC-STs

In this work, the Handy Developed Empirical [HDE] Mix Design Ratios or Handy Developed Empirical Mixture Design [HDEMD] developed by Nwachukwu and others (2025b) will be used for the mixture design for PECC Split Tensile Strength evaluation. Below are the fundamentals:

2.2.1. ADOPTED MIX RATIO FOR PECC - 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. EVALUATING THE CONVENTIONAL MIX RATIOS FOR PARTIAL REPLACEMENT OF PECC-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 PSA: ESA in the ratio of 50%: 50% of the replaceable cement, we have: **0.5: 0.4: 0.3: 0.3: 2: 4**. The rest are shown in Table 1.

2.2.3. MEASUREMENT OF QUANTITY OF PECC- STs MATERIALS AT THE LABORATORY.

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

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

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: **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

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

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

2.3. METHOD FOR SPLIT TENSILE STRENGTH TEST

2.3.1. PECC SPECIMEN PREPARATION / BATCHING/ CURING FOR SPLIT TENSILE STRENGTH TEST

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 depicted in Table 1. The measured actual quantities of PECC- 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 PECC prototype 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 beam specimens were taken out of the curing tank for the PECC Split Tensile Strength [STS] test.

2.3.2. PECC SPLIT TENSILE STRENGTH TEST PROCEDURE/CALCULATION

The cylindrical split tensile 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).

III. RESULTS PRESENTATION AND DISCUSSION

3.1. RESULTS PRESENTATION

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

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

			TITLE: PECC LABORATORY EXPERIMENTS FOR 2024/2025/CIE/FUTO/FINAL YEAR PROJECT STUDENTS UNDER ENGR. DR. APOSTLE KINGSLEY CHIBUZOR NWACHUKWU							• DIMESION OF MOULD: 150 mm * 300mm • APPROXIMATE. WEIGHT OF CAST STS CONCRETE CYLINDER, W: 12.5 KG					• MEASURED QTY OF PECC- STS MATERIAL AT LAB, MQ: • $M^Q = \frac{XW}{T}$ [KG] T • X = INDIVIDUAL MIX RATIO • T = SUM OF MIX RATIOS				
			AIM: PECC- SPLIT TENSILE STRENGHT [STS] DETERMINATION USING HDEMMD							• D = 150mm; L= 300mm • WEIGHING BAL.: 50KG					• DATE OF CASTING: FRIDAY,JUNE 20, 2025. • DATE OF CRUSHING: FRIDAY,JULY 19, 2025.				
S / N	R E P L I C	CODING	MIX RATIO BASED ON 1:2:4							MEASURED QTY AT LAB, M ^Q [KG]						P [K N]	RE SP ON SE [M PA]	AV ER AG E RE SP	
			X ₁	X ₂	X ₃	X ₄	X ₅	X ₆	T O T A	Q ₁	Q ₂	Q ₃	Q ₄	Q ₅	Q ₆				
			W				F	A	W/	C	PS		FA	CA					

	A T E		/C	C	P S A	E S A	A	C A	L [T]	C		A	E S A				SE E EQ N(2)	ON SE F _t [M PA]
1	A	PECC/A ₁ /S TS	0. 5	0. 4	0. 3	0. 3	2. 0	4. 0	7. 5	0.8 3	0.6 7	0.50 0	0. 50	3.33	6.67	110	1.56	1.5 6
	B	PECC/B ₁ /S TS	0. 5	0. 4	0. 3	0. 3	2. 0	4. 0	7. 5	0.8 3	0.6 7	0.50 0	0. 50	3.33	6.67	110	1.56	
2	A	PECC/A ₂ /S TS	0. 53	0. 4	0. 3	0. 3	2. 0	4. 0	7. 53	0.8 8	0.6 6	0.50 0	0. 50	3.32	6.64	125	1.77	1.7 8
	B	PECC/B ₂ /S TS	0. 53	0. 4	0. 3	0. 3	2. 0	4. 0	7. 53	0.8 8	0.6 6	0.50 0	0. 50	3.32	6.64	126	1.78	
3	A	PECC/A ₃ /S TS	0. 60	0. 4	0. 3	0. 3	2. 0	4. 0	7. 6	0.9 9	0.6 6	0.49 0	0. 49	3.29	6.58	179	2.53	2.5 3
	B	PECC/B ₃ /S TS	0. 60	0. 4	0. 3	0. 3	2. 0	4. 0	7. 6	0.9 9	0.6 6	0.49 0	0. 49	3.29	6.58	179	2.53	
4	A	PECC/A ₄ /S TS	0. 63	0. 4	0. 3	0. 3	2. 0	4. 0	7. 63	1.0 3	0.6 6	0.50 0	0. 50	3.28	6.55	152	2.15	2.1 7
	B	PECC/B ₄ /S TS	0. 63	0. 4	0. 3	0. 3	2. 0	4. 0	7. 63	1.0 3	0.6 6	0.50 0	0. 50	3.28	6.55	154	2.18	
5	A	PECC/A ₅ /S TS	0. 68	0. 4	0. 3	0. 3	2. 0	4. 0	7. 68	1.1 1	0.5 5	0.49 0	0. 49	3.30	6.60	160	2.26	2.2 6
	B	PECC/B ₅ /S TS	0. 68	0. 4	0. 3	0. 3	2. 0	4. 0	7. 68	1.1 1	0.5 5	0.49 0	0. 49	3.30	6.60	160	2.26	
6	A	PECC/A ₆ /S TS	0. 70	0. 4	0. 3	0. 3	2. 0	4. 0	7. 7	1.1 2	0.6 5	0.49 0	0. 49	3.25	6.49	100	1.41	1.4 3
	B	PECC/B ₆ /S TS	0. 70	0. 4	0. 3	0. 3	2. 0	4. 0	7. 7	1.1 2	0.6 5	0.49 0	0. 49	3.25	6.49	102	1.44	
7	A	PECC/A ₇ /S TS	0. 73	0. 4	0. 3	0. 3	2. 0	4. 0	7. 73	1.1 8	0.6 5	0.49 0	0. 49	3.23	6.46	130	1.84	1.8 3
	B	PECC/B ₇ /S TS	0. 73	0. 4	0. 3	0. 3	2. 0	4. 0	7. 73	1.1 8	0.6 5	0.49 0	0. 49	3.23	6.46	132	1.87	
8	A	PECC/A ₈ /S TS	0. 75	0. 4	0. 3	0. 3	2. 0	4. 0	7. 75	1.2 1	0.6 5	0.48 0	0. 48	3.23	6.45	140	1.98	1.9 8
	B	PECC/B ₈ /S TS	0. 75	0. 4	0. 3	0. 3	2. 0	4. 0	7. 75	1.2 1	0.6 5	0.48 0	0. 48	3.23	6.45	140	1.98	
9	A	PECC/A ₉ /S TS	0. 80	0. 4	0. 3	0. 3	2. 0	4. 0	7. 80	1.2 8	0.6 4	0.48 0	0. 48	3.21	6.41	153	2.16	2.1 7
	B	PECC/B ₉ /S TS	0. 80	0. 4	0. 3	0. 3	2. 0	4. 0	7. 80	1.2 8	0.6 4	0.48 0	0. 48	3.21	6.41	154	2.18	
10	A	PECC/A ₁₀ /S TS	0. 85	0. 4	0. 3	0. 3	2. 0	4. 0	7. 85	1.3 5	0.6 4	0.48 0	0. 48	3.18	6.39	170	2.40	2.3 4
	B	PECC/B ₁₀ /S TS	0. 85	0. 4	0. 3	0. 3	2. 0	4. 0	7. 85	1.3 5	0.6 4	0.48 0	0. 48	3.18	6.39	165	2.33	
T O T A L [K G]										21. 96	13. 06	26.1 2	52 .2 4					

3.2. RESULT DISCUSSION

The maximum Split Tensile Strength of PECC evaluated based on HDEM Method is **2.53 MPa** for the 28th day result. The corresponding mix ratio is **0.60: 0.40: 0.30:0.30:2.00:4.00** and the measured quantities at the laboratory are in the ratio : **0.99: 0.66 : 0.49 : 0.49 : 3.29 : 6.58** for Water/Cement Ratio, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate respectively. Similarly, the minimum Split Tensile Strength of PECC determined is **1.43 MPa** for the 28th day result with the corresponding mix ratio of **0.70: 0.40: 0.30:0.30:2.00:4.00** and measured quantities at the laboratory as : **1.12: 0.65 : 0.49 : 0.49 : 3.25 : 6.49** for Water/Cement Ratio, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate respectively.

IV. CONCLUSION

So far in this recent research work, **Split Tensile Strength [STS]** of concrete made through partial replacement of cement with PSA and ESA has been evaluated through **HDEM** method. The results of the STS are as stated in Table 1 and in the result discussion section. It can be observed that the new model has numerous advantages which include that the engineer can 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/ Environmental Engineering/Construction are advised to cooperate to this innovation of partial replacement of conventional expensive construction raw materials with less expensive innovative and environmentally friendly ones like PS and ES for the sake of effective pollution control measures as well as sustainability of low cost and affordable housing projects.

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