IJARETY

International Journal of Advanced Research in Education and TechnologY (IJARETY)

Volume 12, Issue 4, July-August 2025

Impact Factor: 8.152

International Journal of Advanced Research in Education and TechnologY(IJARETY)

| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 8.152| A Bi-Monthly, Double-Blind Peer Reviewed & Refereed Journal |

IJARETY

|| Volume 12, Issue 4, July - August 2025 ||

DOI:10.15680/IJARETY.2025.1204085

Flexural Strength Determination of PSA- ESA-Cement Concrete [PECC] Based on Handy Developed Empirical Mixture Design [HDEMD]

K. C. Nwachukwu[1], H. O. Ozioko[2], C. O. Orji[3], O. V. Boniface[4] and B.C. Kings- Nwachukwu[5]

Lecturer, Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria[1]

Department of Civil Engineering, Michael Okpara Federal University of Agriculture, Umudike, Abia State, Nigeria[2]

2024/2025 Final Year Undergraduate Project Students of Civil Engineering Department, Federal University of Technology, Owerri Under Engr. Dr. Apostle Kingsley Chibuzor Nwachukwu[3,4]

C/o **K. C. Nwachukwu** , Department of Civil Engineering, Federal University of Technology, Owerri, Imo State, Nigeria[5]

Corresponding E- Mail: knwachukwu@gmail.com

ABSTRACT: The knowledge of Flexural Strengths of concrete is of utmost importance because tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel reinforcement, temperature gradient and many other reasons. Also, in order to achieve a low cost building, there is need to use alternative less expensive innovative construction materials which are capable of partially replacing the conventional raw materials in the construction and allied industries. Typical examples of such innovative inexpensive materials are Periwinkle Shells [PS] and Egg Shells [ES]. This research work is therefore aimed at investigating the Flexural Strength of **PSA- ESA-Cement Concrete** [PECC] using Handy Developed Empirical Mixture Design **[HDEMD]** by Nwachukwu and others (2025b). 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, 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 beams and the Flexural Strength of PECC were evaluated at each trial mix .The 28th day maximum flexural strength of PECC is **5.33 MPa**, while the minimum value is obtained as **2.13 MPa**. Thus, the PECC flexural strength value can sustain construction of light-weight and some heavy–weight structures at the best economic, aesthetic, safety and environmentally friendly advantages. Thus cement manufacturing industries as well as other stakeholders in the construction industries are advised to buy the idea of partially replacing the costly limestone with the combination of less expensive PSA and ESA for low cost production of cement, sustainability of affordable housing projects and for cleaner and greener environment.

KEYWORDS: Flexural Strength, PECC, PSA, ESA, Concrete/ Cement, HDEMD, Mix Ratio, Low Cost Building.

I. INTRODUCTION

The world populace is in serious search on how to remedy housing deficit. Because of this, there has been urgent need to incorporate alternative inexpensive innovative construction materials that can partially replace expensive conventional building materials. This gave rise to the use of shells such as PS and ES which are rich in calcium carbonate, which makes them to be capable of partially replacing limestone in cement production. This will not only save cost of cement production, but will make it affordable as well helping in curbing the problem of environmental menace in the society.

Cement is one the major component of concrete .According to Oyenuga (2008), concrete 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' capacity to carry compressive forces has made it to gain increasing importance as building and construction materials throughout the world .Again, 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 other building materials, recent researches have opined 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 flexural strength. By definition, flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. It is also defined as the maximum bending stress that can be applied to the material before it yields. 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 as they involve a lot of trial mixes and complex statistical calculations before the desired strength of the concrete can be reached, 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 for mixture design are : Water, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate.

The present research work is aimed at investigating the Flexural Strength of PSA - ESA- Cement Concrete [PECC] Based On Handy Developed Empirical Mixture Design [HDEMD] . Although many researchers have done some works related to the subject matter, none has been able to address it 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 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**.** Agbede and Manasseh (2009) investigated the suitability of Periwinkle Shell as partial replacement for river gravel in concrete. Mtallib and Rabiu (2009) investigated the effects of Eggshells Ash [ESA] on the setting time of cement. Syammaun and others (2023) assessed the performance of Eggshells ash as sustainable bitumen modifier. Bamigboye and others (2021) have investigated the prospects and challenges pertaining to the sustainable use of 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 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. 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. Ezeh and Ibearugbulem (2009) 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. Then 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

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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 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 (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). 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 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. Finally, Nwachukwu and others (2025b) evaluated the Compressive Strength of PSA-ESA-Cement Concrete [PECC] Using Handy Developed Empirical [HDE]. Based on

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the works reviewed so far, it can be envisaged that no work has been done on the subject matter: **Flexural Strength Determination Of PSA- ESA- Cement Concrete [PECC] Based On Handy Developed Empirical Mixture Design [HDEMD].** Henceforth, the need for this present research work**.**

II. METHODOLOGY

2.1. MATERIAL FOR PECC- FS MIXTURE

In this present 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). The cement, which is a brand of Ordinary Portland Cement which conforms to British Standard Institution BS 12 (1978) was procured from local distributors. The Fine aggregate of sizes which range from 0.05 - 4.5mm was purchased from the local distributor. 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. The calcined PS and ES samples were allowed to cool in a deciccator and 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 Flexural Strength investigation.

2.2. HANDY DEVELOPED EMPIRICAL MIXTURE DESIGN [HDEMD] THEORITICAL CONCEPT

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 flexural strength determination.

2.2.1. ADOPTED MIX RATIO FOR PECC - FS MIXTURE DESIGN

The adopted mix ratio for this work is **1:2:4**. The different water/ cement ratios adopted are **0.5, 0.58, 0.6, 0.63, 0.68, 0.7, 0.73, 0.75, 0.80, 0.85**

2.2.2. CONVENTIONAL MIX RATIOS FOR PARTIAL REPLACEMENT OF PECC- FS COMPONENTS

Using W/C ratio of 0.5, we can determine 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- FS 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)

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

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 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.**
T= 7.5, W = 30
For X_1 = 0.5, using Eqn. (1), $\mathbf{Q_1 = 1.95}$ etc, and the measured quantity for point mix ratios equals
$\mathbf{Q_1 : Q_2 : Q_3 : Q_4 : Q_5 : Q_6 = 1.95 : 1.60 : 1.20 : 1.20 : 8.00 : 16.00}$
Then, for the ten (10) different trial mix ratios, the measured quantities are displayed in Table 1.

2.3. METHODS

2.3.1. PECC SPECIMEN PREPARATION/BATCHING/CURING FOR FLEXURAL STRENGHT TEST

In this research work, the standard size of specimen (mould) for the PECC 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 PECC- 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 PECC prototype concrete beams. Twenty-four (24) hours after casting, the specimens were removed from the moulds and were placed in clean water for curing. After 28 days of curing the concrete beam specimens were taken out of the curing tank for the PECC Flexural Strength test.

2.3.2. PECC FLEXURAL STRENGTH 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 specimen/sample which is expressed as the Modulus of Rupture (MOR) was then calculated to the nearest 0.05 MPa using Eqn.(2)

$$MOR = \frac{PL}{bd^2} \quad \textbf{(2)}$$

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

III. RESULTS PRESENTATION AND DISCUSSION

3.1. RESULTS PRESENTATION

The results of the Flexural Strength of PECC, together with the mix ratios and measured quantity of PECC- FS are shown in Table 1

3.2. RESULT DISCUSSION

The maximum flexural strength of PECC determined using **HDEMD Method is 5.33 MPa** for the 28th day result .The corresponding mix ratio is **0.68: 0.40: 0.30:0.30:2:4** and the measured quantities at the laboratory are in the ratio : **2.66: 1.56 : 1.17 : 1.17 : 7.81 : 15.63** for Water/Cement Ratio, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate respectively. Similarly, the minimum flexural strength of PECC determined **is 2.13 MPa** for the 28th day result with the corresponding mix ratio of **0.70: 0.40: 0.30:0.30:2:4** and measured quantities at the laboratory as : **2.73: 1.56 : 1.17 : 1.17 : 7.79 : 15.58** for Water/Cement Ratio, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate respectively

Table 1: Presentation Of Results Of Flexural Strength Of PECC, The Mixture Design Mix Ratios And The Measured Quantity Of PECC

<table>
<tr><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td colspan="5">TITLE: PECC LABORATORY EXPERIMENTS FOR 2024/2025/CIE/FUTO/FINAL YEAR PROJECT STUDENTS UNDER ENGR. DR. APOSTLE KINGSLEY CHIBUZOR NWACHUKWU</td><td colspan="5">• DIMESION OF MOULD: 150X150X600 MM^2
• APPROXIMATE. WEIGHT OF CAST FS CONCRETE BEAM, W: 30KG</td><td colspan="6">• MEASURED QTY OF PECC-FS MATERIAL AT LAB, MQ:
• $M^Q = \frac{X\,W}{T}$ [KG]
• X = INDIVIDUAL MIX RATIO
• T = SUM OF MIX RATIOS</td></tr>
<tr><td colspan="5">AIM: PECC-FLEXURAL STRENGHT[FS] DETERMINATION USING HDEMD</td><td colspan="5">• d = 150mm; d = 150mm; L= 600mm
• WEIGHING BAL.: 50KG</td><td colspan="6">• DATE OF CASTING: FRIDAY,JUNE 20, 2025.
• DATE OF CRUSHING: FRIDAY,JULY 19, 2025.</td></tr>
<tr><td rowspan="2">S/N</td><td rowspan="2">REPLI</td><td rowspan="2">CODING</td><td colspan="7">MIX RATIO BASED ON 1:2:4</td><td colspan="6">MEASURED QTY AT LAB, M^Q [KG]</td><td rowspan="2">P [KN]</td><td rowspan="2">RESPONSE [M</td><td rowspan="2">AVERAGE RE</td></tr>
<tr><td>X_1</td><td>X_2</td><td>X_3</td><td>X_4</td><td>X_5</td><td>X_6</td><td>TOT</td><td>Q_1</td><td>Q_2</td><td>Q_3</td><td>Q_4</td><td>Q_5</td><td>Q_6</td></tr>
</table>

	CATE		W/C	C	PSA	ESA	FA	CA	AL [T]	W/C	C	PSA	ESA	FA	CA		PA] SEE EQN(2)	SPONSE G [MPA]
1.	A	PECC/A$_1$/FS	0.5	0.4	0.3	0.3	2.0	4.0	7.5	1.95	1.60	1.20	1.20	8.00	16.00	24	4.27	4.27
	B	PECC/B$_1$/FS	0.5	0.4	0.3	0.3	2.0	4.0	7.5	1.95	1.60	1.20	1.20	8.00	16.00	24	4.27	
2.	A	PECC/A$_2$/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	21	3.73	3.73
	B	PECC/B$_2$/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	21	3.73	
3.	A	PECC/A$_3$/FS	0.60	0.4	0.3	0.3	2.0	4.0	7.6	2.37	1.58	1.18	1.18	7.89	15.79	19	3.38	3.29
	B	PECC/B$_3$/FS	0.60	0.4	0.3	0.3	2.0	4.0	7.6	2.37	1.58	1.18	1.18	7.89	15.79	18	3.20	
4.	A	PECC/A$_4$/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	22	3.91	3.91
	B	PECC/B$_4$/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	22	3.91	
5.	A	PECC/A$_5$/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	30	5.33	5.33
	B	PECC/B$_5$/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	30	5.33	
6.	A	PECC/A$_6$/FS	0.70	0.4	0.3	0.3	2.0	4.0	7.7	2.73	1.56	1.17	1.17	7.79	15.58	12	2.13	2.13
	B	PECC/B$_6$/FS	0.70	0.4	0.3	0.3	2.0	4.0	7.7	2.73	1.56	1.17	1.17	7.79	15.58	12	2.13	
7.	A	PECC/A$_7$/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	16	2.84	2.84
	B	PECC/B$_7$/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	16	2.84	
8.	A	PECC/A$_8$/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	17	3.02	3.11
	B	PECC/B$_8$/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	18	3.20	
9.	A	PECC/A$_9$/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	16	2.84	2.93
	B	PECC/B$_9$/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	17	3.02	
10.	A	PECC/A$_{10}$/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	15	2.67	2.67
	B	PECC/B$_{10}$/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	15	2.67	
TOTAL[KG]										53.10	31.24	23.42	23.42	156.44	312.88			

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IJARETY

|| Volume 12, Issue 4, July - August 2025 ||

DOI:10.15680/IJARETY.2025.1204085

IV. CONCLUSION

In this present research work so far, **Flexural Strength [FS]** of concrete made through partial replacement of cement with PSA and ESA has been showcased. The work also revealed how the newly development mixture design model, **HDEMD**, can be used to determine both the mix ratios and measured quantities of **PECC** for flexural strength evaluations. The results of the flexural strengths are as stated in Table 1 and in the result discussion section. Once again, the new model has advantage that the engineer can easily know the quantities of materials to be procured for flexural strength determination by merely looking at the total measured quantity at a glance. Thus, all stakeholders in the construction industries as well as civil / environmental engineering sectors are advised to cooperate to this innovation of partial replacement of conventional raw materials with less expensive innovative ones like shells for effective pollution control measures, sustainability of low cost and affordable housing and for cleaner and greener environment.

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| ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 8.152| A Bi-Monthly, Double-Blind Peer Reviewed & Refereed Journal |

|| Volume 12, Issue 4, July - August 2025 ||

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|| Volume 12, Issue 4, July - August 2025 ||

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International Journal of Advanced Research in Education and Technology

ISSN: 2394-2975 Impact Factor: 8.152

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