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The Use of Kings- HDEMD [K-H] Model in the Flexural Strength [FS] Investigation of PSA- SSA- Cement Concrete [PSCC]

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ABSTRACT: PSCC is a concrete made through partial replacement of cement with Periwinkle Shells Ash [PSA] and Snail Shells Ash [SSA] whose compressive strengths have been determined by the works of Nwachukwu and others (2024b). This time, we are interested in the flexural strength determination. Therefore this research work is aimed at evaluating the Flexural Strength of **PSA- SSA-Cement Concrete** [PSCC] using **Kings –HDEMD [K-H]** Model. K-HDEMD Model is the modified name nomenclature of Handy Developed Empirical Mixture Design **[HDEMD]** , initially developed by K.C.Nwachukwu in the Nwachukwu and others (2025b) publication . For the development of the mix ratios using K-HDEMD method, only 60 per cent (%) of cement is replaced with the mix proportion of PSA-SSA kept in 50% - 50% ratio so that the mix ratio of Cement: PSA: SSA 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 PSCC were evaluated at each point trial mix .The 28th day maximum flexural strength of PSCC is **10.23 MPa**, while the minimum value was obtained as **4.92 MPa**. Thus, the PSCC flexural strength value can sustain construction of light-weight and some heavy–weight structures at the best economic, aesthetic, safety and environmentally friendly advantages. Therefore all partners in the Civil/ Environmental Engineering/Construction/ Building firms as well as the cement manufacturing industries are strongly advised to support this innovation of partial replacement of conventional expensive cement raw materials with less expensive innovative and environmentally friendly ones such as PS and SS with the aim of carrying out effective pollution control measures as well as ensuring sustainability of low cost and affordable housing projects in the tune of SDG-11.1 (2015) Agenda by 2023.

KEYWORDS: Kings- HDEMD [K-H] Model, Flexural Strength [FS], PSCC, PSA, SSA, Concrete/ Cement, Mix Ratio, Low Cost Building, SDG

I. INTRODUCTION

As expected, affordable housing is the strength of every economy. It gives direction to the nation's Per Capita Income as well as telling the volume of the nation' s economic growth. It also improves economic mobility, reduces poverty and has a positive impact on health outcomes, as shelter is one of the basic necessities of life. At the same time, affordable housing achievability requires that the cost of some construction materials, especially the expensive ones be reduced to the barest minimum. One of the surest way to achieve this feat is to incorporate alternative inexpensive innovative construction materials that can partially replace the expensive conventional building materials. In this way, the use of shells such as PS and SS which are rich in calcium carbonate in cement partial replacement can be tolerated.

Concrete is a homogeneous mixture of cement, sand, gravel and water and is very strong in carrying compressive forces. According to Oyenuga (2008), Concrete is a composite inert material comprising of a binder course (cement), mineral filter or aggregates and water. 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. From Neville (1990) perspective, 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,

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etc. In order to find solution to the expensive nature of concrete due to high cost of cement production recent researches have suggested the incorporation of the shells ash as binders when calcinated at sufficient high temperatures. The use of PSA and SSA can improve both the economic and safety criteria of cement . The special property of PSCC 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.

For the PSCC Mixture Design, 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. This model is modified as **Kings –HDEMD [K-H]** Model in the development of mix ratios in this present work. The six components for PSCC mixture design are: Water, Cement, PSA, SSA, Fine Aggregate [FA] and Coarse Aggregate [CA].

This present research work is aimed at determining the Flexural Strength of PSA - SSA- Cement Concrete [PSCC] using **Kings –HDEMD [K-H]** Model. Despite the fact that 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, Snail Shells (SS), ES, ESA, SSA, MS, MSA and other Mollusks Shells and Ashes in the 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**.** 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

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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 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. 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

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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. Finally, Nwachukwu and others (2025e) investigated the Split Tensile Strength Of PSA- ESA- Cement Concrete [PECC] Using Handy Developed Empirical Mixture Design [HDEMD]. Based on the works reviewed so far, it can be envisaged that no work has been done on the subject matter: **The Use Of Kings- HDEMD [K-H] Model In The Flexural Strength [FS] Investigation Of PSA-SSA- Cement Concrete [PSCC] .** Henceforth, the need for this present research work**.**

II. METHODOLOGY

2.1. MATERIALS FOR PSCC- FS MIXTURE DESIGN

In this recent research work, the component materials under PSCC –FS investigation are : Water, Cement, PSA, SSA, Fine and Coarse Aggregates. Water is procured from potable clean water source and was applied in accordance with ASTM C1602/C1602M-22 (2022). A brand of Ordinary Portland Cement that conforms to British Standard Institution BS 12 (1978) was procured from local distributor. The Fine aggregate of sizes which range from 0.05 - 4.5mm was also 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 Periwinkle Shells [PS] and Snail Shells [SS] used in this work were procured as a waste in an aquaculture industry markets and were washed and sundried for few days. After enough drying, the PS and SS were calcined in a Gallenkamp Muffle Furnace [GMF] at suitable high temperature. The calcined PS and SS samples were allowed to cool in a deciccator and then grinded into very fine powder [VFP] ash forms as PSA and SSA respectively using a ceramic mortar and pestle. The resulted PSA and SSA were later sieved through a BS sieve of 75 microns and kept in air tight container for use in the PSCC mixtures for Flexural Strength investigation.

2.2. THEORITICAL FRAMEWORK OF KINGS- HDEMD [K-H] MODEL

Initially, the Handy Developed Empirical **[HDE]** Mix Design Ratios or Handy Developed Empirical Mixture Design **[HDEMD]** developed by Nwachukwu and others (2025b) has been in use. However, in this present work, the author and the developer of the model, Engr. Dr. Apostle Kingsley Chibuzor Nwachukwu has decided to change the nomenclature of the model name to **Kings - HDEMD [K-H]** Model. This name nomenclature will be used for the mixture design for PSCC flexural strength evaluation in this present work.

2.2.1. ADOPTED MIX RATIO FOR PSCC - FS MIXTURE DESIGN

Here, we adopt **1:2:4** as mix ratio for this work. Also, 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. EVALUATING THE CONVENTIONAL MIX RATIOS FOR PARTIAL REPLACEMENT OF PSCC-FS 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: SSA 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 QUANTITIES OF PSCC- FS MATERIALS AT THE LABORATORY.

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

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

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), $\mathbf{Q_1}$ **= 1.95** etc, and the measured quantities for point 1 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**

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

2.3. METHODS FOR PSCC-FS CONCRETE MIXTURE AND CASTING

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

In this research work, the standard size of specimen (mould) for the PSCC 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 PSCC- 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 PSCC prototype 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 PSCC Flexural Strength test.

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

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

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.

III. RESULTS PRESENTATION AND DISCUSSION

3.1. PSCC- FS RESULTS PRESENTATION

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

Table 1: Presentation of Results of Flexural Strength of PSCC, the Mixture Design Mix Ratios And The Measured Quantities Of PSCC At The Laboratory

S/N	REPLICATE	CODING	MIX RATIO BASED ON 1:2:4							MEASURED QTY AT LAB, M^Q [KG]						FS RESPONSE [MPA] SEE EQN(2)	AVERAGE RESPONSE [MPA]
			X_1 W/C	X_2 C	X_3 PSA	X_4 SSA	X_5 FA	X_6 CA	TOTAL [T]	Q_1 W/C	Q_2 C	Q_3 PSA	Q_4 SSA	Q_5 FA	Q_6 CA		
1.	A	PSCC/A_1/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	8.33	8.38
	B	PSCC/B_1/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	8.43	
2.	A	PSCC/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	9.44	9.74
	B	PSCC/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	10.03	
3.	A	PSCC/A_3/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	7.84	8.04
	B	PSCC/B_3/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	8.23	

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4.	**A**	**PSCC/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**	**6.08**	**6.55**
	B	**PSCC/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**	**7.02**	
5.	**A**	**PSCC/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**	**10.24**	**10.23**
	B	**PSCC/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**	**10.23**	
6.	**A**	**PSCC/A_6/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**	**5.09**	**5.09**
	B	**PSCC/B_6/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**	**5.09**	
7.	**A**	**PSCC/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**	**6.76**	**6.42**
	B	**PSCC/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**	**6.07**	
8.	**A**	**PSCC/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**	**4.93**	**4.92**
	B	**PSCC/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**	**4.91**	
9.	**A**	**PSCC/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**	**5.00**	**5.01**
	B	**PSCC/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**	**5.02**	
10.	**A**	**PSCC/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**	**7.05**	**7.05**
	B	**PSCC/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**	**7.05**	
TOTAL [KG]										**53.10**	**31.24**	**23.42**	**23.42**	**156.44**	**312.88**		

3.2. RESULT DISCUSSION

The maximum flexural strength of PSCC determined using **Kings –HDEMD [K-H]** Model **is 10.23 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, SSA, Fine Aggregate and Coarse Aggregate respectively. Similarly, the minimum flexural strength of PSCC determined **is 4.92 MPa** for the 28th day result with the corresponding mix ratio of **0.75: 0.40: 0.30:0.30:2:4** and measured quantities at the laboratory as : **2.90: 1.55 : 1.16 : 1.16 : 7.74 : 15.48** for Water/Cement Ratio, Cement, PSA, SSA, Fine Aggregate and Coarse Aggregate respectively

IV. CONCLUSION

So far, the use of **Kings- HDEMD [K-H]** Model (which is the modified/redefined HDEMD Model) in the **Flexural Strength [FS]** Investigation of **PSCC,** which is concrete made through partial replacement of cement with PSA and SSA has been witnessed and demonstrated. The results of the FS are as stated in Table 1 and in the result discussion section. It can be seen that the new **K-H** model has several advantages which include easily determination of the quantities of materials to be procured by the Engineer for PSCC- FS investigation. This can be achieved by merely looking at the total measured quantities at a glance. Thus, all stakeholders in the Civil/ Environmental Engineering/Construction firms are strongly advised to join hands together and support this innovation of partial replacement of conventional expensive construction raw materials (example cement) with less expensive innovative and environmentally friendly ones like PS and SS with the aim of carrying out effective pollution control measures

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as well as ensuring sustainability of low cost and affordable housing projects as mapped out by SDG-11.1 (2015) Agenda by 2023.

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