IJARETY

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

Volume 12, Issue 4, July-August 2025

Impact Factor: 8.152

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

INNO SPACE SJIF Scientific Journal Impact Factor

doi crossref

निस्केयर NISCAIR

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 |

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

DOI:10.15680/IJARETY.2025.1204046

Compressive Strength Property Investigation of PSA-ESA-Cement Concrete [PECC] using Handy Developed Empirical [HDE] Mixture Design for Sustainable Low Cost Building

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ABSTRACT: To actualize low cost building agenda sometimes require the usage of alternative inexpensive innovative construction materials that are capable of partially replacing the conventional raw materials in the building and construction industries. Periwinkle Shells [PS] and Egg Shells [ES] are two important innovative construction materials whose ash forms (PSA and ESA respectively) can be combined and used to partially replace cement in both cement and concrete production for sustainable low cost building. This research work is therefore aimed at investigating the Compressive Strength Property Of **PSA- ESA-Cement Concrete** [PECC] Using Handy Developed Empirical [HDE] Mixture Design. In the development of the mix ratios, 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 cubes and the Compressive Strength of PECC were evaluated at each trial mix .The 28th day optimum compressive strength of PECC is **27.3 MPa** . The optimum value is higher than the minimum value specified by the American Concrete Institute (ACI), as 20 MPa for good concrete and also very close to the minimum required value specified by ASTM C 469 and ASTM C 39 for high performance concrete. This means that the PECC compressive 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 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 and sustainability of affordable housing projects.

KEYWORDS: PECC, PSA, ESA, Concrete/ Cement, Compressive Strength, HDE, Mixture Design, Mix Ratio, Low Cost Building.

I. INTRODUCTION

Due to urgent need to provide shelter for all mankind, there is also urgent need to incorporate alternative inexpensive innovative construction materials that can partially replace expensive conventional building materials. The use of shells such as PS and ES are capable of actualizing this feat. Ordinarily the disposal PS and ES in the environment is capable of presenting global environmental pollution, but when they are harnessed appropriately, they can be grinded to ash form, combined and used to partially replace cement during cement and concrete productions due their high calcium carbonate content. From the literature, the calcium carbonate content of PS and ES are 93% and 95% respectively. If the major component of cement is the limestone with about 92% of calcium carbonate, then the combination of PS and ES as possible partial replacement of cement is a perfect match.

It is worthy to note that cement is a very important construction material, which is described as the widely used construction material globally. 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 incarrying 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 solve the expensive nature of concrete due to high cost of cement and other building materials, recent researches have favoured the incorporation of the shells ash as binders when calcinated at suitable hightemperatures. The use of PSA and ESA can improve both the economic and safety criteria of cement .The specialproperty of PECC to be investigated in this present study is the concrete's compressive strength. By definition, this mechanical property of concrete is the strength of hardened concrete measured by the compression test or theUniversal Testing Machine [UTM]. It is also a measure of the concrete's ability to resist loads which tend to compress it. It is measured by crushing concrete cubes in a UTM. The compressive strength of the concrete cube test also provides an idea about all the characteristics of concrete under investigation.

On Mixture Design , according to Shacklock (1974), one of the objectives of mix design is to determine the most appropriate proportions in which to use the component materials to meet the needs of construction work. Another definition by Jackson and Dhir (1996) sees concrete mix design as the procedure which, for any given set of condition, the proportions of the constituent materials are chosen so as to produce a concrete with all the required properties for the minimum cost. Thus, the cost of any concrete includes, in addition to that of the materials themselves, the cost of the mix design, of batching, mixing, placing the concrete and of the site supervision as well as the mix design methods. 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, the method employed in this recent work is more direct, simplified and comprehensive. Thus, in this present study, Handy Developed Empirical [HDE] Mixture Design will be used in the development of mix ratios and the six components for mixture design are Water, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate.

This present research work is aimed at investigating the Compressive Strength Property Of **PSA- ESA-Cement Concrete** [PECC] Using Handy Developed Empirical [HDE] Mix Ratios in the Mixture Design. Though many researcher have done some works related to the subject matter, none has been able to address it sufficiently, as per combination of PSA and ESA. For example, on Periwinkle Shells (PS), PSA, ES, ESA, SSA, MS, MSA and other Mollusks Shells works applications in the construction industry, Adeala and Olaoye (2019) investigated the Structural Properties Of Snail Shell Ash Concrete (SSAC). Zaid and Ghorpade (2014) 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) 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) 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. On works done on the application of optimization in concrete mixtures, old and recent works have shown that many researchers have used Scheffe's and Kings- Scheffe's method to carry out one form of optimization work or the other. 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. The work 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) too ptimize the compressive strength of GFRC where they compared the results with their previous work, Nwachukwuand 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

IJARETY | 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 ||
DOI:10.15680/IJARETY.2025.1204046

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. Finally, Nwachukwu and others (2025) investigated the compressive strength of PMCC using Kings- Scheffe's (6,2) Model

Based on the works reviewed so far, it can be envisaged that no work has been done on the subject matter: Compressive Strength Property Investigation Of PSA-ESA-Cement Concrete [PECC] Using Handy Developed Empirical [HDE] Mix Ratios For Sustainable Low Cost Building. Henceforth, the need for this present research work**.**

II.METHODOLOGY

2.1.MATERIAL FOR PECC MIXTURE

In this present research work, the component materials under investigation Water/Cement ratio, Cement, PSA, ESA, Fine and Coarse Aggregates. The water is procured from potable clean water source and was applied in accordance with ASTM C1602/C1602M-22 (2022). The cement type which is a brand of Ordinary Portland Cement and conforms to British Standard Institution BS 12 (1978) was procured from local distributors. Fine aggregate of sizes that 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 compressive strength investigation.

2.2. HANDY DEVELOPED EMPIRICAL MIX RATIOS AND MEASUREMENT OF QUANTITY OF MATERIALS IN THE LABORATORY

2.2.1. ADOPTED MIX RATIO FOR PECC - CS 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- CS COMPONENTS

Using W/C ratio of 0.5, we have 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- CS 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

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

DOI:10.15680/IJARETY.2025.1204046

And W = Average weight of Concrete cube/beam/cylinder

For the Compressive Strength concrete cube mould of 15cm*15cm*15cm, Average Y from experience = 8kg

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

$$T= 7.5, \quad W = 8$$

For $X_1 = 0.5$, using Eqn. (1), $Q_I = 0.53$ etc, and the measured quantity for point mix ratios equals

$$\mathbf{Q_I : Q_2 : Q_3 : Q_4 : Q_5 : Q_6 \quad = 0.53:0.43:0.32:2.13:4.27}$$

For the 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 COMPRESSIVE STRENGHT TEST

The specimen used for the compressive strength is concrete cube. They were cast in steel mould measuring150mm*150mm*150mm. The mould and its base were damped together during concrete casting to prevent leakage of mortar and then thin engine oil was applied to the inner surface of the moulds to make for easy removal of the cubes. 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 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 cubes. Curing commenced 24hours after demoulding . Then, the specimens were removed from the moulds and were placed in clean water for curing. After 28 days of curing the specimens were taken out of the curing tank for the PECC compressive strength test.

2.3.2. PECC COMPRESSIVE STRENGHT TEST PROCEDURE/CALCULATION

Compressive strength testing was done in accordance with BS 1881 – part 116 (1983) - Method of determination of compressive strength of concrete cube and ACI (1989) guideline. Two samples were crushed for each mix ratio and in each case, the compressive strength was calculated using Eqn.(2) as:

$$\text{Compressive Strength (MPa) , G} = \frac{\text{Average failure Load,P}}{\text{Cross- sectional Area, A}} \qquad \textbf{(2)}$$

III. RESULTS AND DISCUSSION

3.1. RESULT PRESENTATION

The results of the compressive strength of PECC, together with the mix ratio and measured quantity of PECC are shown in Table 1

3.2. RESULT DISCUSSION

The maximum compressive strength of PECC evaluated using **HDE Mixture Design Method is 27.3 MPa** for the 28th day result .The corresponding mix ratio is **0.60: 0.40: 0.30:0.30:2:4** and the measured quantities at the laboratory are in the ratio : **0.63:0.42:0.34:0.34:2.11:4.21** for Water/Cement Ratio, Cement, PSA, ESA, Fine Aggregate and Coarse Aggregate respectively

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

			TITLE: PECC LABORATORY EXPERIMENTS FOR 2024/2025/CIE/FUTO/FINAL YEAR PROJECT STUDENTS UNDER ENGR. DR. APOSTLE KINGSLEY CHIBUZOR NWACHUKWU							• DIMESION OF MOULD: 150X150X150MM^2 • APPROXIMATE. WEIGHT OF CAST CS CONCRETE CUBE, W: 8KG					• MEASURED QTY OF PECC MATERIAL AT LAB, MQ: • $M^Q = \frac{X\,W}{T}$ [KG] • X = INDIVIDUAL MIX RATIO • T = SUM OF MIX RATIOS				
			AIM: PECC-COMPRESSIVE STRENGHT[CS] – MIXTURE DESIGN							• AREA, A : 22500MM^2 • WEIGHING BAL.: 50KG					• DATE OF CASTING: FRIDAY,JUNE 20, 2025. • DATE OF CRUSHING: FRIDAY,JULY 19, 2025.				
S/N	**REPLICATE**	**CODING**	**MIX RATIO BASED ON 1:2:4**							**MEASURED QTY AT LAB, M^Q [KG]**						**P [KN]**	**RESPONSE [MPA] $G = \frac{P}{A}$**	**AVERAGE RESPONSE G [MPA]**
			X_1 W/C	**X_2** C	**X_3** PSA	**X_4** ESA	**X_5** FA	**X_6** CA	**TOTAL [T]**	**Q_1** W/C	**Q_2** C	**Q_3** PSA	**Q_4** ESA	**Q_5** FA	**Q_6** CA			
1.	**A**	**PECC/A₁/CS**	**0.5**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.5**	**0.53**	**0.43**	**0.32**	**0.32**	**2.13**	**4.27**	**551**	**24.5**	**24.5**
	B	**PECC/B₁/CS**	**0.5**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.5**	**0.53**	**0.43**	**0.32**	**0.32**	**2.13**	**4.27**	**551**	**24.5**	
2.	**A**	**PECC/A₂/CS**	**0.58**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.58**	**0.61**	**0.42**	**0.32**	**0.32**	**2.11**	**4.22**	**328**	**14.6**	**14.7**
	B	**PECC/B₂/CS**	**0.58**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.58**	**0.61**	**0.42**	**0.32**	**0.32**	**2.11**	**4.22**	**330**	**14.7**	
3.	**A**	**PECC/A₃/CS**	**0.60**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.6**	**0.63**	**0.42**	**0.34**	**0.34**	**2.11**	**4.21**	**614**	**27.3**	**27.3**
	B	**PECC/B₃/CS**	**0.60**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.6**	**0.63**	**0.42**	**0.34**	**0.34**	**2.11**	**4.21**	**614**	**27.3**	
4.	**A**	**PECC/A₄/CS**	**0.63**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.63**	**0.63**	**0.42**	**0.31**	**0.31**	**2.10**	**4.19**	**505**	**22.4**	**22.5**
	B	**PECC/B₄/CS**	**0.63**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.63**	**0.63**	**0.42**	**0.31**	**0.31**	**2.10**	**4.19**	**506**	**22.5**	
5.	**A**	**PECC/A₅/CS**	**0.68**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.68**	**0.71**	**0.42**	**0.31**	**0.31**	**2.08**	**4.17**	**406**	**18.0**	**18.1**
	B	**PECC/B₅/CS**	**0.68**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.68**	**0.71**	**0.42**	**0.31**	**0.31**	**2.08**	**4.17**	**407**	**18.1**	
6.	**A**	**PECC/A₆/CS**	**0.70**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.7**	**0.73**	**0.42**	**0.31**	**0.31**	**2.08**	**4.16**	**466**	**20.7**	**20.5**
	B	**PECC/B₆/CS**	**0.70**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.7**	**0.73**	**0.42**	**0.31**	**0.31**	**2.08**	**4.16**	**456**	**20.3**	
7.	**A**	**PECC/A₇/CS**	**0.73**	**0.4**	**0.3**	**0.3**	**2.0**	**4.0**	**7.73**	**0.76**	**0.41**	**0.31**	**0.31**	**2.07**	**4.14**	**428**	**19.0**	**19.0**

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

DOI:10.15680/IJARETY.2025.1204046

	B	PECC/B_7/CS	0.73	0.4	0.3	0.3	2.0	4.0	7.73	0.76	0.41	0.31	0.31	2.07	4.14	427	19.0	
8.	A	PECC/A_8/CS	0.75	0.4	0.3	0.3	2.0	4.0	7.75	0.77	0.41	0.31	0.31	2.06	4.13	266	11.8	11.9
	B	PECC/B_8/CS	0.75	0.4	0.3	0.3	2.0	4.0	7.75	0.77	0.41	0.31	0.31	2.06	4.13	268	11.9	
9.	A	PECC/A_9/CS	0.80	0.4	0.3	0.3	2.0	4.0	7.80	0.82	0.41	0.31	0.31	2.05	4.10	490	21.8	20.5
	B	PECC/B_9/CS	0.80	0.4	0.3	0.3	2.0	4.0	7.80	0.82	0.41	0.31	0.31	2.05	4.10	489	19.1	
10.	A	PECC/A_{10}/CS	0.85	0.4	0.3	0.3	2.0	4.0	7.85	0.87	0.41	0.31	0.31	2.01	4.08	398	17.7	17.8
	B	PECC/B_{10}/CS	0.85	0.4	0.3	0.3	2.0	4.0	7.85	0.87	0.41	0.31	0.31	2.01	4.08	400	17.8	
TOTAL [KG]										14.12	8.34	6.44	6.44	41.6	83.2			

IV.CONCLUSION

In this present research work so far, efforts have been made to showcase the use of HDE Method in the partial replacement of cement with PSA and ESA. The work not only show that the use of these alternative less expensiveinnovative materials can help in the low cost cement production, it has also demonstrated that their use can help reduce global environmental pollution. The results of the compressive strength are as stated in Table 1 and in the result discussion section. The maximum value from the HDE model is found to be greater than the minimum value specified by the American Concrete Institute [ACI] for the compressive strength of good concrete andalso close to minimum standard (of 4500psi or 30.75MPa) specified by the American Society of Testing and Machine, ASTM C 39 and ASTM C 469 for high performance concrete. One advantage of this HDE method is that the engineer can easily know/note the quantities of materials to be procured by merely looking at the total measured quantity at a glance. Thus, all stakeholders in the construction industries as well as environmental engineering sectors are advised to cooperate to this innovation for sustainability of low cost building and affordable housing and for effective pollution control measures.

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IJARETY | ISSN: 2394-2975 | www.ijarety.in| | Impact Factor: 8.152| A Bi-Monthly, Double-Blind Peer Reviewed & Refereed Journal |
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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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International Journal of Advanced Research in Education and Technology

ISSN: 2394-2975 Impact Factor: 8.152

www.ijarety.in editor.ijarety@gmail.com