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Enhancing concrete durability and performance with coconut shell and POFA additives

ABSTRACT

Cement concrete serves as the primary building material for most of a country's infrastructure. A significant portion of the concrete's overall volume is made up of the aggregate. However, the ongoing use of granite rock for coarse aggregate increases the demand for natural resources by future generations. Because of its huge carbon footprint, the cement sector contributes significantly to global warming. A more cost-effective and sustainable growth of the building industry may arise from the appropriate reduction of cement usage in concrete without compromising its primary properties. In this work, lightweight coconut shell concrete is created by replacing crushed granite aggregate in concrete with coconut shell, an agricultural waste. The POFA is a pozzolanic waste product from the palm oil industry. Between 5% and 15% POFA replacements were added to the cement. The findings demonstrated that a 10% POFA replacement enhanced the lightweight coconut shell concrete's fresh, mechanical and durability properties. In the building industry, using coconut shell and POFA together in concrete would be the most eco-friendly option.

Keywords: *POFA; Coconut shell aggregate; eco-friendly; Sorptivity*

1. INTRODUCTION

In most regions of the world, concrete is acknowledged as the most often used building material. Concrete is one of the most frequently used materials in the world, second only to drinkable water[1]. Significant amounts of natural resources are used in its manufacturing process of concrete. Waste materials can be recycled and used as alternatives to aggregate or binder in concrete[2].About 60–80% of the volume of concrete is composed of aggregates [3].Many ecological issues arise as a result of the substantial sustainability constraints associated with the use of natural coarse aggregates[4]. The ideal substitute for natural materials in the manufacturing of concrete is waste and by-product materials, which promote sustainable development [5]. One of the practical agricultural waste material for making concrete is crushed coconut shell [6,7]. Coconut shells are widely distributed throughout the world's coconut-producing nations, including India. The Indian Ministry of Agriculture and Farmer's Welfare reported that the country produced 20,535.88 million nuts in total in 2023 [8]. There are a number of benefits to using coconut shell in place of coarse aggregate in concrete, including reduced production costs and less environmental impact.Research showed that concrete may be made 30% less expensive by using coconut shell in place of gravel [9].Concrete's dependency on natural resources is reduced by using coconut shell. Furthermore, it becomes beneficial and simple to recycle and distribute leftover coconut shell material in concrete. As a result, it is a concrete material that is both efficient and environmentally beneficial. According to Basri et al. [10], the organic character of wood-based components incorporated into a concrete matrix won't contaminate or infiltrate to form hazardous chemicals.

It has been discovered that there is no need for pretreatment and that the link between the cement composite and coconut shell aggregate is compatible and mildly inhibitive.According to Prakash et al. [11], coconut shell concrete's durability qualities are on par with those of traditional lightweight concretes.Coconut shell reduces the density of concrete since it is a lightweight aggregate, which lessens the structure's dead load[12]. Lightweight concretes are more durable in harsh settings because of their

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homogeneous microcrack distribution and less stiffness [13]. When compared to normal weight concrete, coconut shell coarse aggregate increases the lightweight concrete's sound absorption coefficient [14, 15].

Cement manufacturing is one of the main sources of pollution in the environment since it releases enormous amounts of carbon dioxide into the atmosphere. It is feasible to lower the enormous amounts of cement used in the creation of concrete by substituting some or all of the cement with supplementary cementitious materials (SCMs). Ground granulated blast furnace slag (GGBS), fly ash, silica fume, pond ash, limestone particles, rice husk ash, metakaolin, and palm oil fuel ash (POFA) are examples of SCMs.

POFA is a waste product of the palm oil industry.The palm husk and shells are used as boiler fuel once the palm oil is extracted. When palm fibers and shells are burned in a boiler at temperatures between 900°C and 1000°C as fuel, approximately 5% of the solid waste product is produced as POFA [15].Global production of palm oil increased from about 73 million metric tons in 2021–2022 to over 78 million metric tons in the 2022–2023 marketing year [16]. Because there aren't enough nutrients for it to be used as manure, this ash is typically dumped into open fields, which pollutes the land and poses health risks. Because POFA has a high silica content, it has good pozzolanic qualities that can help improve the concrete's strength and durability [17]. However, compared to FA and slag, POFA's industrial adoption is restricted, particularly in the production of mixed cement. Standardizing these new pozzolans with commonly used substances like slag and FA is crucial. Therefore, the fresh, hardened, and durability properties of POFA mixed concrete are experimented in this study.When POFA is partially substituted for cement in concrete, less cement is used, which lowers CO_2 emissions from cement production.The addition of POFA to concrete improves not just the material's workability and flowability but also its compressive strength [18].

This study investigated the effects of POFA as a cement substitute on the mechanical characteristics of LWC made using coconut shell aggregate, including impact resistance, elastic modulus, flexural strength, split tensile strength, and compressive strength. The research of POFA in normal concrete has been extensively documented in the literature. However, there is little standard literature on the investigation of POFA in coconut shell concrete. Now, this study will examine how the properties of coconut shell light weight concrete are affected when POFA is added at weight percentages of 5%, 10%, and 15% in place of some of the cement.

2. METHODOLOGY

Materials

This study employed regular Portland cement , which has a specific density of 3.13 and a specific surface area of 3,350 cm2/g and complies with IS:12269-1987.The treated POFA met ASTM-C618 standards with chemical compositions of 63.90% SiO2, 6.8% Al2O3, and 6.1% Fe2O3, specific gravity of 2.6, and Blaine fineness of 1150 m2/kg (Table 1).Fine aggregate was made from Cauvery River sand that met Zone II specifications. The specific gravity was 2.37 and the fineness modulus was 2.90. Figure 1a, 1b 1c and 1d shows the POFAwaste, treated POFA sample, SEM image of POFA and the X-Ray diffraction of POFA respectively. The chemical components of OPC and POFA are shown in Table 1.

Table 1. Chemical constituent of Binders

Chemical composition	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**CaO**	**MgO**	**SO_3**	**Na_2O**	**K_2O**	**LOI**
Cement	20.80	4.60	3.3	64.9	1.2	3.0	0.35	0.69	0.72
POFA	63.98	6.82	6.15	6.74	4.21	0.25	0.093	6.92	0.58

The CS sample was taken from a nearby copra preparation yard. Before being sieved, the CS sample was pounded and broken up into tiny bits. Crushed CS samples with particle sizes ranging from 12.5 to 4.75 mm were utilized as coarse aggregate.The prepared CS aggregate was then sun-dried and washed with clean water. CS aggregates require a 24-hour soak in water due to their remarkable capacity to hold moisture.The soaking CS aggregates were dried to remove surface water before to being used in concrete, achieving the aggregate's saturated surface dry (SSD) condition. The workability of the concrete is unaffected when the CS aggregate is in SSD condition because it does not absorb more water from the concrete.Figure 2a shows the amount of CS waste that had accumulated in the copra preparation yard. After collection, this CS waste was ground into aggregates (Fig. 2b). The mechanical and physical characteristics of CS aggregate are listed in Tables 2 and 3. Concrete was mixed using the college's readily available bore well water, and Conplast SP430 was utilized as a water-reducing ingredient.

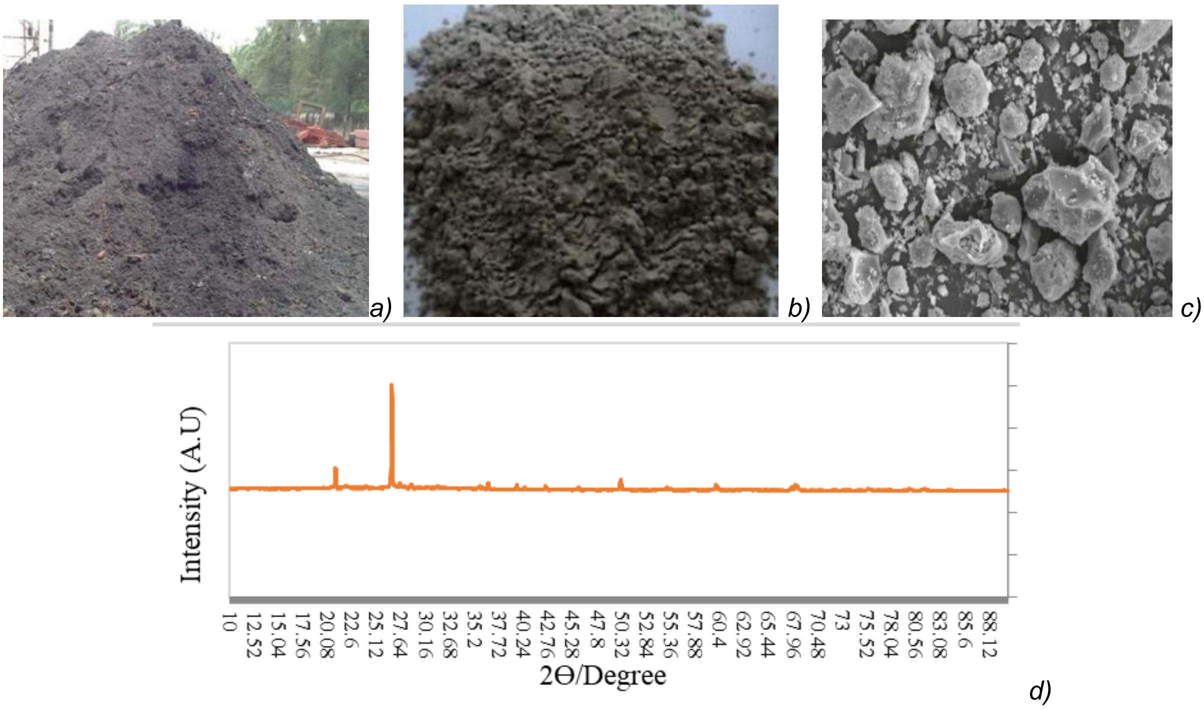


Figure 1. a). POFAwaste b). Treated POFA sample c). SEM image of POFA 50 µm d). X-Ray Diffraction of Treated POFA

Table 2. Physical properties of CS aggregate

Sieve size	Thick.	moisture absorption	Sp.gr.	Fineness modulus	Bulk density	Void ratio
12 to 4.75 mm	4-9 mm	24%	1.2	5.98	0.66 g/cc	0.59

Table 3.Mechanical characteristics of Coconut Shell aggregate

Abrasion value	Crushing value	Impact value
1.9 %	3.02 %	8.0 %

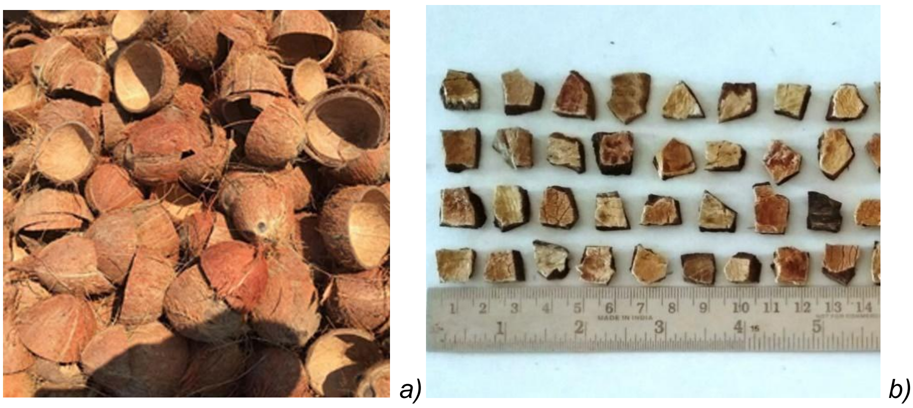


Figure 2. (a). CS waste, (b). Processes CS Aggregates

Concrete Mix Proportions

ACI 211.2-98 standards were followed in the formulation of the trial mixtures. The mixture that performed the best was then chosen for investigation in this study. Cement was replaced with POFA in weight percentages of 5%, 10%, and 15%. These mixtures were designated as CSP5, CSP10, and CSP15, respectively. The binder-to-water ratio was consistently maintained at 0.35 in each composition. To get the desired workability of the concrete, 1.0% of the weight of the binder was added to Conplast SP430, a high-range water-reducing agent.Table 4 displays the mix proportions for every concrete mix produced during this investigation. For around three minutes, CS aggregate and river sand were combined in a rotating drum mixer as part of the mixing procedure.POFA and cement were then added, and the mixture was stirred for an additional six minutes. After that, water and superplasticizer were added to the drum, and it was mixed for an additional eight minutes. Compaction was then applied after the slurry was poured into molds. After a 24-hour interval, the specimens were taken out of the molds and put through a water curing process until the day of testing.

Table 4. Mix proportions of various concrete mixes per m^3

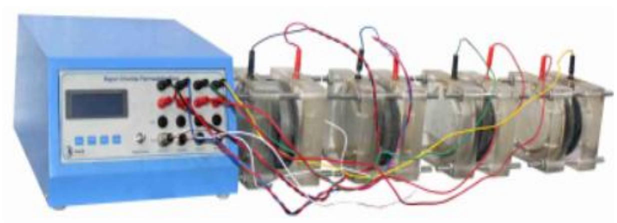
Mix ID	POFA	OPC	Fine aggregate (Sand)	Coconut Shell Aggregate	w/c ratio	ConplastSP430
CSP	0%	510	750	332	0.35	1.0%
CSP5	5%	484.5	750	332	0.35	1.0%
CSP10	10%	459	750	332	0.35	1.0%
CSP15	15%	433.5	750	332	0.35	1.0%

Testing methods

In accordance with ASTM C143/C143M-12, the slump test was carried out. In accordance with IS 456:2000, the compressive strength of 100 mm cube specimens was ascertained. Following a 28-day curing period, three cylindrical specimens measuring 100 mm by 200 mm and three prismatic specimens measuring 100 mm by 100 mm by 500 mm were used to assess the split tensile and flexural strengths. A compression testing device with a maximum capacity of 2,000 kN and a loading rate of 2.3 kN/s was used in the experiment. The concrete specimens were subjected to water absorption and sorptivity testing in compliance with ASTM C1585 guidelines.In compliance with ASTM C 1202 guidelines, the Rapid Chloride Permeability Test (RCPT) was conducted. Figure 3 shows the several experiments that were conducted in this experiment.

(a)

(b)



(c)

(d)

Figure 3. (a) Compressive strength Test, (b) Flexural strength test, (c). RCP Test, (d). Sorptivity Test

3. RESULTS AND DISCUSSION

Slump

The quality of the constituents and the fresh concrete's workability during placing, compaction, and transportation all affect the concrete structure's quality. The light-weight aggregates detach from the heavier cementitious matrix due to the significant slump of LWC.Compaction and inadequate finishing will follow this separation. For adequate compaction and finishing, the ACI 213R-87 restricts LWC's slump to no more than 100 mm.It was believed that LWC could accomplish good compaction and finishing with a 50–75 slump. Because lightweight aggregate did substantially less labor by gravity, Hossain [19] asserted that a high slump was not required for good finishing and compaction of LWC.

In the current experiment, CS aggregate was used under saturated surface dry conditions, which prevented it from absorbing water during the mixing process, even though it normally has a high water absorption rate. Consequently, the mix's ability to function might not be affected. The mixes used in this study had constant levels of superplasticizer and water.

Fig. 4 shows the slump of CS LWC for the various dosage of POFA content. The inclusion of 5%, 10%, and 15% POFA decreased the slump by 8%, 19%, and 30%, respectively. More water is typically absorbed by a higher POFA content. This feature results from the POFA's smaller particle size, which has a bigger surface area and can absorb more water.

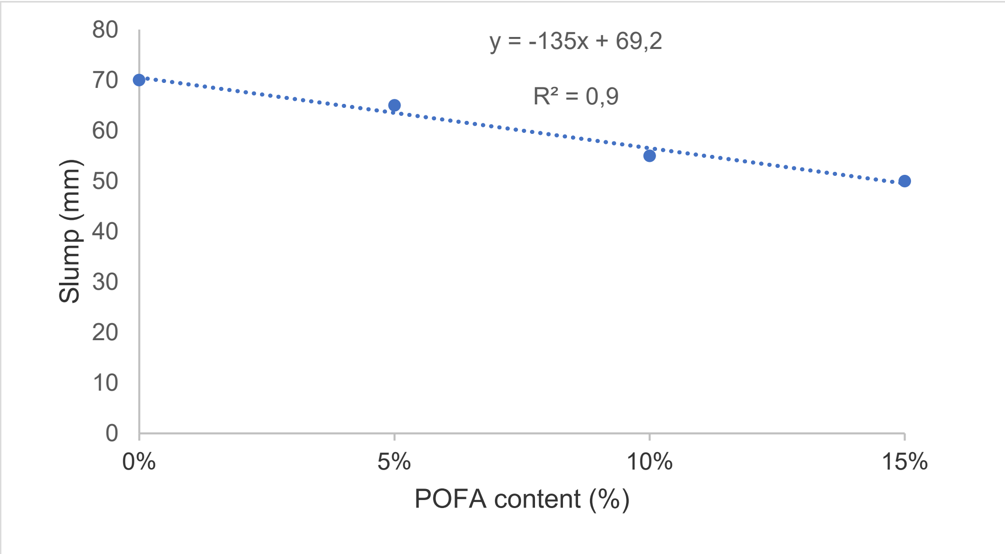


Figure4.Slump of CS concrete with POFA additive

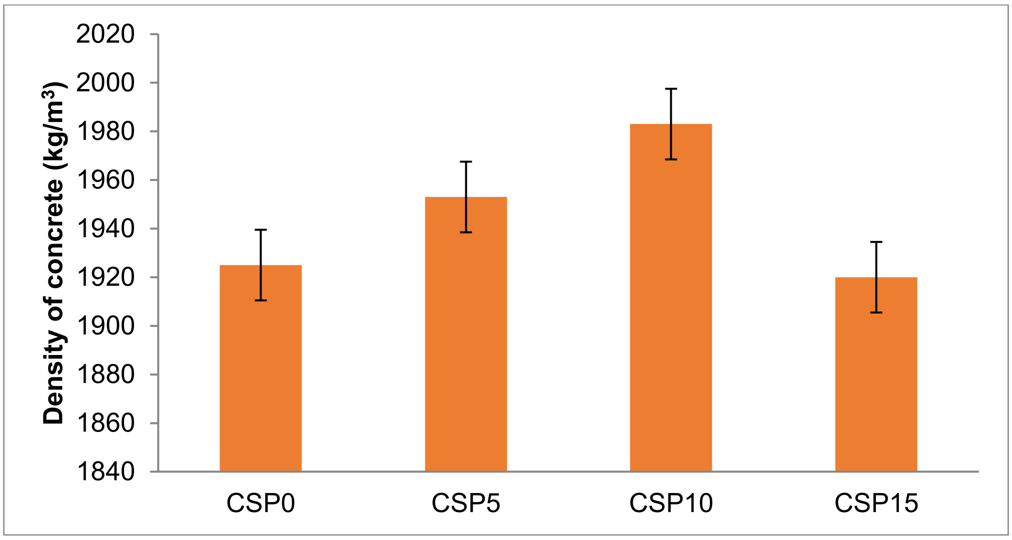


Figure 5. Density of CS concrete with POFA additive

Density

Newman and Choo [20] state that the density of structural LWC is between 1600 and 2000 kg/m3. Interestingly, concrete density somewhat increases as POFA content rises. POFA particles are more densely packed between cement particle gaps, which causes this increase in density. The densities of each blend were less than 2000 kg/m^3, which satisfies LWC's density criteria. Figure 5 displays the density of the CS concrete that was POFA-replaced. It was found that adding 10% POFA increased density by no more than 2.8%. POFA does make lightweight concrete made from coconut shells denser, but the change is negligible, thus the structure's total weight won't be affected.

Compressive Strength

Tambichik et. al. [21] found that the inclusion POFA with the combination of RHA improved the compressive strength of concrete. Alsubari et. al. [22]discovered that SCC made with 20% POFA increased the compressive strength.Alabi andMahachi [23] discovered that replacing cement with 10% POFAfound to be a optimum dosage for developing the compressive strength. Zaimi et al. [24]revealed thatThe compressive strength of cement mortar and found that POFA content improved the its strength . The compressive strength for different CS concrete formulations are shown in Table 4.

Table 4. Compressive strength POFA supplemented CS concrete

Mix ID	Compressive strength, (MPa)
CSP0	30.6
CSP5	32.9
CSP10	36.7
CSP15	30.0

According to this study, adding POFA raised compressive strength by up to 10% before it started to decline. The mixture with 10% POFA showed the maximum compressive strength across the different POFA addition percentages.After 28 days, the compressive strength increased by 20% in comparison to the control CS concrete mix.The result is similar to the findings of earlier studies who found that regular concrete's compressive strength increased. The concrete is stronger now that fine POFA particles have been added since they have increased the particle density of the binder mass. The addition of lime (CaO) enhances and promotes the production of secondary hydrated C-S-H gel products, leading to increased early-age strength development and lower heat generation throughout the hydration process. The observed loss in compressive strength in concrete mixes containing 15% POFA is caused by the instability of the binder caused by an increase in the quantity of free lime (CaO), alumina (Al2O3), and magnesia (MgO).When these substances are moistened, the concrete expands excessively and develops microcracks. As a result, the concrete's resistance to compressive loads is reduced.

Split tensile strength

Overall, the tensile strength of lightweight concrete (LWC) is low.Supplementary cementitious materials (SCM) can be added to concrete while keeping the density limit for lightweight concrete (LWC) in order to address the inherent weakness in the strength characteristics of concrete, including crushed sand (CS), especially in terms of split tensile strength.Tambichik et al. [21]found that typical concrete's split tensile strength increased by a maximum of 10%.When compared to other POFA replacement levels, Alabi and Mahachi's [23]investigation found that the concrete with the highest split tensile strengths was produced by using 10% POFA in place of cement.The consequences of partially substituting fly ash and POFA mixes for cement were the main focus of this study. The specimens with the highest split tensile strengths were made up of 10% POFA and 25% fly ash.

Table 5. Splitting tensile strength of sisal fibre-reinforced CS concrete

Mixture ID	Splitting tensile strength (MPa)
CSP0	2.90
CSA5	3.19
CSA10	3.52
CSC15	3.00

The split tensile strength values of CS concrete with POFA substitution are shown in Table 5. POFA generally improved the split tensile strength of calcium silicate (CS) concrete. The CSP10 mixture's split tensile strength increased by a high of 11.5% at the 28-day mark, reaching 3.52 MPa.This gain is comparable to roughly 9.6% of the equivalent mixture's compressive strength. The outcome is like what other researchers have reported about split tensile strength improvement in ordinary concrete. According to ASTM C330 requirements, lightweight concrete (LWC) used in structural applications must have a split tensile strength of at least 2.0 MPa. Therefore, using any combination of experimental mixtures as structural lightweight concrete (LWC) is feasible. Regression analysis was used in this work to show empirical connections between split tensile strength and compressive strength, as shown in Figure 6.

Regression analysis can be used to determine the relationship between split tensile strength and compressive strength using equation (1).

$$f_t = 0.5576\sqrt{f_c} \quad (1)$$

A comparison of the theoretical and actual results based on split tensile strength is shown in Figure 7. Clearly, the practical results are in good agreement with the expected theoretical results from Equation 1.

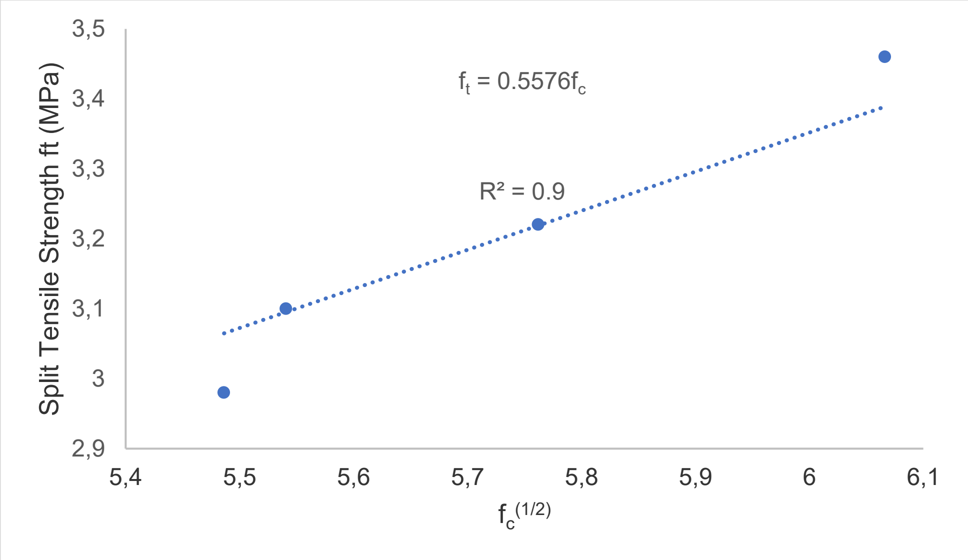


Figure 6. Regression analysis between compressive strength and Split tensile strength of POFA supplemented CS concrete

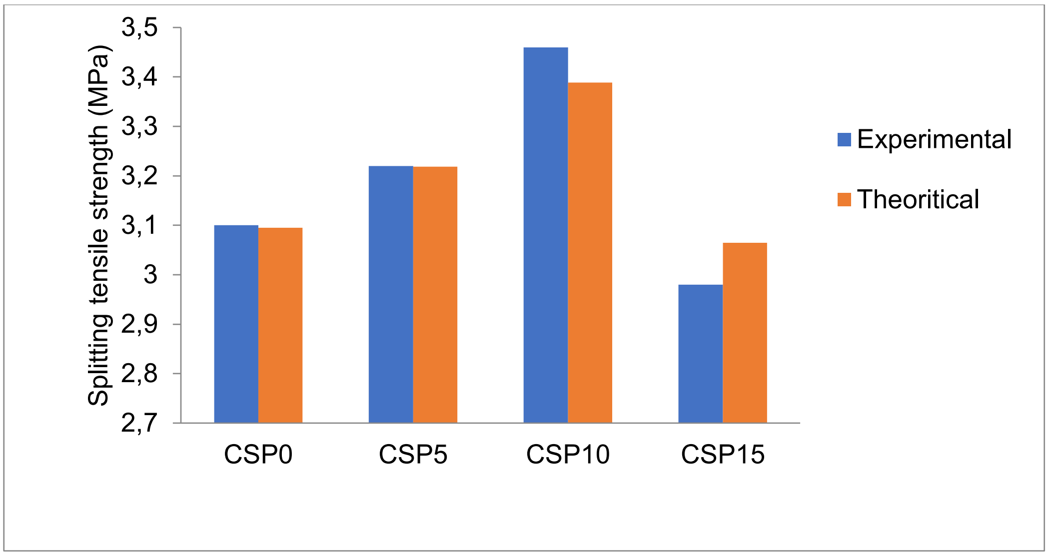


Figure 7. Comparision of Experimental and theoretical split tensile strengthof POFA supplemented CS concrete

Flexural strength

The data on the flexural strength of CS concrete is shown in Table 6. According to measurements, the control concrete specimen's flexural strength was 4.95 MPa, or around 14.5% of its compressive strength. It was discovered throughout this investigation that adding POFA to CS LWC significantly increased the concrete's flexural strengthThe use of 10% POFA cement concrete was shown to significantly increase flexural strength in a study by Alabi and Mahachi[23].Sanjeev Kumar et al. did a study on POFA in lightweight concrete was shown to significantly increase its flexural strength [25].

The current investigation shows that adding POFA to CS concrete increased its flexural strength by up to 20%, marking a significant improvement. The flexural strength of CS concrete increased by 8% and 18%, respectively, when POFA was added at concentrations of 5% and

10%. However, the flexural strength of the calcium silicate (CS) concrete was somewhat reduced upon adding a 15% POFA admixture.

The current investigation shows that adding POFA to CS concrete significantly increased its flexural strength, with improvements of up to 20% seen. The flexural strength of CS concrete increased by 8% and 18%, respectively, when POFA was added at concentrations of 5% and 10%. The outcome is consistent with previous studies' findings of an increase in split tensile strength in ordinary concrete. However, the flexural strength of calcium silicate (CS) concrete was somewhat reduced upon adding a 15% POFA admixture.

$$f_r = 0.514 f_c^{2/3} \tag{2}$$

Table 6. Flexural strength

Mixture ID	Flexural strength (MPa)
CSP0	4.95
CSP5	5.29
CSP10	5.90
CSP15	4.85

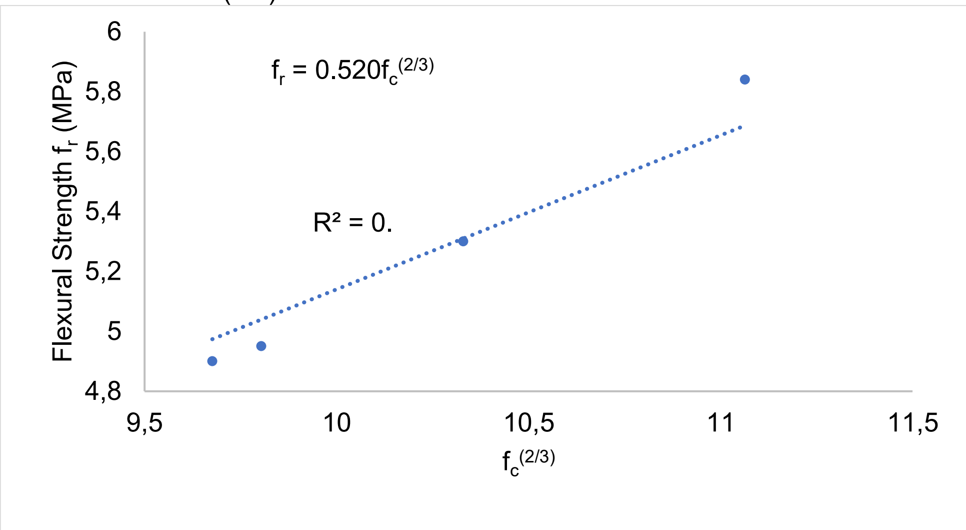


Figure 8. Correlation between compressive strength and flexural strengthof POFA supplemented CS concrete

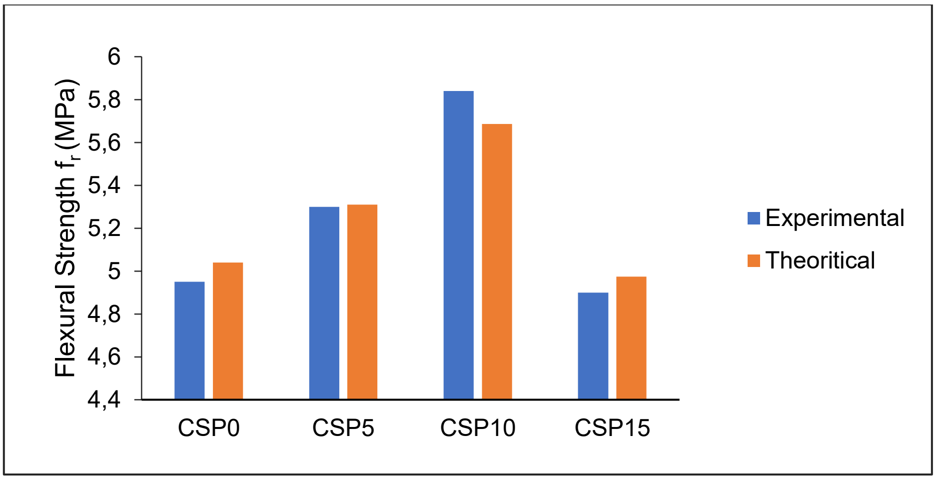


Figure 9. Experimental and theoretical flexural strengthof POFA supplemented CS concrete

Water absorption

Concrete's absorption characteristic can be analyzed to determine how long it will last. The movement of fluids within permeable solids due to the capillary action exerted by surface tension is the phenomenon under study[26]. By measuring the specimens' absorption in water, one can calculate their open pore volume [27]. Research demonstrated that adding POFA to concrete improved durability by reducing water absorption. [21]. The water absorption properties of each mixture are shown in Figure 10.

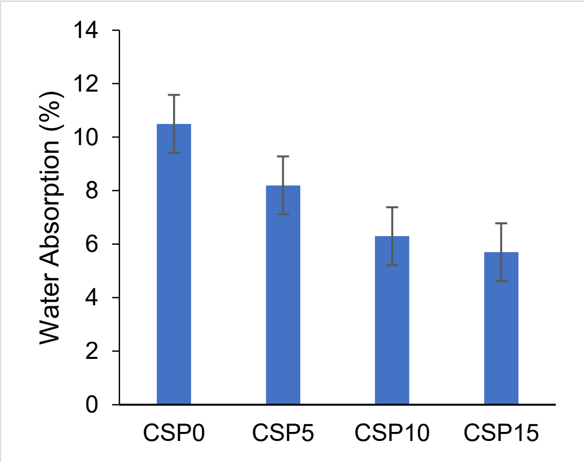


Figure 10. Water absorptionof POFA supplemented CS concrete

After 28 days, the water absorption rate in the control combination was found to be 10.6%. By substituting fly ash for 5%, 10%, and 15% of the mixture, respectively, this rate dropped to 8.2%, 7.1%, and 5.5%.The complete evaporation of water from the CS aggregate, which CS held during the concrete immersion process, may be the cause of this result. It was then demonstrated that mixtures containing POFA had lesser water absorption than the control combination.When less POFA was added, the mixture's water absorption rose; when more POFA was added, the mixture's water absorption fell. POFA's small particle size caused the pore size of the concrete to decrease when it was added. POFA and water absorption have an inversely proportional connection, which reduces the amount of space inside the specimen that may be used to store water.

Sorptivity

Concrete's permeability properties can be better understood by measuring its sorptivity [27]. A high degree of resistance to water absorption is indicated by low sorptivity levels. If the sorptivity value of concrete is less than 0.1 mm/min0.5, it is generally considered to have a good grade. Researchers discovered that POFA in concrete increases durability by lowering the sorptivity coefficient [21]. The POFA-admixed fiber-reinforced SCC mix was found to have a lower sorptivity value than the control concrete [28]. The sorptivity values of the concrete mix with POFA and CS added are shown in Figure 11. At 28 days of age, the CSA0 mixture's sorptivity was found to be between 0.096 and 0.099 mm/min0.5. Following the addition of POFA, these values further declined. This is explained by POFA's large specific surface area, which comes from its small particle size. The transition zone between the aggregates was reduced when POFA was present. The POFA replacement at 14% was found to have the lowest sorptivity levels, with values falling between 0.088 and 0.094 mm/min0.5.The sorptivity values found in this study are in line with earlier investigations into several kinds of lightweight concretes, including expanded shale and sintered pulverized fuel ash. The sorptivity values of these materials are 0.03 mm/min0.5 and 0.06 mm/min 0.5, respectively.

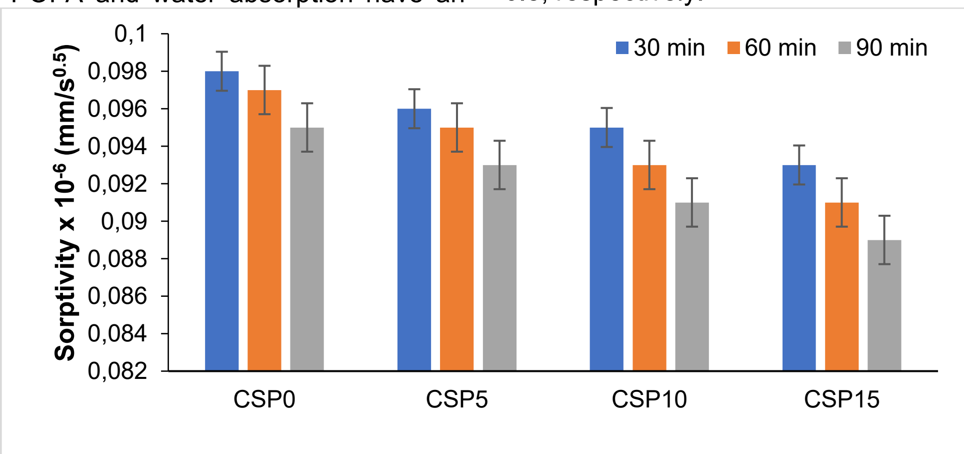


Figure 11. SorptivityofPOFA supplemented CS concrete

Rapid chloride penetrability test (RCPT)

Chloride intrusion poses a serious environmental risk to concrete because it corrodes rebar and lowers the structural element's serviceability and structural capacity. Premature degradation and the need for structural member maintenance could result from the aforementioned conclusion. Preventing chloride from penetrating the concrete, or at the very least restricting its penetration to the area surrounding the steel reinforcement, is the main strategy used to reduce rebar corrosion.By building a concrete structure with a comparatively high level of impermeability, this technique can be implemented. For quality control and design reasons, it is crucial to ascertain the degree of chloride penetration into concrete.

However, it is not possible to directly determine chloride penetrability within a given time period.Consequently, it is essential to create a process that speeds up the evaluation of chloride penetration so that diffusion coefficients can be found in a reasonable amount of time. The Rapid Chloride Penetration Test (RCPT) findings for concrete mixtures with different POFA replacement amounts are shown in Figure 11.

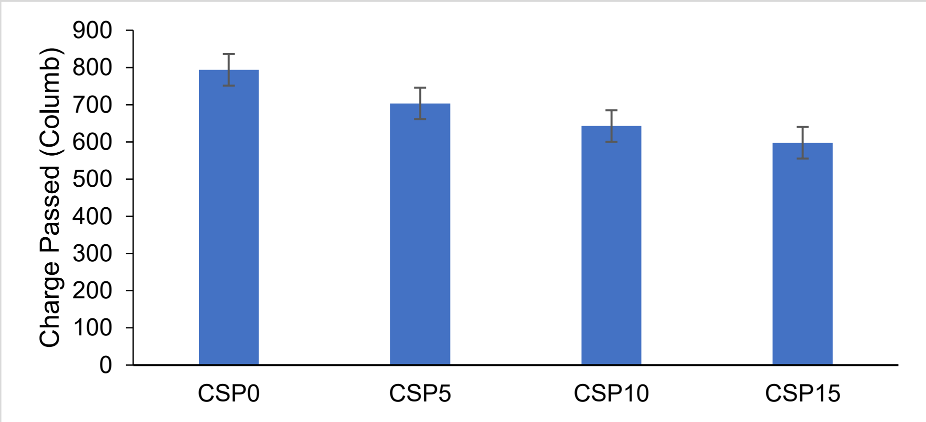


Figure 12.Charge passedofPOFA supplemented CS concrete

At 28 days of age, the CSP0's RCPT value was found to be 793.7.Furthermore, the charge transmitted decreased in the concrete mixes with different concentrations of CS (i.e., CSP5, CSP10, and CSP15), and this decrease grew as the POFA concentration rose. The alkali binding qualities and decreased permeability of voids in concrete that has been mixed with POFA are responsible for the observed result. The literature reports that expanded clay lightweight aggregate concrete's RCPT (Rapid Chloride Penetration Test) results range from 2115 to 3336 coulombs [28]. According to Tangchirapat et al. [20], the addition of 10% POFA to normal concrete reduced the amount of chloride penetration by up to 284 coulombs. The findings of this investigation were consistent with those of previous studies on standard concrete.

Sustainability Performance

In many nations, coconut shells are discarded as agricultural trash. In 2023, the Ministry of Agriculture and Farmer Welfare of the Government of India projects that 20,535.88 million nuts will be wasted in India. The cost of purchasing coarse aggregate for concrete is reduced when these waste materials are used to replace crushed granite aggregate. As POFA is a waste byproduct, it offers many benefits, such as improved mechanical and durability performance, when used in place of cement by merely 10%.The surrounding ecosystem endures severe damage by the disposal of coconut shells. The use of CS in the manufacturing of concrete protects granite, a resource that is fast running out, and provides an efficient technique for disposing of it. Limestone is a natural resource used to make cement, and its depletion is reduced when POFA is used in concrete production as a partial substitute for cement. As a result, the building industry's sustainability aspect can be enhanced. In addition to lowering the amount of greenhouse gases like CO2 and NOx released into the atmosphere, this study will help preserve limestone for future generations. Thus, the development of coconut shell concrete, which partially replaces POFA, will help ensure that concrete production is sustainable.

4. CONCLUSIONS

Using coconut shell, an agricultural waste, and partially substituting POFA for cement, LWC was created. By lowering the cement content and improving the concrete's strength and durability, POFA integration made concrete production more environmentally friendly. This study led to the specific conclusions listed below.

(i) A linear decline in slump is the outcome of increasing POFA content. Nonetheless, every mix met the minimal specifications for LWC

(ii)When POFA is added, there are marginal changes in the density of coconut shell concrete is found.

(iii) As the POFA content rises, the characteristics of hardened concrete are seen to improve. The specimen with the highest values of compressive strength, splitting tensile strength, and flexural strength was the one that included 10% POFA substitution.

(iv) Compressive strength increased by 20%, splitting tensile strength increased by 18%, and flexural strength increased by 17% when 10% POFA was added to the mixture.

(v) Water absorption was significantly decreased when POFA was added to the CS concrete mixes. This is explained by both the increased production of hydration products and the reduction in concrete pores brought on by the POFA's small particles.

(vi) POFA improved the interfacial transition zone between the weak aggregate and the CS lightweight concrete by lowering the sorptivity of the concrete..

(vii) The CS concrete's chloride permeability decreased after POFA was added.

(viii) The splitting tensile and flexural strengths of POFA-replaced CS concrete are linked to the compressive strength with a very high coefficient of determination.

The findings suggest that a practical method for producing concrete that is both economical and ecologically friendly is to use coconut shell, an agricultural byproduct, as coarse aggregate in combination with POFA, a supplementary cementitious material (SCM), as a partial cement substitute. Additionally, there is potential for this concrete combination to be used in structural applications.

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IZVOD

POVEĆANJE IZDRŽLJIVOSTI I PERFORMANSI BETONA POMOĆU KOKOSOVE LJUSKE I POFA ADITIVA

Cementni beton služi kao primarni građevinski materijal za veći deo infrastrukture jedne zemlje. Značajan deo ukupne zapremine betona čini agregat. Međutim, kontinuirana upotreba granitne stene za krupni agregat povećava potražnju za prirodnim resursima budućih generacija. Zbog svog ogromnog ugljeničnog otiska, cementni sektor značajno doprinosi globalnom zagrevanju. Isplativiji i održivi rast građevinske industrije može nastati odgovarajućim smanjenjem upotrebe cementa u betonu bez ugrožavanja njegovih primarnih svojstava. U ovom radu, lagani beton od kokosovih ljuski se stvara zamenom drobljenog granitnog agregata u betonu kokosovim ljuskama, poljoprivrednim otpadom. POFA je pucolanski otpadni proizvod iz industrije palminog ulja. U cement je dodato između 5% i 15% zamena za POFA. Rezultati su pokazali da je zamena od 10% POFA poboljšala svojstva lakog betona od kokosovih ljuski u pogledu svežesti, mehaničkih svojstava i izdržljivosti. U građevinskoj industriji, upotreba kokosovih ljuski i POFA zajedno u betonu bila bi najprihvatljivija opcija.

Ključne reči*: POFA, Agregat od kokosovih ljuski, ekološki prihvatljiv, Sorptivnost*

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