



Journal of Materials and Engineering Structures

Research Paper

Experimental Evaluation for Improving the Engineering Properties of Concrete Using Partial Replacement of Natural Waste

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ARTICLE INFO

Article history :

Received 7 December 2024

Revised 28 June 2025

Accepted 4 July 2025

Keywords:

Fine Aggregate,
Coconut Shell Ash,
Coarse Aggregate,
Coconut Shell Fine Aggregate,
Compressive Strength,
Agricultural Waste,
Coconut Shell Coarse Aggregate.

ABSTRACT

With the global growth of building construction and infrastructure around the world, the global demand for concrete materials in the construction industry is increasing day by day. Natural waste can be considered an alternative substitute that can be partially mixed into concrete up to a certain limit while maintaining the strength and properties of the concrete for a long duration. In this research, crushed coconut shell as fine and coarse aggregate and coconut shell ash as cement are used as a partial replacement for fine aggregate, coarse aggregate, and cement in concrete. A mix design of M20-grade concrete was prepared as per BIS 1026 2019, and 150 × 150 × 150 mm³ sized cubes of concrete were designed. Concrete materials were replaced with a different form of coconut shells, as cement was replaced with coconut shell ash. In this research, the effects of replacing cement, fine aggregate (FA), and coarse aggregate (CA) were tested in concrete with alternative materials (CSA, CSFA, CSCA) at different levels (0–25%). Concrete strength was measured after 28 days, which represents reduced strength from 24.58 MPa (0%) to 12.80 MPa (25%) in replacing cement with CSA. Increased strength at 5% (28.58 MPa) but dropped to 8.29 MPa at 25% in replacing FA with CSFA. Reduced strength to 8.14 MPa at 25% in replacing CA with CSCA. Replacing all three together lowered strength to 7.25 MPa at 25%. So, only replacements of small proportion (CSFA at 5%) can improve strength, but higher percentages reduce concrete performance. After being prepared, the mould was kept for curing for 3, 7, 14, and 28 days, after which its compressive strength was tested. The result analysis shows that mixing up to 5-10% of crushed coconut shell (CCS) and coconut shell ash (CSA) in concrete does not affect the strength or durability. The limitation of using this natural waste is that it can be substituted up to a certain limit, and the strength graph decreases significantly beyond that limit.

1 Introduction

The large-scale building constructions are occurring as a result of the daily increase in urbanization and development, so the construction materials requirements are also increasing for the development of infrastructure all over the world. Concrete

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is a major part of construction materials. Cement, sand, and aggregate are the main elements of concrete, and water is also used. Quarries are dug to meet the ever-increasing demand for these materials, and the raw material is processed to make usable material [1, 2]. Excavation of mines has an impact on the environment. Keeping all these things in mind, we have tried to use some coconut shells in concrete because coconut is produced in more than 80 countries. India ranks third in that. The highest production of coconut is done in Indonesia. We have used coconut shells in all three forms. We have burned coconut shells, made their ash, and used it with cement. Coconut shell has also been used as fine and coarse aggregate.

Construction material is the essential requirement for global infrastructure development. Concrete (cement, sand, fine, and coarse aggregate) is a major component of construction materials, and the ever-increasing demand for these materials opens the research for the use of waste materials to be partially used while maintaining strength. The mine excavation by the cement and concrete industries and its environmental impact can be minimized by partially substituting natural waste materials into concrete [3, 4]. In this research, coconut shells are used in concrete, as coconut is produced in more than 80 countries. Indonesia is the highest coconut production country, and India is the third. This research used coconut shells in three forms: burned coconut shells made their coconut shell ash (CSA), which is partially replaced with cement; crushed shell used as coconut shell fine aggregate (CSFA); and coconut shell coarse aggregate (CSCA), that are partially replaced with fine and coarse aggregate.

1.1 Theoretical Background

Concrete as a main composite material is extensively used in modern constructions globally, which is characterized by its physical properties such as strength, durability, and versatility. Due to the rapid urbanization and infrastructure development, the high global demand for concrete is increasing day by day, which creates significant challenges for environmental sustainability. Due to mining, quarrying, and manufacturing processes, the conventional concrete materials that are resource-intensive have strong environmental impacts [5–8]. The potential solution for this issue is partially replacing conventional concrete components by mixing natural waste materials. In India, coconut shells as natural waste are abundant in festival seasons, and they are underutilized. That is an opportunity to enhance environmental sustainability by partially mixing them in concrete production. The research and studies in [9–12] indicated that utilization of agricultural and industrial waste materials into concrete mix can maintain the physical characteristics of concrete and it also leads to eco-friendly construction practices. In this research, the workability of crushed coconut shells (CCSs) and coconut shell ash (CSA) is explored by experimental analysis as natural alternative materials to be partially substituted up to a certain limit for fine aggregate, coarse aggregate, and cement to maintain the strength and durability of the concrete.

1.2 Challenges

Integrating partially CCS and CSA as natural waste materials in concrete mix represents many challenging issues:

- **Material Compatibility, Variability and Quality Control:** Integrating CCS and CSA into concrete mix may affect the bonding and structural integrity of the construction. CSs as natural waste material have significant inherent variability characteristics in their composition. So, this can affect the consistency and reliability of the concrete mix. The quality control depends on the quantity applied to the concrete mix. Up to a certain limit of the partially substituted quantity, the concrete mix pertains to its quality. Implementing rigorous testing and quality control procedures are the challenging task for the coconut shells waste materials.
- **Performance Metrics:** The performance measurement of concrete with partial replacements of cement, fine, and coarse aggregate with CSA and CCS is a challenging task as compared to conventional concrete. When coconut shell like unconventional waste materials are partially applied in concrete mix, then precisely measuring (under standard procedure) the properties (compressive strength, durability, workability) of concrete can be complex task.
- **Public Acceptance:** There may be doubt among people who want to partially use CSs with concrete regarding reliability, safety, and durability in constructions.
- **Standardization:** However, there is no established standard for incorporating natural waste into concrete, and the process of standardizing it globally may be challenging.

1.3 Motivation and Objective

The requirements of challenging environmental sustainability and increasing demand for building construction materials become the motivation behind this research work. Utilizing sustainable natural alternatives such as CCS and CSA in this research promotes waste utilization in construction, ecofriendly projects, and the economy, as well as maintaining the strength properties of concrete and durability. The main objective of this research is to evaluate the performance and feasibility of utilizing CCS and CSA as partial replacements for fine aggregate, coarse aggregate, and cement in the concrete mix. The analysis of compressive strength at curing periods (3, 7, 14, and 28 days) and investigating the long-term performance with promoting the use of natural waste in construction to maintain environmental sustainability is the overall outline of this research work.

2 Related Work

Due to the aluminum content (Al_2O_3) in sugarcane ash and hardness of the coconut shell, Srivani *et al.* [13] partially replaced both in concrete with different proportions. Sugarcane ash was replaced with cement by 0% to 20%, and coconut shell was replaced with aggregate by 0% to 40%. They investigated the workability, compressive strength, and thermal stability of concrete and found that the slump value decreased, which means the workability increased. They obtained the best optimal compressive strength (28.9 MPa after 28 days) by replacing 10% sugarcane ash and 20% coconut shell. With the increment of temperature, the compressive strength decreases; there is a decrease of 18.9% when the temperature increases to 300 °C, and there is an increase of 600 °C, the compression strength decreases up to 60%.

Saraswat *et al.* [14] found in their experiment that CSA is a suitable replacement for cement. They found that the highest optimal compressive strength was obtained by replacing up to 10% of cement by CSA, and beyond that percentage of replacement, the compressive strength got reduced drastically. Udhayasankar *et al.* [15] developed cardanol-based biocomposites with CS particles taking different sizes (25, 50, and 75 μm) using biopolymers, and they found improved bonding and considerable mechanical properties in their mix composites by their experimental results.

Hasan *et al.* [16] replaced CA by CSCA and investigated physical properties like tensile, compressive, and flexural strength in curing periods of 7th, 14th, and 28th days and compared results using statistical methods. They found that, with the increment of CSCA, the slump value decreases gradually. The compressive strength also decreases with an increment of CSCA incorporation into concrete mix, which provides it with a lightweight property.

To minimize the environmental impact while maintaining performance of the concrete structure, Ranatunga *et al.* [17] investigated the optimal use of CSA in concrete mix as a partial replacement for cement.

Adajar *et al.* [18] found in their study that coconut shell ash contains iron oxide, aluminum dioxide, and silica dioxide, which makes it suitable for use as a partial replacement in OPC cement. They have partially replaced OPC with CSA and then statistically analyzed its sorptivity and compressive strength test and found that after 10% replacement with ordinary Portland cement, the compressive strength is reduced to 92.10% of that of control concrete. The microstructure of conventional CSA concrete shows that as CSA content increases, voids between the aggregates increase. Thus, sorptivity increases with increasing CSA content, making it more susceptible to sulfate attack.

Azunna *et al.* [19] In this research, coconut cells have been replaced with fine aggregate in concrete. After replacement, the mechanical and physical properties of the concrete were tested. The replacement percentage has been kept between 10 and 20. The target strength of 35 MPa has been kept in replacement percentage. After replacement, density decreased, flexural strength increased, and compressive strength increased, with an increase in the absorption properties of concrete as the coconut shell replacement increased.

Mhaya *et al.* [20] evaluated coconut shell as a fine aggregate replacement in concrete to determine water absorption and permeability tests. Three scenarios were observed: 1. Genetic Expression Programming (GEP); 2. Artificial Neural Networks (ANN). 3. Response Surface Methodology (RSM); when the replacement percentage is 0% to 10%, water absorption is 5%, and permeability is less than 1.5×10^{-11} m/s, the replacement percentage increases up to 60%, while water absorption is 6.5% and permeability is low. 2.7×10^{-11} m/s. Replacement increases by 90% to 100% with a high permeability of more than 4.5×10^{-11} m/s and water absorption above 10%.

Vo *et al.* [21] used fly ash as a partial replacement for cement in fresh concrete to reduce drift support costs and improve environmental protection. Laboratory tests at Hanoi University of Mining and Geology showed that fly ash can increase the workability, flexural strength, and compressive strength of underground concrete. Their research concludes that fly ash is suitable for lower grades of cement and can save costs in the coal and thermal industries.

Kedir *et al.* [22] developed construction bricks using coal fly ash (CFA) and baking yeast to find a use for this byproduct of thermal power plants. Yeast plays a crucial role in pore formation. Yeast absorbs dust and CO₂. Porous bricks were prepared and analyzed using various techniques. Their high load-bearing capacity demonstrated superior strength. Porous bricks absorbed 2.5 percent dust and 36 percent water. CFA bricks have a strength of 17.5 MPa. Additionally, yeasts reduced CFA toxicity and facilitated crack repair.

Dao *et al.* [23] examined the bond performance of reinforced fly ash-based geopolymer concrete using experiments and numerical analysis. This research involved three mixture proportions and reinforcement diameters. Results showed that the bond strength of reinforced fly ash-based geopolymer concrete increases with compressive strength, with a concrete cover-to-diameter ratio increasing from 4.86 to 5.75. The bond stress-slip curves from ABAQUS software closely match the experimental results. Parametric analyses also showed that the bond strength of reinforced fly ash-based geopolymer concrete increases with compressive strength.

Lawande *et al.* [24] found the use of coconut shell ash in concrete construction to save natural sand for sustainable development. The study compares the compressive strength of concrete with different percentages of coconut shell ash, PPC, and PSC over 7 days and 28 days. Results show that increasing the replacement percentage decreases the concrete's compressive strength, highlighting the need for sustainable materials and environmental concerns in the construction industry.

Janani *et al.* [25] explored the use of CS as a coarse aggregate in low-cost housing using light weight concrete. CS is a high-potential material due to its strength, modulus, and weather resistance. It is a biodegradable and naturally available material, making it an economical choice for construction. The study reviews the mechanical properties, durability, and elasticity modulus of concrete with CS as a coarse aggregate, highlighting its potential for low-cost housing and reducing the depletion of available raw materials.

3 Materials and Method

3.1 Design Mix Standard

M20 concrete is a standard grade of concrete widely used in residential and commercial construction. As per IS 456:2000, it refers to concrete with a characteristic compressive strength of 20 MPa after 28 days of curing. The mix design can be done either by the nominal mix method (1:1.5:3) or by design mix based on laboratory testing and field conditions. In this design mix example, the concrete constituents have been proportioned using the guidelines of IS 10262:2019, targeting optimum strength, workability, and durability. The sample of mix design is prepared using M20 grade concrete to attain medium workability according to I.S. 10262:2019 [26] with a water-cement ratio of 0.45. The mix ratio 1:1:42:3.047 and Final Mix Proportions per Cubic Meter (as presented in Table 7) is applied according to standard BIS: 456-2000 [27]. The methods for physical and chemical tests are conducted under the rule of the BIS:4032-1985 [28]. The physical and chemical requirements for ordinary Portland cement (OPC) and its manufacturing specifications are covered under the code BIS:269-2015 [29]. The requirements for aggregates, crushed or uncrushed, obtained from natural sources such as riverbeds, gravels, rocks, and boulders for use in the production of concrete cover under the standard BIS:383-1970 [30].

Code References

- I. **IS 456:2000** – Plain and Reinforced Concrete – Code of Practice.
- II. **IS 10262:2019** – Concrete Mix Proportioning – Guidelines.
- III. **IS 383:2016** – Coarse and Fine Aggregate Specifications.
- IV. **BIS:4032-1985** – Method of chemical analysis of hydraulic cement.
- V. **BIS:269-2015** – ordinary Portland cement.

Table 1- Properties and parameters of CA, CS, FA, CSFA

S.No.	Test Parameters	Apparatus	Test Procedure	Specification as per IS-383-2016	CA	CSCA	FA	CSFA
1.	Sieve Analysis	IS Sieves 80 mm to 75 μ m, Balance	IS-2386 -1963 (Part-I)		Min 25 mm, 4.75 Max	Min 25 mm, 4.75 Max	Zone IV	Zone II
2.	Fineness Modulus	IS Sieves 75 μ m, Balance	IS-2386 (Part-I)-1963	Fine aggregate Pass IS Sieve-4.75 mm, Coarse aggregate retain IS sieve-4.75 mm	2.75	2.6	2.55	2.62
3.	Shape		IS-2386 (Part-I)-1963		Round, Angular	Irregular, Flack	Rounded	Cubical
4.	Elongation Index	IS Sieves, Balance, Metal gauge	IS-2386 (Part-I)-1963	40% Max	20.50	38.70		
5.	Flakiness Index	IS Sieves, Balance, Metal gauge	IS-2386 (Part-I)-1963	40% Max	20.50	38.63		
6.	Silt Content	Rotating the jar, 1000 ml measuring cylinder, rotating jar, oven, balance	IS-2386 1963 (Part-II)-	Not Exceed 8%	2.5%	3.8%	5.5%	6.5%
7.	Bulk Density	Balance, Cylindrical Metal measure, Tamping rod	IS-2386 1963 (Part-III)-		2540	1350	2630	1660
8.	Void ratio	Balance, Cylindrical Metal measure, Tamping rod	IS-2386 1963 (Part-III)-	Fine Aggregate 40% Coarse Aggregate 45%	30%	32%	35%	34%
9.	Bulking	Sand 6 mm dia. Stell rod, 250 ml measuring cylinder, scale	IS-2386 1963 (Part-III)-	Max 4.6%	4.0%	4.5%	4.2%	4.8%
10.	Specific Gravity	Balance, Oven, wire basket, watertight container, airtight container, Cloth	IS-2386 1963 (Part-III)-	Not more than 3.2	2.78	1.15	2.65	1.08
11.	Moisture Content %	Balance, Flask	IS-2386 1963 (Part-III)-		0.10%	4.5%	2.6%	6.8%
12.	Water Absorption %	Balance, Oven, wire basket, watertight container, airtight container, Cloth	IS-2386 1963 (Part-III)-	Fine Aggregate-1% Coarse Aggregate-0.50%	0.15%	24%	0.70%	22.0%
13.	Cursing Value %	Tamping rod, Balance, IS Sieves, A 15 cm diameter open-ended steel cylinder, compression testing machine	IS-2386 1963 (Part-IV) -	Not exceed 45%	40.50%	4.25%		
14.	Impact Value%	Cylindrical steel cup, IS Sieves, cylindrical metal measure, hammer, Tamping Rod, Balance, Oven, Impact testing machine	IS-2386 1963 (Part-IV)-	Not exceed 45%	19.60%	7.80%		
15.	Abrasion test	Los Angeles machine, IS Sieves	IS-2386 1963 (Part-IV)-	30 percent	11.10%	1.90%		
16.	Soundness	IS Sieves, Containers, Temperature Regulation, Balance, Drying Oven	IS-2386 1963 (Part-V)-	For fine aggregate-10% for Na_2SO_4 , 15% for MgSO_4 for coarse aggregate-12% for Na_2SO_4 , 18% for MgSO_4	Na_2SO_4 -0.45%, MgSO_4 -0.55%	Na_2SO_4 -4.48%, MgSO_4 -6.55%	Na_2SO_4 -1.15%, MgSO_4 -1.17%	Na_2SO_4 -7.54%, MgSO_4 -8.35%

The sieve analysis for aggregate and particle size and shape covers according to the standard BIS:2386 (Parts I)-1963 [31], the organic impurities in aggregate are analyzed and classified according to the standard BIS:2386 (Parts II)-1963 [32], the specific gravity, density, voids, water absorption, and bulking of aggregate are specified according to the standard BIS:2386 (Parts III)-1963 [33], and finally the impact, abrasion, and crushing value of the aggregate are specified according to the standard BIS:2386 (Parts IV)-1963 [34].

Materials

The Figure 1 represents the overall methodological process of this research work. The OPC 43-grade, fine and coarse aggregate and coconut shells (CSs) used in this research were collected for this research, and CSs specially collected from various temples and homes in Bhopal city as presented in Figure 2. The coconut shells were crushed (as presented in Figure 3) to prepare CSFA and CSCA. Using the sieving method, the CSFA and CSCA were separated. Further, the crushed coconut shells were burned (as presented in Figure 4) to prepare the coconut shell ash (CSA).

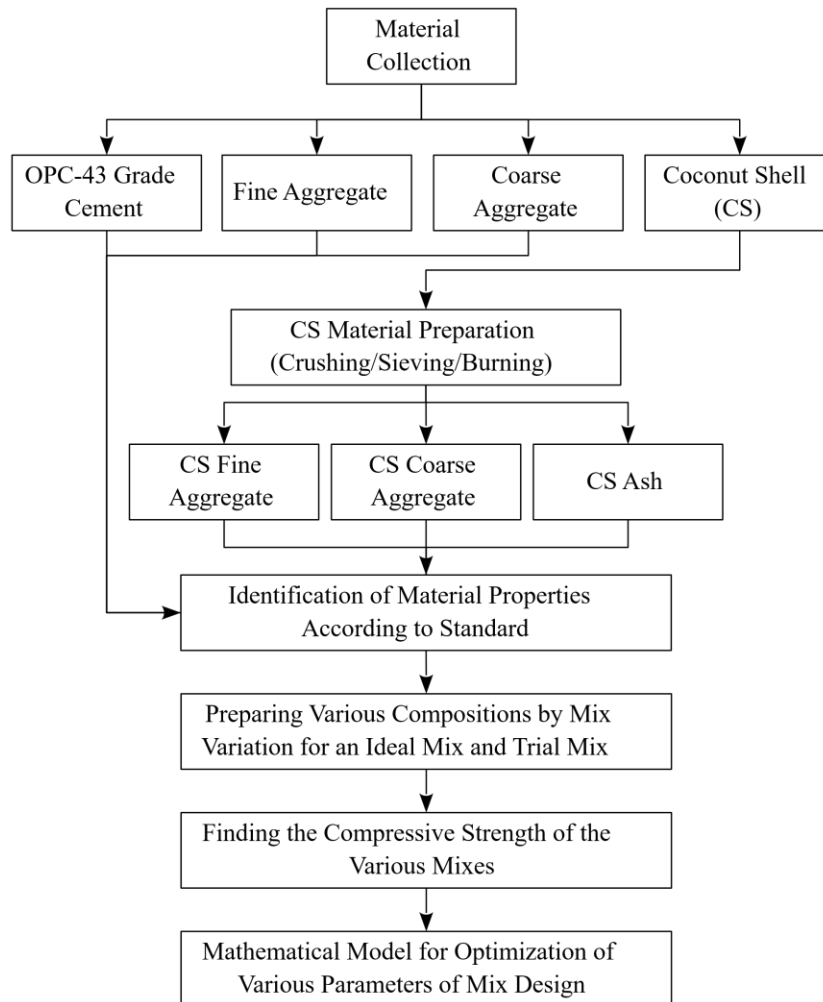


Fig. 1- Methodology



Fig. 2 - Collections of Coconut Shells

Table 2- Chemical composition test results for OPC-43-grade

S.No.	Test Procedure	Compound	Chemical Formula	Standard Requirement IS 269:2015 (OPC-43 Grade)	Cement OPC-43 Grade (%)
1.	IS:4032-1985	Chloride content	-	0.1% Max	0.027
2.	—	Ratio of % Of Al_2O_3 that Fe_2O_3	-	0.66 % Min	0.332
3.	—	Ratio of Percent-Age of lime SiO_2 , Al_2O_3 & Fe_2O_3	-	Ratio % of CaO % of SiO_2 , Al_2O_3 , $Fe_2O_3/(2.8SiO_2 + 1.2Al_2O_3 + 0.65Fe_2O_3)$ (Limit + 0.66-1.02 %)	0.991
4.	IS:4032-1985	Insoluble residue	IR	5% Max.	3.350
5.	IS:4032-1985	Magnesium Oxide	Mgo	6% Max.	4.320
6.	IS:4032-1985	Loss on Ignition	LIO	5% Max.	1.760
7.	IS:4032-1985	Sulfuric Anhydride	SO ₃	3.5% Max.	0.790
8.	IS:4032-1985	Calcium oxide	CaO	60 – 67 %	62.50
9.	IS:4032-1985	Aluminium oxide	Al_2O_3	3 – 8 %	4.52
10.	IS:4032-1985	Silicon dioxide	SiO_2	17 – 25 %	19.15
11.	IS:4032-1985	Iron (II) oxide	FeO_3	0.5 – 6 %	3.46

**Fig. 3 - Crushed Coconut Shells**



Fig. 4 - Preparation of Coconut Shell Ash

The Figure 5 represents the prepared CSFA and CSCA and further identifies the properties of the used materials for research according to the standard. Figure 6 represents the sample preparation by filling the prepared concrete materials into moulds. Figure 7 represents the continuous curing process up to 28 days. Figure 8 represents the performance of the compressive strength test for this research work.



Fig. 5 - Prepared Fine Aggregate, Coconut Shell Fine Aggregate, Coarse Aggregate, and Coconut Shell Coarse Aggregate



Fig. 6 - Sample Preparation (Mould Filing)



Fig. 7 - Curing of the Sample



Fig. 8 - Compressive Strength Test Performance

3.2 Slump Analysis

As illustrated in Fig. 13, the obtained decrease in slump in the mix design as compared to the ordinary mix due to factors that influence the workability of fresh concrete. The main factor is the potential increase in the void ratio. It typically indicates a lower packing density of the CSA, CSFA and CSCA resulting in some volume of voids within the mix. Some void ratio may increase due to the internal friction between particles. The changes in aggregate grading, particle shape and surface texture, or variations in admixture dosage may also affect slump. In future, by addressing these issues, the overall performance and reliability of concrete can be enhanced in various applications. Future research can be conducted into the aggregate shape and size at nano scale or characteristics, mix design parameters, and paste content to better understand the root causes of the slump reduction and ensure consistent workability in future mix designs.

Table 3- Chemical composition test results for coconut shell ash

S.No.	Test Procedure	Compound	Chemical Formula	Standard Requirement IS 269:2015 (OPC-43 Grade)	CSA (%)
1.	IS:4032-1985	Chloride Content	-	0.1% Max.	1.22
2.	–	Ratio of % of Al_2O_3 that Fe_2O_3	-	0.66 % Min	21.95
3.	–	Ratio of Percent-age of lime SiO_2 , Al_2O_3 & FeO_3	-	Ratio % of CaO % of SiO_2 , Al_2O_3 , $\text{Fe}_2\text{O}_3/(2.8\text{SiO}_2 + 1.2\text{Al}_2\text{O}_3 + 0.65\text{Fe}_2\text{O}_3)$ (Limit + 0.66-1.02 %)	0.27
4.	IS:4032-1985	Insoluble residue	IR	5% Max.	8.67
5.	IS:4032-1985	Magnesium oxide	Mgo	6% Max.	0.193
6.	IS:4032-1985	Loss on Ignition	LIO	5% Max.	0.087
7.	IS:4032-1985	Sulfuric anhydride	SO_3	3.5% Max.	2.95
8.	IS:4032-1985	Calcium oxide	Cao	60 – 67 %	6.76
9.	IS:4032-1985	Aluminium oxide	Al_2O_3	3 – 8%	3.40
10.	IS:4032-1985	Silicon dioxide	SiO_2	17 – 25 %	4.46
11.	IS:4032-1985	Iron (II) oxide	FeO_3	0.5 – 6 %	1.32

Table 4- Natural sand: (fine aggregate) sieve analysis

IS Sieve Size	Weight of Sample Retained (gm)	Retained Weight %	Cumulative Retained Weight %	Cumulative Weight Passing (%)
10 mm	0	0	0	100
4.75 mm	0	0	0	100
2.36 mm	50	0.50	0.50	99.5
1.18 mm	16	1.60	2.10	97.90
600 μm	97	9.70	11.80	88.20
300 μm	532	53.20	64.80	35.20
150 μm	260	26.00	90.80	9.20

Table 5- Artificial sand: (CSFA) sieve analysis

IS Sieve Size	Weight of Sample Retained (gm)	Retained Weight %	Cumulative Retained Weight %	Cumulative Weight Passing (%)
10 mm	0	0	0	100
4.75	10	0	0	100
2.36	19	1.90	1.90	98.00
1.18	295	29.50	31.40	68.00
600 μm	219	21.50	52.90	47.10
300 μm	197	19.70	72.60	27.40
150 μm	146	14.60	87.20	10.80

Table 6- Coarse aggregate (CA) sieve analysis

IS Sieve Size	Weight of Sample Retained (gm)	Retained Weight %	Cumulative Retained Weight %	Cumulative Weight Passing (%)
25 mm	35	53	1.43	98.53
20 mm	356	409	11.05	88.95
10 mm	3274	3683	99.54	0.46
4.75	7	3690	99.72	0.28
Pan	6	0	100	0

Table 7 Final Mix Proportions per Cubic Meter

Material	Mix Ratio	Material Quantity per 1M ³	Units
Cement	1	420	kg
Fine Aggregate	1.42	602	kg
Coarse Aggregate	3.047	1282	kg
Water	0.45	189.35	Liters

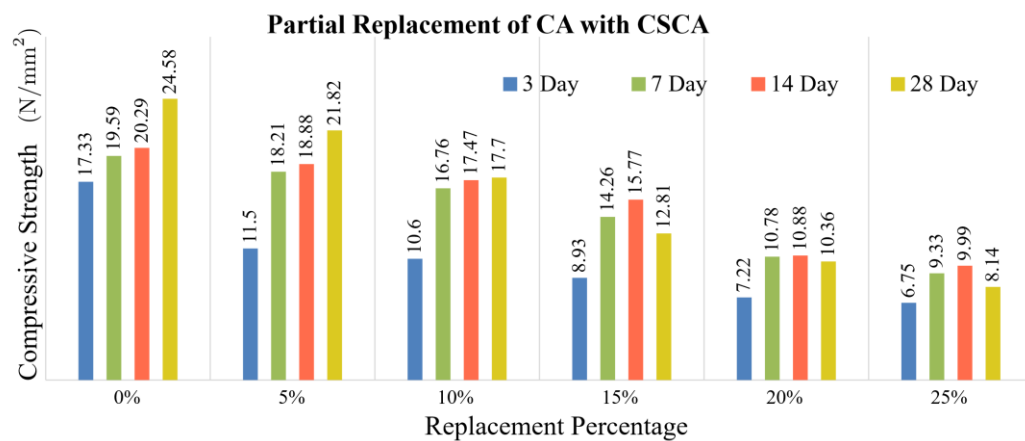


Fig.9 - Compressive Strength Test Result (Partial Replacement of CA with CSCA)

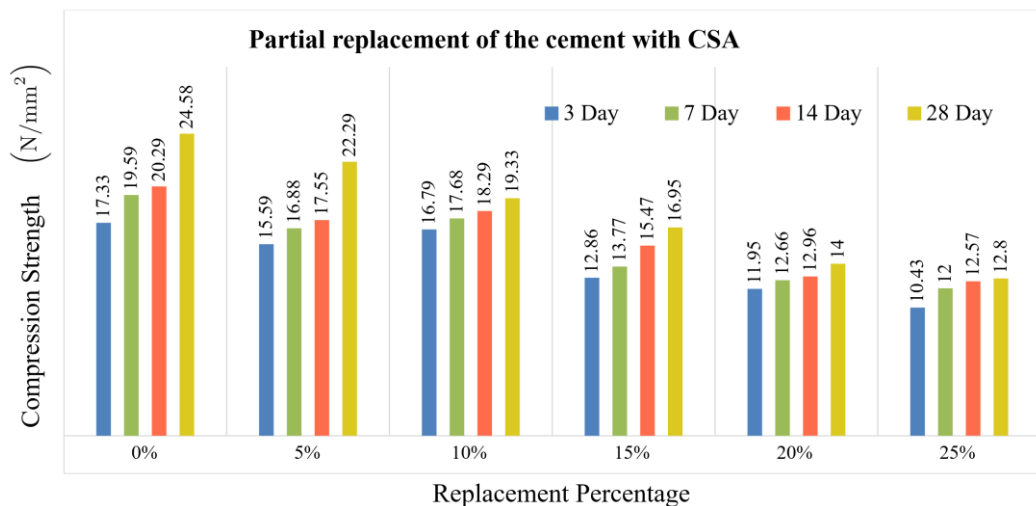


Fig. 10 - Compressive Strength Test Result (Replacement of Cement with CSA)

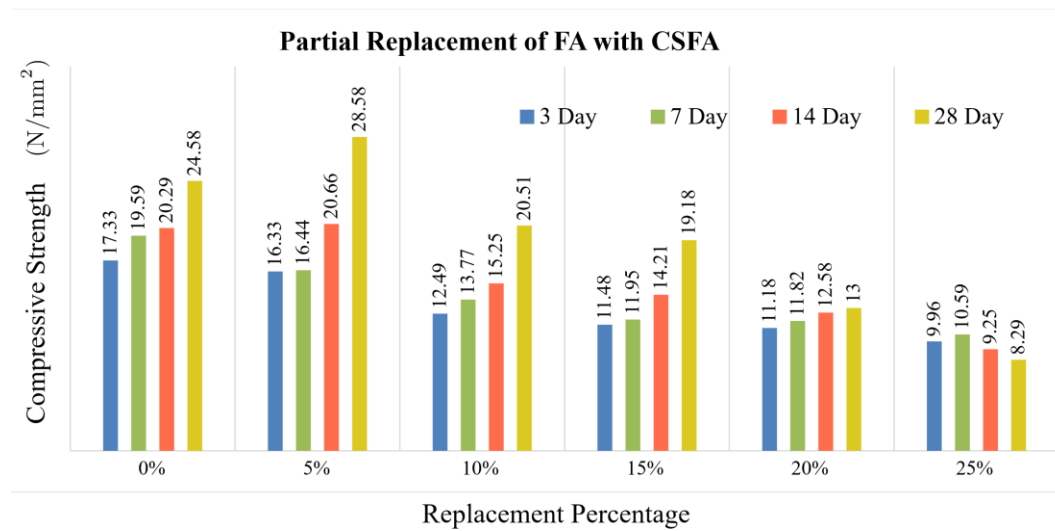


Fig. 11 - Compressive Strength Test Result (Replacement of FA with CSFA)

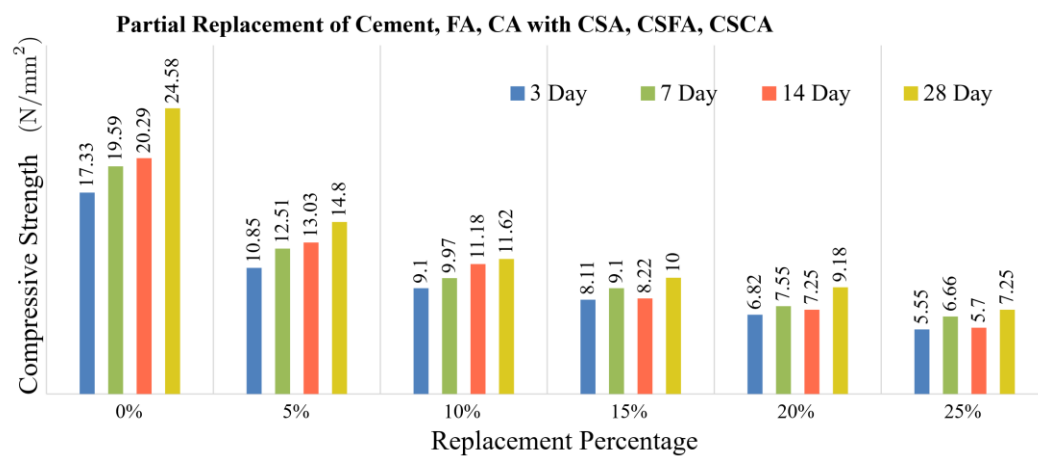


Fig. 12 - Compressive Strength Test Result (Replacement of Cement, FA, CA with CSA, CSFA, CSCA)

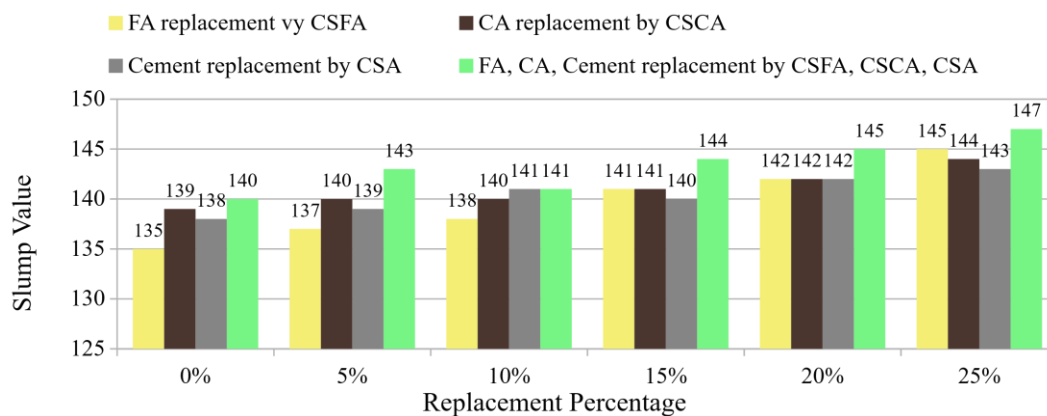


Fig. 13 - Slump Value

Table 8- Partial replacement of fa by CSFA and compressive strength test result

Trial	Cement %	FA %	CA %	CSFA %	Compressive Strength Test Result (Sample 1,2,3)			
					3 Days	7 Days	14 Days	28 Days
T_0	100	100	100	0	17.33	19.59	20.29	24.58
T_1	100	95	100	5	16.33	16.44	20.66	28.58
T_2	100	90	100	10	12.49	13.77	15.25	20.51
T_3	100	85	100	15	11.48	11.95	14.21	19.18
T_4	100	80	100	20	11.18	11.86	12.58	13.00
T_5	100	75	100	25	9.96	10.59	9.25	8.29

Table 9- Replace of fa with CSFA by weight (3 samples in kg)

Replacement %	Cement	FA	CSFA	CA	Compressive Strength Test Result After 28 Days
0	18	25.56	0	54.846	24.58
5	18	24.282	1.278	54.846	28.58
10	18	23.004	2.556	54.846	20.51
15	18	21.726	3.834	54.846	19.18
20	18	20.448	5.112	54.846	13
25	18	19.17	6.39	54.846	8.29
Total	108	134.19	19.17	329.076	–

Table 10- Partial replacement of cement with CSA and compressive strength test result

Trial	Cement %	FA %	CA %	CSFA %	Compressive Strength Test Result Sample (1, 2, 3)			
					3 Days	7 Days	14 Days	28 Days
T_0	100	0	100	100	17.33	19.59	20.29	24.58
T_1	95	5	100	100	15.59	16.88	17.55	22.29
T_2	90	10	100	1	16.79	17.52	18.29	19.33
T_3	85	15	100	1	12.86	14.29	15.47	16.95
T_4	80	20	100	1	11.95	12.66	12.96	14.00
T_5	75	25	100	1	10.43	11.25	12.57	12.80

Table 11- Replace of cement with CSA by weight (3 samples in kg)

Replacement %	Cement	FA	CA	CSCA	Compressive Strength Test Result After 28 Days
0	18	0	25.56	54.846	24.58
5	17.1	0.9	25.56	54.846	22.29
10	16.2	1.8	25.56	54.846	19.33
15	15.3	2.7	25.56	54.846	16.95
20	14.4	3.6	25.56	54.846	14
25	13.5	4.5	25.56	54.846	12.8
Total	94.5	13.5	153.36	329.076	-

Table 12- Partial replacement of ca with CSCA and compressive strength test result

Trial	Cement %	FA %	CA %	CSFA %	Compressive Strength Test Result (Sample 1, 2, 3)			
					3 Days	7 Days	14 Days	28 Days
T ₀	100	100	100	0	17.33	19.59	20.29	24.58
T ₁	100	100	95	5	11.50	18.21	18.88	21.92
T ₂	100	100	90	10	10.60	16.76	17.47	17.70
T ₃	100	100	85	15	8.93	14.26	15.77	12.81
T ₄	100	100	80	20	7.22	10.78	10.88	10.36
T ₅	100	100	75	25	6.75	9.33	9.99	8.14

Table 13- Replace of ca with CSCA by weight (3 samples in kg)

Replacement %	Cement	FA	CSFA	CA	Compressive Strength Test Result After 28 Days
0	18	25.56	54.846	0	24.58
5	18	25.56	52.092	2.736	21.92
10	18	25.56	49.356	5.472	17.7
15	18	25.56	46.602	8.208	12.81
20	18	25.56	43.866	10.944	10.36
25	18	25.56	41.13	13.68	8.14
Total	108	153.36	287.892	41.04	-

Table 14- Partial replacement of all three ingredients in concrete, like cement in CSA, FA is replaced with CSFA and CA is replaced with CSCA.

Trial	Cement %	CSA %	FA %	CA %	CSFA %	CSCA %	Compressive Strength Test Result Sample (1, 2, 3)			
							3 Days	7 Days	14 Days	28 Days
T ₀	100	0	100	100	0	0	17.33	19.59	20.29	24.58
T ₁	95	5	95	95	5	5	10.85	12.51	13.03	14.80
T ₂	90	10	90	90	10	10	09.10	09.97	11.18	11.62
T ₃	85	15	85	85	15	15	8.11	9.10	8.22	10.00
T ₄	80	20	80	80	20	20	6.82	7.55	7.25	9.18
T ₅	75	25	75	75	25	25	5.55	6.66	5.70	7.25

Table 15- Replace of all three ingredients cement with CSA, FA with CSFA and CA with CSCA by weight (3 samples in kg)

Replacement %	Cement	CSA	FA	CSFA	CA	CSCA	Compressive Strength Test Result After 28 Days
0	18	0	25.56	0	54.846	0	24.58
5	17.1	0.9	24.282	1.278	52.092	2.736	14.8
10	16.2	1.8	23.004	2.556	49.356	5.472	11.62
15	15.3	2.7	21.726	3.834	46.602	8.208	10
20	14.4	3.6	20.448	5.112	43.866	10.944	9.18
25	13.5	4.5	19.17	6.39	41.13	13.68	7.25
Total	94.5	13.5	134.19	19.17	287.892	41.04	-

Table 16- Regression analysis

S.No.	Cement	CSA	FA	CSFA	CA	CSCA	Compressive Strength Test Result After 28 Days
1	1.5	0	2.13	0	4.5705	0	24.58
2	1.425	0.075	2.0235	0.1065	4.341	0.228	14.8
3	1.275	0.225	1.8105	0.3195	3.8835	0.684	10
4	1.2	0.3	1.704	0.426	3.6555	0.912	9.18
5	1.5	0	2.13	4.5705	0	0	24.58
6	1.425	0.075	2.13	0	4.5705	0	22.29
7	1.275	0.225	2.13	0	4.5705	0	16.95
8	1.2	0.3	2.13	0	4.5705	0	14
9	1.5	2.13	0	0	4.5705	0	24.58
10	1.5	2.0235	0.1065	0	0	4.5705	22.58
11	1.5	1.8105	0.3195	0	0	4.5705	19.18
12	1.5	1.704	0.426	0	0	4.5705	13
13	1.5	2.13	0	0	4.5705	0	24.58
14	1.5	2.13	0	0	4.341	0.228	21.92
15	1.5	2.13	0	0	3.8835	0.684	12.81
16	1.5	2.13	0	0	3.6555	0.912	10.36

Table 17- Multiple regression analysis

S.No.	Cement	CSA	FA	CSFA	CA	CSCA	Compressive Strength Test Result After 28 Days
1	1.35	0.15	1.917	0.213	4.113	0.456	14.62
2	1.125	0.375	1.5975	0.5325	3.4275	1.14	7.25
3	1.35	0.15	2.13	0	4.5705	0	19.33
4	1.125	0.375	2.13	0	4.5705	0	12.8
5	1.5	1.917	0.213	0	0	4.5705	20.51
6	1.5	1.5975	0.5325	0	0	4.5705	18.29
7	1.5	2.13	0	0	4.113	0.456	17.7
8	1.5	2.13	0	0	3.4275	1.14	8.14

4 Material Property Test Result

The following steps are taken for the utilization of coconut in concrete: In this investigation, the materials used were OPC (43-Grade), CSA, FA, CSFA, CSCA, Water, and Temple. Waste coconut shell was used as a partial replacement of fine aggregate and coarse aggregate, and coconut shell ash as a partial replacement of OPC cement. Details of the used materials are provided in the following section. Cement: Use OPC (43-Grade). The cement test was carried out according to IS 4032-1985 and Standard Requirement IS 263:2015 (OPC-43 Grade). The chemical composition test results are presented in Table II. Coconut Shell Ash: The coconut shell ash was used as a partial replacement for OPC 43-Grade Cement, so the test was carried out according to IS 4032-1985 Standard Requirement IS 263:2015 (OPC 43-Grade). This ash is due to its low cellulose content and low moisture absorption.

FA: Locally available river sand is made from erosion processes. The weight of the sample is 1000 gm. Test producer Recommendation of IS 383:1970 Sieve analysis for the natural sand conforming to Zone IV was used as FA in this work. The FA sieve analysis is presented in Table IV, and the test results for its properties are presented in Table I.

CSFA: It is processed by a mechanical crushing machine. Crushing the CS to the desired size. Use as a FA with a particle size of less than 4.75 mm. After the crushing sieving of the material, sieve analysis is presented in Table V, and sieve analysis for the artificial sand conforming to Zone II and the test results for its properties are presented in Table I.

CA: CA are granular materials that are composed of geological materials such as gravel and crushed stone. This gives volume, stability, resistance, wear, or erosion. The minimum size of CA is 4.75 mm, and the maximum size is 25 mm. It uses the durability and strength of concrete. The main function of CA is to reduce the production cost of concrete. The weight of the sample is 3700 gm, and sieve analysis tests of M20-grade concrete are presented in Table VI. Its properties and parameters are presented in Table I.

CSCA: CSCA is used for the partial replacement of CA. It is an agricultural or temple waste material. The cost of using it in concrete material is reduced because it is a low-cost material. Crushed coconut shell is a lightweight material. The minimum size of crushed coconut shell is 4.75 mm, and the maximum size is 25 mm. Its properties and parameters are presented in Table I.

Physical Test: The physical property tests performed for CA, CSCA, FA, and CSFA are presented in Table I.

To reduce the errors, we have created three models for each sample. Then the results of all three were analyzed and their average was calculated.

4.1 Result Analysis

In this research, different concrete ingredients (cement, CA, and FA) were partially replaced with CSA, CSCA, and CSFA according to their size, compatibility, and standard, with the percentage of replacement as 0, 5, 10, 15, 20, and 25. The concrete cube samples ($150 \times 150 \times 150$ mm³) are made by mixing all the ingredients, and compressive strength is analyzed after the 3rd, 7th, 14th, and 28th days. The cubes achieve their 99.99% strength after 28 days.

Without any replacement (control mix), the compressive strength test result after 28 days is 24.58 MPa; at 5%, it is 22.29 MPa, and at 10%, it is 19.33 MPa, which becomes 12.80 MPa at 25% replacement if cement was partially replaced with CSA (as presented in Figure 10 and Table 10), and Table 11 represents the quantity of the materials in kg.

Similarly, FA was replaced with CSFA, and the compressive strength test results after 28 days, then at 5% replacement, its result is 28.58 MPa; at 10% replacement, it comes to 20.51 MPa, whereas at 25% replacement, it comes to 8.29 MPa (as presented in Figure 11 and Table 8), and Table 9 represents the quantity of the materials in kg.

Similarly, if CA is replaced with CSCA, then at 5%, the result is 21.92 MPa; at 10%, the result is 17.70 MPa; and at 25% replacement, the result is 8.14 MPa (as presented in Figure 9 and Table 12). and Table 13 represents the quantity of the materials in kg.

If all three materials together are replaced in the ratio of 5, 10, 15, 20, and 25%, then after 28 days the compressive strength result is 14.80 MPa at 5%, 11.62 MPa at 10%, and 7.25 MPa at 25% (as presented in Figure 12 and Table 14), and Table 15 represents the quantity of the materials in kg. Finally, the considerable slump value was found in this experimental work as presented in Figure 13.

4.2 Correlation and Regression

Correlation and regression are used as statistical tools to analyze results of mechanical (compressive strength) and durability properties of green concrete and the analyzed results discussed in statistical terms with relevance to civil engineering research on Natural waste concrete.

Regression analysis was performed on the available data in order to find out relation Approximately 70% data is used for training and 30% for testing data. Consider compressive strength as independent variable and dependent variable are Cement, FA, CA, CSA, CSFA and CSCA.

Multiple regression equation of y on $x_1, x_2, \dots, x_n$ is

$$y = a_0 + a_1x_1 + a_2x_2 + \dots + a_nx_n + e \quad (1)$$

For linear relationship

$$Y = 4166.50X_1 + 4136.484X_2 + 4135.38X_3 + 4155.353X_4 + 4155.107X_5 + 4153.516X_6 - 34025.6 \quad (2)$$

Where, Y = Compressive Strength of Concrete after 28 days,

X_1 = Cement, X_2 = CSA, X_3 = FA, X_4 = CSFA, X_5 = CS, X_6 = CSCA

Due to less data set we get reseat accuracy of R^2 value 0.87 and NOVA Signific F is 0.001255 this model can accept with reasonable in validation test data of 30% which is not included in training Sample. MSE and RMSE was calculate 2.86 and 1.69 respectively. RMSE error is more than means there other factor are also responsible for the strength of concrete such other ingredient as.

5 Conclusion and Future Work

When we replace cement with coconut shell ash and analyze its compressive strength test result, we find that at 0% replacement, the result is 24.58 MPa, at 10% it is 19.33 MPa, and at 25% it is 12.80 MPa, which shows that the compressive strength can remain good only until the percentage of replacement is 10%. If the replacement is done more than that, the compressive strength result decreases. If we replace FA with CSFA, then at 0% the result is 24.5 MPa, at 5% it is 28.58 MPa, at 10% it is 20.51 MPa, at 15% it is 19.18 MPa, and at 25% it is 8.29 MPa. If we keep the percentage of replacement at 5, then the compressive strength increases up to 14%, which is good for our concrete. If we replace CA with CSCA, we find that after 5% replacement, the compressive strength result is 21.92 MPa, at 10% it is 17.70 MPa, and at 2% it is 8.14 MPa. This leads to the conclusion that the percentage of replacement should be up to 10% only; if the percentage is greater than that, then the compressive strength result will decrease. If we replace all three materials together, then the compressive strength result at 5% comes to 14.80 MPa, at 10% it comes to 11.62 MPa, and at 25% replacement it comes to 7.25 MPa. Thus, it is concluded that all three materials cannot be replaced together because, on replacing all three together, the compressive strength is decreasing drastically.

Appendix A. Liste of abbreviations

CSA: Coconut shell ash

CSFA: Coconut shell fine aggregate

CSCA: Coconut shell coarse aggregate

CCSs: Crushed coconut shells

Al_2O_3 : Aluminium Oxide

CA: Coarse Aggregate

OPC: Ordinary Portland Cement

GEP: Genetic Expression Programming

ANN: Artificial Neural Networks

RSM: Response Surface Methodology

CFA: Coal fly ash

CS: Coconut shell

FA fine aggregate

LOI: Loss on Ignition

MgO: Magnesium Oxide

PCC: Plain Cement Concrete

SiO₂: Silicon Dioxide

SO₃: Sulfuric Anhydride

Fe₂O₃: Iron(III) oxide

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