BEST
BCREC Engineering & Science Transaction
Journal website: www. bcrecjournal.org

INFLUENCE OF WASTE COCONUT SHELLS ON THE STRENGTH CHARACTERISTICS OF ECO-FRIENDLY LIGHT WEIGHT CONCRETE

Chanchal Das[1*], Arijit Kumar Banerji[2], Md. Hamjala Alam[3], Shovan Roy[4], Ayan Singha[5]

[1]Department of Civil Engineering, Dr. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: chanchal.das@bcrec.ac.in

[2]Department of Civil Engineering, Dr. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: arijit.banerji@bcrec.ac.in

[3]Department of Civil Engineering, Dr. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: mdhamjala.alam@bcrec.ac.in

[4]Department of Civil Engineering, Dr. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: shovan.roy@bcrec.ac.in

[5]Department of Civil Engineering, Dr. B. C. Roy Engineering College, Durgapur, West Bengal, India. Email: ayan.singha@bcrec.ac.in

Abstract—This study aims to determine the influence of adding cement, sand, virgin aggregates, and coconut shell to eco-concrete on its mechanical and flexural properties. The research focuses on the density, flexural and compressive strengths of eco-concrete made from coconut shells. Five different mixtures are produced, four containing virgin aggregate and coconut shell as coarse aggregate. In this study, the authors examined M20 grade concrete to investigate the strength characteristics of concrete, including coconut shell as a substitute for virgin coarse aggregates, in various percentages, including 0%, 25%, 50%, 75%, and 100%. This study aims to determine the optimal amount of coconut shell that can be partially substituted in concrete to improve its strength and reduce it by overcoming disposal issues. The experimental results demonstrate that up to 25% by weight of virgin aggregates can be replaced with coconut shells without impacting the strength characteristics of concrete. Using coconut shell as a coarse aggregate in concrete manufacturing not only improves the performance and strength of concrete but also solves the problem of solid waste disposal and contributes to the conservation of natural resources.

Keywords — ***Concrete, coconut shells, virgin aggregate, flexural strength, compressive strength, strength characteristics.***

1. INTRODUCTION

Beyond any other material, concrete is the most commonly utilised construction material in the world. It consists of cement, aggregates, water, and admixtures. About 10 billion tonnes of concrete are generated yearly. Seventy to eighty per cent of the overall volume is aggregate, the majority of which is coarse aggregate, and the remaining is fine aggregate. There are adverse consequences associated with increased concrete production, such as the depletion and environmental imbalance caused by the constant exploitation of aggregates from natural resources [1]. Rapid growth in the construction industries has led to increased demand for natural resources, which are becoming increasingly scarce. Numerous studies [1-5] have attempted to find a coarse aggregate replacement to make concrete more cost-

Corresponding Author: chanchal.das@bcrec.ac.in

effective and promote sustainable development. Over the past few decades, engineers have been investigating new eco-friendly and sustainable materials for construction that can replace conventional ones. Utilising biodegradable waste products can be a viable strategy for decreasing the environmental impact of the routine use of natural raw materials [2]. In addition, this topic has been the subject of intensive research for decades to develop an economically viable construction material. The latest research studies on using coconut shells are a significant attraction.

The shell of the coconut is considered an agricultural byproduct and can be found in all of the world's tropical countries. India generates enormous amounts of scrap from coconut and is utilised in various food processing sectors. Coconuts are grown in India at a rate that makes it the world's third-largest producer. Kerala in southern India and Kolkata in the eastern part are home to many coconut plantations. Also, it has one of the largest populations in India that regularly uses coconuts and items made from coconuts in their daily lives. Because of this, coconut shells can remain on the mainland before natural processes break them down. Because of this, getting rid of these coconut shells poses a significant environmental problem [3].

It is now a concern on a worldwide scale that, in light of the emphasis placed on resource conservation and sustainable development, alternative components of natural resources should be utilised, and the search for a viable alternative for conventional construction materials should continue. It has never been the usual practice to utilise alternative aggregate in concrete, coconut shells. The standards for concrete can be met using a total consisting of coconut shells if the concrete is produced utilising those shells [4]. The aggregate made from coconut shells achieved an acceptable level of strength, which is essential for structural concrete. There is a possibility that coconut shells could be used in the construction industry as a viable construction material. When used as coarse aggregate, coconut shell does not require any pretreatment because it is suitable for employing cement. Concrete that is constructed using coconut shells possesses superior workability. This is due to the smooth surface that is present on one side of the shells. Concrete made from coconut shells has a high resilience to impact. Coconut shell has more potential for absorbing water and retaining moisture than the standard aggregate [5].

Due to its high rigidity and impact strength, using coconut shells as coarse aggregate in concrete results in a significant shift in the techniques used to produce concrete. The strength and modulus qualities of coconut shells are exceptionally high. It also has a high concentration, which is an extra benefit. The high lignin concentration in the composites makes them more resistant to the environment [6]. As a result of its low cellulose content, it has a lower capacity for absorbing moisture compared to other forms of agricultural waste. Coconuts are freely available in nature, and the shells of coconuts do not decompose. Therefore, they are a suitable material for use in concrete. This material has the potential to fulfil practically all of the requirements placed on concrete in its traditional form.

2. OBJECTIVES AND SCOPE

The primary research objective is to develop ecological concrete with unique properties to the typical concrete mixture. This investigation is undertaken by substituting virgin coarse aggregate with coconut shell waste materials. The primary purpose of this study was to examine the strength characteristics of concrete made with coconut shell as a virgin coarse aggregate in M20 grade concrete. According to the IS 10262:2019 standard, coconut shell is substituted for coarse aggregate in M20-grade concrete in varied proportions, including 0%, 25%, 50%, 75%, and 100% by weight. This investigation emphasises the density, flexural and compressive strength behaviour of coconut shells. Five distinct mixtures are constructed, four with crushed coconut shell replacements of 25%, 50%, 75%, and 100% of coarse aggregates, and one with conventional aggregate as coarse aggregate.

3. MATERIAL DESCRIPTION AND METHODOLOGY

Ordinary Portland Cement (OPC), sand as fine aggregate, crushed aggregate and coconut shell as coarse aggregate, all available locally, were the materials employed in this experiment. We used potable water for mixing and curing.

A. Cement

As per IS 12269-2013 [11], ordinary Portland cement of grade 53 was used. Portland types of cement can be categorised and compared based on their physical qualities. Physical property characterisation necessitates the development of physical tests that adequately characterise essential parameters, such as setting time, soundness, fineness, and strength. Table 1 details the physical characteristics of cement.

Table 1 – Physical Properties of Cement

Property	Results
Grade	53
Type	OPC
Colour	Grey
Specific gravity	3.01
Fineness	305 m^2/kg
Soundness	1 mm
Final setting time	620 min
Initial setting time	30 min
Consistency	26 %

B. Sand

The fine aggregate was Zone-III sand compliant with the standards of IS 383-1970 [12]. Before being combined, the sand was air-dried and screened to remove any contaminants. The sand is found naturally in the area and is fine enough to filter through a 4.75 mm IS sieve. The fine aggregate had a specific gravity of 2.60. River sand is readily available in the area and complies with grading zone I of IS 383-1970 [12]. Locally accessible clean and dry river sand will be used. All specimens will be cast in the sand that has been sieved using an IS 4.75mm sieve. The fine aggregate should have a rounded form to improve workability and reduce costs by requiring less cement. The fine aggregate is used to fill the spaces left by the coarse aggregate and to improve the material's workability.

C. Virgin Aggregates (VA)

It is reasonable to expect that the aggregates, which typically account for 70–80 per cent of the concrete volume, will significantly impact the material's characteristics. Table 2 describes the properties of virgin coarse aggregates and sand used for this study.

Table 2 – Physical Properties of Virgin Coarse Aggregates and Sand

Property	Results (VA)	Results (Sand)
Impact test	12.5	-
Water absorption	1.1	4.05
Specific gravity	2.75	2.60
Fineness modulus	7.12	2.29
Bulk density (kg/m^3)	1550	1700

D. Coconut Shell (CS)

The coconut shells are acquired from a coconut garden that is located nearby. They are first manually crushed after being sun-dried in the open air. Depending on the genetic variety and the stage of maturation of the nut when it is harvested, there is a broad range of variations in the size, weight, shape, and colour of coconuts. Between 5 and 20 millimetres is where the particle sizes of the coconut shell fall. On the concave faces of the shell, the surface texture was relatively smooth, but on the convex faces, it was rough. Because fewer cavities can be developed when concrete is allowed to absorb water, the concrete's strength will not be negatively impacted by this process [7,8]. Compared to other types of aggregate, the capacity of coconut shells to both retain moisture and absorb water is significantly higher. When developing the mix design for M20 grade concrete following the IS 10262:2019 regulation [10], water absorption and the specific gravity requirement of CS are considered. The characteristics of the crushed coconut shell used for this study are shown in Table 3, and Figure 1 displays the crushed CS used for the study.

Figure 1 – Crushed Coconut Shell

Table 3 – Physical Properties of Coconut Shell

Property	Results
Impact test	8.4

Water absorption	1.95
Specific gravity	1.27
Fineness modulus	5.04
Bulk density (kg/m³)	652

E. Water

According to the IS 456:2000 standard [13], the water that is used to prepare the concrete mix and for curing needs to be pure and devoid of any potentially harmful pollutants. To prevent corrosion in concrete and reinforcement, the pH of the water being utilised should fall between 6 and 8.

F. Methodology

Figure 2 provides a summary of the methodology used in this study. Following IS 10262:2019 [10], the proportions of all ingredients mentioned in Table 4 are considered when designing mixtures. As stated previously, CS can replace VA in concrete in proportions of 0%, 25%, 50%, 75%, and 100%.

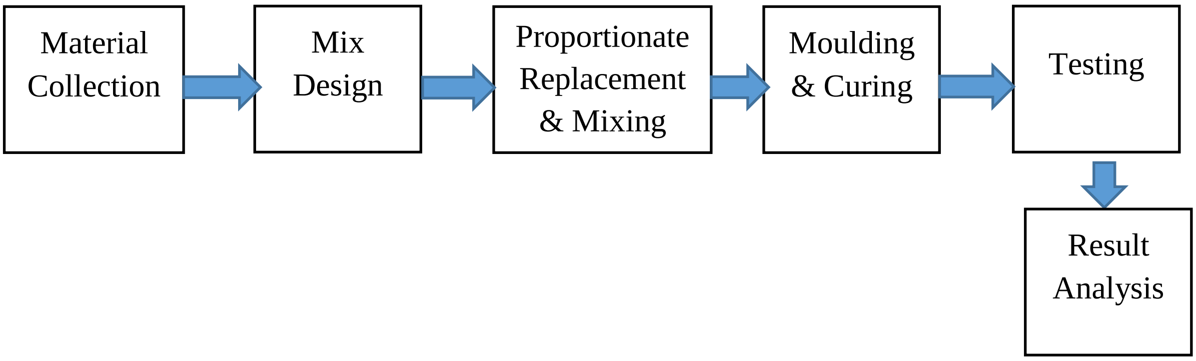

Figure 2 – Research Methodology

Table 4 – Mix Proportions for Coconut Shell Concrete

Designation	Cement	Water	VA	CS	Sand
CSC-0	339	169.5	1020.5	-	564.2
CSC-25			765.38	255.12	
CSC-50			510.25	510.25	
CSC-75			255.13	765.37	
CSC-100			-	1020.5	

Figure 3 – Lab Performance for Strength Test of Coconut Shell Concrete

All the concrete ingredients listed in Table 4 are added to the concrete mixer. The compressive strength is evaluated using 150 mm x 150 mm x 150 mm cube specimens per the IS 516:1959 standard [10]. Similarly, 150 mm x 150 mm x 700 mm beams are used to test flexural strength following IS 516:1959 standard [10]. Figure 3 depicts laboratory specimens for the determination of coconut shell concrete.

4. STRENGTH CHARACTERISATION

A. Compressive Strength

In accordance with IS 516:1959 [10], all specimens are subjected to a compressive strength test after 28 days of curing to evaluate the concrete's strength characteristics. The acquired results for the strength of all mixtures are shown in Table 5. Similarly, Figure 4 illustrates the results of compressive strength tests conducted on all mixtures. For each of the considered mixtures, 150 mm cube specimens were utilised. Figure 4 demonstrates that the compressive strength reaches the characteristic compressive strength until 25% of the VA is replaced by CS (CS-25), after which marginal strength reductions are found for mixes containing 25%

and 50% CS. From the experimental results of this inquiry, it can be determined that the optimal percentage substitution of CS with VA can be accomplished without compromising strength up to 25%.

Table 5 – Compressive Strength Test of Concrete

Mix Designation	Avg. Weight of Cube (kg)	Density (kg/m³)	Peak Load (kN)	Compressive Strngth (MPa)
CSC-0	8.4	2480.59	768.4	34.15
CSC-25	8.26	2447.40	439.8	19.55
CSC-50	7.76	2300.14	220.7	9.80
CSC-75	7.05	2088.88	142	6.31
CSC-100	5.61	1774.54	85.2	3.76

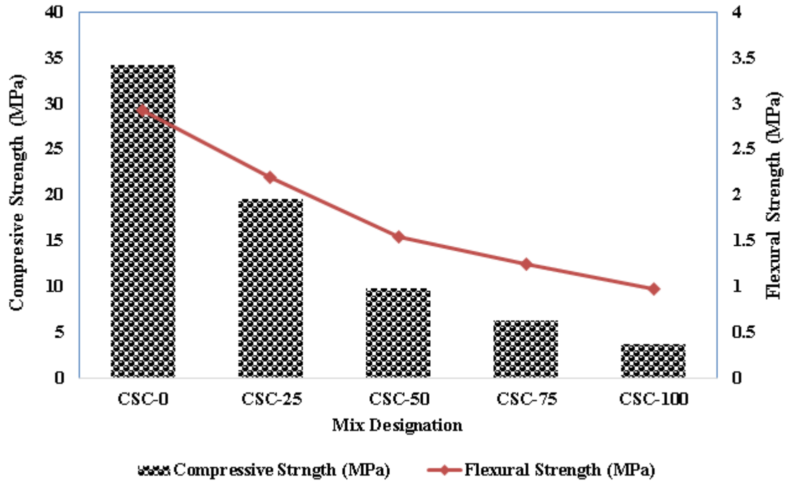

Figure 4 – Stregth Characterization Results of Coconut Shell Concrete

B. Flexural Strength

In accordance with IS 516:1959 [10], a flexural test is performed to evaluate the strength properties of each mixture listed in Table 6 after 28 days of curing. The flexural strength of concrete is evaluated using prisms of 150 mm by 150 mm by 700 mm. Table 6 displays the results for the flexural strength of all five mixtures. Figure 4 illustrates the graphical representation of the flexural strength of each mixture. Figure 5 demonstrates that similar to compressive and flexural strength, as the fraction of CS replaced by VA increases, strength decreases for all mixtures compared to the reference mix CSC-0. Similarly, up to 25% substitution of CS with VA has met the strength requirements for M20 grade concrete. Afterwards, a slight reduction is observed for CSC-25, CSC-75, and CSC-100, which follows the same trend as compressive strength and flexural strength. In order to utilise agricultural waste such as CS as a substitute for VA, up to 25% of the CS can be substituted with CA without affecting the strength properties.

Table 6 – Flexural Strength Test of Concrete

Mix Designation	Peak Load	Flexural

	(kN)	Strength (MPa)
CSC-0	14.01	2.92
CSC-25	10.46	2.20
CSC-50	7.40	1.55
CSC-75	6.16	1.25
CSC-100	4.54	0.97

4. CONCLUSION

Recently, the demand for sustainable or environmentally friendly concrete has increased at an accelerated rate. Many studies have been done to mitigate the harmful effects of the concrete industry. Similarly, this study was undertaken to lessen the impact and improve the concrete quality by adding admixtures. This study studied the density and strength characteristics of concrete produced by volume substitution of 0%, 25%, 50%, 75%, and 100% virgin coarse aggregate with crushed coconut shells. It was discovered that increasing the proportion of coconut shells in concrete decreased its strength and density. Flexure and compression tests were performed, and the findings were deemed suitable. In light of these findings, it is reasonable to assume that the substitution of CS can only be tolerated within a range of 25%. When the partial replacement of CS by CA rises, the density of concrete decreases across the board. It implies that using CS as CA in concrete contributes to reducing concrete's density by making it lighter.

Acknowledgement: The research is based upon the work supported by Dr. B. C. Roy Engineering College, Durgapur.

References

[1] Tangadagi, R. B., Manjunatha, M., Preethi, S., Bharath, A., & Reshma, T. V., “Strength characteristics of concrete using coconut shell as a coarse aggregate–A sustainable approach”, Materials Today: Proceedings, 47, 3845-3851, 2021.

[2] Subramani, T., & Anbuvel, A., “Experimental behaviour of reinforced concrete beams with coconut shell as coarse aggregate”, International Journal of Application or Innovation in Engineering and Management, 5(5), 67-75, 2016.

[3] Kanojia, A., & Jain, S. K., “Performance of coconut shell as coarse aggregate in concrete”, Construction and Building Materials, 140, 150-156, 2017.

[4] Tomar, R., Kishore, K., Parihar, H. S., & Gupta, N., “A comprehensive study of waste coconut shell aggregate as raw material in concrete”, Materials Today: Proceedings, 44, 437-443, 2021.

[5] Kumar, V. P., Gunasekaran, K., & Shyamala, T., “Characterization study on coconut shell concrete with partial replacement of cement by GGBS”, Journal of Building Engineering, 26, 100830, 2019.

[6] Verma, S. K., & Shrivastava, S., “Use of coconut shell as partly substitution of coarse aggregate-An experimental analysis”, In AIP Conference Proceedings (Vol. 2158, No. 1, p. 020021). AIP Publishing LLC, 2019.

[7] Zaid, O., Ahmad, J., Siddique, M. S., Aslam, F., Alabduljabbar, H., & Khedher, K. M., “A step towards sustainable glass fiber reinforced concrete utilizing silica fume and waste coconut shell aggregate”, Scientific Reports, 11(1), 1-14, 2021.

[8] Yerramala, A., & Ramachandrudu, C., “Properties of concrete with coconut shells as aggregate replacement”, International journal of engineering inventions, 1(6), 21-31, 2012.

[9] IS:10262-2019. Indian Standards for Concrete mix proportioning- guidelines, Bureau of Indian Standards, New Delhi, India

[10] IS:516 -1959. Indian Standard Method of Tests for Strength of Concrete, Bureau of Indian Standards, New Dehli.

[11] IS:12269-2013, Indian Standard Specifications for Ordinary Portland Cement - 53 grade (First Revision), Bureau of Indian Standards, New Dehli.

[12] IS:383-1970, Indian Standard Specification for Coarse and Fine Aggregates From Natural Sources for Concrete, Bureau of Indian Standards, New Dehli.

[13] IS:456-2000, Plain and and reinforced concrete- Code of practice, Bureau of Indian Standards, New Dehli.

Chanchal Das is a B.Tech in Civil Engineering from B.I.E.T., Suri and an M.E. in Structural Engineering from Bengal Engineering and Science University, Shibpur. Since January, 2015 he is working as Assistant Professor at Dr. B.C Roy Engineering College, Durgapur, West Bengal. He is having more than ten years of teaching experience. His areas of interests are Structural and Materials Engineering, Geotechnical Engineering and Pavement Design.

Arijit Kumar Banerji is a B.Tech in Civil Engineering from BIET Suri and an M.Tech in Transportation Systems Engineering from IIT Guwahati. Since July, 2014 he is working as Assistant Professor at Dr. B.C Roy Engineering College, Durgapur, West Bengal. He is having more than eight years of teaching experience. His areas of interests are Pavement material characterization, Pavement Design and Finite Element Modelling of pavement.

Md. Hamjala Alam is a B.Tech in Civil Engineering from Narula Institute of Technology, Kolkata and an M.Tech in Environmental Science & Engineering from Indian School of Mines Dhanbad. Since August, 2014 he is working as Assistant Professor in Civil Engineering at Dr. B.C Roy Engineering College, Durgapur, West Bengal. His areas of interests are Water Quality, Air and Noise Pollution and Control, Soil Stabilization, Soil Strength enhancement, Concrete properties and Pavement Design. He is having more than eight years of teaching experience.

Dr. Shovan Roy is a B.Tech in Civil Engineering from Sri Ramdeobaba Kamla Nehru Engineering College and M.Tech in Geotechnical Engineering from North Eastern Regional Institute of Science & Technology (NERIST). Since August 2014 he is working as Assistant Professor at Dr. B. C. Roy Engineering College, Durgapur, West Bengal. His areas of interests are Geotechnical Engineering and Floating Offshore structures.

Ayan Singha is a Diploma in Civil Engineering from K.G Engineering Institute,Bishnupur. Since March, 2013 he is working as a Technical Assistant in Civil Engineering at Dr. B.C Roy Engineering College, Durgapur, West Bengal. His areas of interests are Soil Stabilization, Soil Strength enhancement, Concrete properties and Pavement Design.