

Utilization Of Agricultural Waste Coconut Shell Partial Replacement with Cement and Coarse Aggregate

¹Ms. Shraddha Rajkumar Somwanshi, ²Prof. A.Y. Kankuntla

¹PG Student, Department of Civil Engineering, Pradnya Niketan Education Society, Pune.Nagesh Karajagi
Orchid College of Engineering & Technology Solapur, Maharashtra, 413002

²Assistant Professor, Department of Civil Engineering, Pradnya Niketan Education Society, Pune.Nagesh
Karajagi Orchid College of Engineering & Technology Solapur, Maharashtra, 413002

Abstract

The rapid expansion of the construction industry has intensified the demand for conventional materials such as cement and natural aggregates, leading to environmental concerns including high carbon emissions and resource depletion. Simultaneously, the disposal of agricultural waste like coconut shells poses ecological challenges. This study investigates the feasibility of utilizing coconut shell ash (CSA) as a partial replacement for cement and crushed coconut shell (CSC) as a substitute for coarse aggregate in concrete production. Concrete mixes were prepared with varying replacement levels of 0%, 5%, 10%, and 15%, and tested for workability and compressive strength at curing periods of 7, 14, and 28 days. The results indicate that compressive strength improves with increasing replacement up to 10%, achieving a maximum strength of 31.83 N/mm² at 28 days, which exceeds that of conventional concrete. However, further increase to 15% results in reduced strength due to increased porosity and weaker bonding. Workability was observed to decrease with higher replacement levels. The study concludes that a 10% replacement level offers the best balance between strength and sustainability. The findings highlight the potential of coconut shell-based materials in producing eco-friendly, cost-effective, and sustainable concrete.

Keywords: Coconut Shell Ash (CSA), Coconut Shell Crush (CSC), Sustainable Concrete, Compressive Strength, Lightweight Concrete, Waste Utilization

1. Introduction

Concrete is one of the most widely used construction materials in the world due to its versatility, durability, and ability to be molded into various shapes and sizes. It plays a crucial role in the development of infrastructure such as buildings, bridges, roads, and dams. The demand for concrete has increased significantly with rapid urbanization and population growth, especially in developing countries like India. Its strength, fire resistance, and long service life make it an essential material in both structural and non-structural applications. However, the large-scale production and use of concrete have raised serious environmental concerns. The primary component of concrete, cement, requires high energy consumption during manufacturing, making it a resource-intensive material. Additionally, concrete production relies heavily on natural aggregates such as sand and gravel, which are extracted from the environment in large quantities. This continuous extraction has led to ecological imbalance and depletion of natural resources. Therefore, while concrete remains indispensable in construction, there is an urgent need to address its environmental impact through innovative and sustainable approaches.



Fig.1. Coconut Shell Ash

One of the major environmental challenges associated with concrete production is the emission of carbon dioxide during the manufacturing of cement. The cement industry alone contributes a significant percentage of global CO₂ emissions, which accelerates climate change and global warming. Alongside this, the excessive extraction of natural aggregates from rivers and quarries has led to habitat destruction, soil erosion, and groundwater depletion. Another growing concern is the disposal of agricultural and industrial waste materials, which accumulate in large quantities and create pollution problems. Coconut shells, for instance, are widely generated as agricultural waste in tropical regions and are often discarded or burned, contributing to environmental degradation. These issues highlight the need for alternative materials that can reduce dependency on conventional resources while also addressing waste management challenges. Sustainable construction practices are gaining importance, focusing on the use of eco-friendly materials that minimize environmental impact without compromising the performance of concrete.

In this context, the use of coconut shell ash (CSA) and coconut shell crush (CSC) presents a promising solution for sustainable concrete production. Coconut shell ash, obtained by burning and processing coconut shells, exhibits pozzolanic properties and can be used as a partial replacement for cement. Similarly, crushed coconut shells can serve as a lightweight alternative to conventional coarse aggregates. The incorporation of these materials not only reduces the demand for cement and natural aggregates but also provides an effective way to utilize agricultural waste. This study aims to evaluate the feasibility of using CSA and CSC as partial replacement materials in concrete. The research focuses on analyzing the workability and compressive strength of concrete at different replacement levels of 0%, 5%, 10%, and 15%, tested over curing periods of 7, 14, and 28 days. The ultimate objective is to develop a cost-effective, eco-friendly, and sustainable concrete that meets structural performance requirements.

2. Literature Review

The utilization of waste materials in concrete production has gained significant global attention due to the increasing demand for sustainable and environmentally friendly construction practices. Anviti Bhartiya et al. (2018) highlighted that agricultural and industrial wastes such as coconut shells and eggshells exhibit pozzolanic properties, making them suitable as partial substitutes for cement. Their study on M20 grade concrete with coconut shell ash (CSA) replacement levels of 0%, 5%, 10%, 12%, and 13% demonstrated improved compressive strength at optimal levels after 7 and 28 days of curing. Similarly, Lavanya B.A et al. (2018) investigated the use of coconut shell as a partial replacement for coarse aggregate in M25 grade concrete, with replacement levels ranging from 10% to 40%. Their findings indicated that concrete performance could be maintained with appropriate replacement, although strength gradually decreased at higher percentages. Dr. B. Rajeevan et al. (2018) further explored the feasibility of using coconut shell aggregate and reported that a 15% replacement level yielded compressive strength comparable to conventional concrete. In addition, Thejaswi Prema et al. (2019) emphasized the environmental benefits of reducing cement consumption through CSA, demonstrating that replacement levels up to 20% can effectively lower carbon emissions while maintaining satisfactory strength characteristics.

Further studies have reinforced the potential of coconut shell derivatives as sustainable construction materials. Rajesh Kumar et al. (2020) conducted an experimental investigation using CSA as a cement replacement (0%–25%) and found that 10–15% replacement achieved optimal compressive strength and density suitable for both normal and lightweight concrete. Likewise, Utsev J. T. et al. (2020) reported similar findings, where CSA replacement of 10–15% resulted in improved strength development up to 31.78 N/mm² at 28 days. Lohar Pandurang et al. (2020) discussed the broader advantages of incorporating coconut shell aggregates, particularly in producing lightweight concrete for non-structural applications, while also addressing rising material costs and resource depletion. Furthermore, K. Santhi et al. (2020) examined higher replacement levels (up to 50%) of coconut shell as coarse aggregate and observed that while workability improved, compressive strength decreased beyond 30%, indicating limitations in structural applications. Overall, these studies confirm that coconut shell-based materials can be effectively utilized in concrete, with optimal performance generally observed at replacement levels between 10% and 15%, thereby supporting sustainable construction and efficient waste management practices.

3. Research Method

3.1 Materials Used

The experimental investigation was carried out using conventional concrete materials along with coconut shell-based substitutes. The materials used in this study included cement, coconut shell ash (CSA), coconut shell crush (CSC), coarse aggregate, fine aggregate, and water. Ordinary Portland Cement (OPC) of 53 grade was used as the primary binding material. The concrete mix was designed for M20 grade with a proportion of 1:1.5:3 (cement: fine aggregate: coarse aggregate). Cement acts as a binding agent that hardens over time and binds other materials together through hydration.



Fig.2. OPC Cement

Coconut shell ash was used as a partial replacement for cement. It is an agricultural waste material obtained from burning coconut shells and possesses pozzolanic properties, making it suitable as a supplementary cementitious material. Crushed coconut shell was used as a partial replacement for coarse aggregate. The shells were processed to pass through a 20 mm sieve and retained on a 12.5 mm sieve. Due to their high water absorption capacity, the crushed shells were pre-soaked in water for 24 hours before mixing. Natural coarse aggregates of 20 mm size and fine aggregates passing through a 4.75 mm sieve were used. Clean potable water was utilized for both mixing and curing processes.



Fig.3 Coconut Shell Ash



Fig. 4: Coconut Shell Crush

Table 1: Varying percentage of coconut shell ash and coconut shell crush

Mix	Replacement	Coconut shell ash	Coconut shell crush
M0	0%	0%	0%
M1	10%	5%	5%
M2	20%	10%	10%
M3	30%	15%	15%

3.2 Mix Proportion and Water-Cement Ratio

The concrete mix was designed for M20 grade with a mix ratio of 1:1.5:3. A water-cement ratio of 0.48 was maintained to achieve the desired workability and strength. It is important to control the water content, as excess water can reduce the strength of concrete and lead to segregation, while insufficient water can affect workability. The coconut shell ash and crushed coconut shell were incorporated as partial replacements for cement and coarse aggregate, respectively, at varying percentages.

3.3 Workability Test (Slump Cone Test)

The workability of fresh concrete was determined using the slump cone test. The apparatus consisted of a standard slump cone mould. Before conducting the test, the internal surface of the mould was thoroughly cleaned to remove any moisture or previously adhered concrete. The concrete mix was placed in the mould in layers, compacted properly, and the mould was carefully lifted to measure the slump value. The difference in height between the mould and the subsided concrete indicated the workability of the mix.

3.4 Casting of Specimens

Concrete cube specimens of size 150 mm × 150 mm × 150 mm were prepared for compressive strength testing. The cube moulds were cleaned and oiled before casting to prevent adhesion. The concrete was placed in the moulds in layers and compacted using a tamping rod or vibrating table to eliminate air voids. After 24 hours, the specimens were removed from the moulds and prepared for curing.

3.5 Curing of Specimens

The cast concrete specimens were cured by immersing them in clean water for specified durations of 7, 14, and 28 days. The curing water temperature was maintained at $27^{\circ}\text{C} \pm 2^{\circ}\text{C}$ to ensure proper hydration of cement. Curing is essential for achieving the desired strength and durability of concrete.

3.6 Compressive Strength Testing

The compressive strength of concrete specimens was determined using a compression testing machine. The tests were conducted after curing periods of 7, 14, and 28 days. Each specimen was placed in the testing machine, and load was applied gradually until failure occurred. The maximum load at failure was recorded, and compressive strength was calculated. This test provided an assessment of the mechanical performance of concrete with different replacement levels of coconut shell ash and crushed coconut shell.

4. Result and Discussion

The experimental results present the compressive strength behavior of concrete with varying percentages of coconut shell ash and coconut shell crush at 7, 14, and 28 days, highlighting strength development, performance trends, and the identification of the optimum replacement level.

Replacement Of CSA (%) and CSC In Slump (Mm)

Table 2: Slump Test Result

Replacement of CSA and CSC (%)	Slump (mm)
0	65
5	52
10	45
15	25

Compressive Test Results

Table 3: Compressive Strength Result

PARTIAL REPLACEMENT (%)		COMPRESSION STRENGTH (N/MM2)			C/S AREA (MM2)	AVERAGE WEIGHT OF CUBE (KG)	AVERAGE FAILURE LOAD (KN)	AVERAGE COMPRESSION STRENGTH (N/MM2)
0%	time	C1	C2	C3	(150*150)	-		-
	7 days	15.56	17.41	16.01	22500	8.20	367.3	16.32
	14 days	19.01	18.74	18.66	22500	8.25	423.1	18.80
	28 days	25.11	23.02	23.45	22500	8.29	536.9	23.86
5%	7 days	16.39	15.44	17.27	22500	8.11	368.3	16.36
	14 days	19.21	22.80	19.49	22500	8.30	451.2	20.05
	28 days	25.36	26.66	25.55	22500	8.41	581.1	25.85
10%	7 days	18.00	18.96	19.60	22500	8.12	424.2	18.85
	14 days	24.16	23.11	22.10	22500	8.21	520.3	23.12
	28 days	30.95	30.09	34.45	22500	8.24	716.2	31.83
15%	7 days	11.90	11.69	12.46	22500	8.18	270.4	12.01
	14 days	13.98	14.00	15.50	22500	8.32	326.1	14.49
	28 days	20.11	19.85	20.94	22500	8.45	450.1	20.03

7-Days Strength Analysis

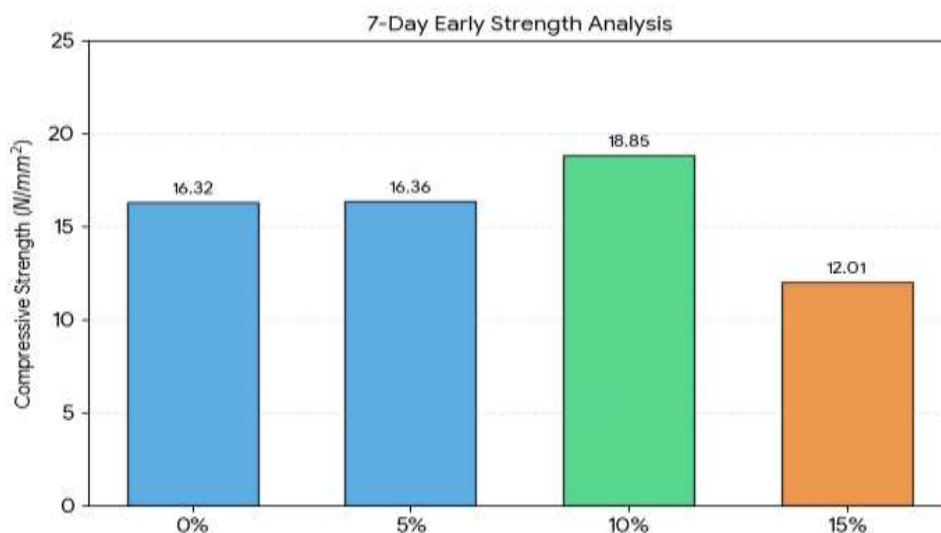


Fig. 5. 7 Days Compressive Strength Analysis

The 7-day compressive strength results reflect the early performance of concrete with coconut shell ash (CSA) and coconut shell crush (CSC). At this stage, concrete generally attains about 65–70% of its final strength. The control mix

(0%) and 5% replacement mix show nearly identical strength values of around 16.3 N/mm², indicating that a small replacement does not significantly affect early strength development. A clear improvement is observed at the 10% replacement level, where the compressive strength reaches 18.85 N/mm², approximately 15% higher than the control mix. This increase is due to the pozzolanic activity of CSA and improved particle packing, which enhances bonding within the concrete matrix. However, at 15% replacement, the strength drops significantly to 12.01 N/mm². This reduction is attributed to excessive replacement, which slows down hydration and weakens the cementitious structure. Overall, the results indicate that 10% replacement is optimal for better early-age strength performance.

14-Days Strength Analysis

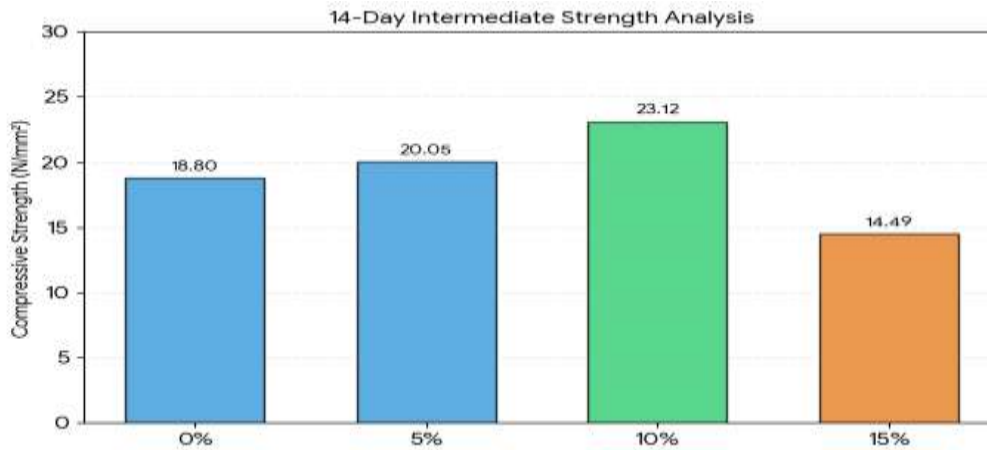


Fig. 6. 14 Days Compressive Strength Analysis

The 14-day compressive strength results represent the intermediate stage of concrete development, where approximately 85–90% of the ultimate strength is typically achieved. The results indicate a clear improvement in performance with the inclusion of coconut shell ash (CSA) and coconut shell crush (CSC). The 10% replacement mix continues to exhibit the highest strength, reaching 23.12 N/mm², which already exceeds the characteristic strength requirement of M20 grade concrete. This highlights the effective pozzolanic reaction and improved microstructure at this replacement level. The 5% replacement mix also shows significant improvement, achieving 20.05 N/mm², which is higher than the control mix value of 18.80 N/mm². This indicates that the contribution of CSA and CSC becomes more pronounced as curing progresses, enhancing the bonding and strength of the concrete. However, the 15% replacement mix continues to underperform, recording only 14.49 N/mm². This persistent lag suggests that excessive replacement reduces cementitious content, slowing hydration and weakening the structure. Overall, 10% replacement remains the most effective for strength development.

28-Days Strength Analysis

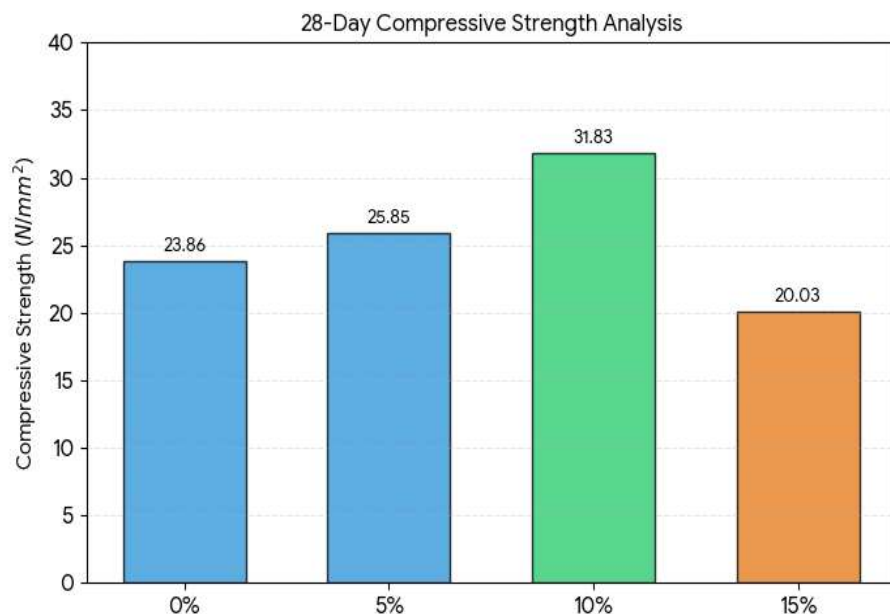


Fig. 7. 28 Days Compressive Strength Analysis

The 28-day compressive strength results represent the final and most critical stage of concrete performance evaluation. The findings clearly identify the 10% replacement mix of coconut shell ash (CSA) and coconut shell crush (CSC) as the optimal composition, achieving the highest strength of 31.83 N/mm². This value not only exceeds the target strength of M20 grade concrete but also demonstrates the positive contribution of CSA through pozzolanic activity and improved microstructural bonding. A consistent increasing trend in strength is observed from 0% to 10% replacement, indicating enhanced performance due to better particle packing and secondary hydration reactions. However, a sharp decline of approximately 37% is noted when the replacement level increases from 10% to 15%. This significant drop is attributed to excessive reduction in cement content, leading to insufficient formation of binding compounds and increased porosity. While the 15% mix still meets the minimum requirement for M20 grade concrete, its performance is comparatively weak. Overall, the results confirm that 10% replacement provides the best balance between strength and sustainability.

Combined Growth Analysis

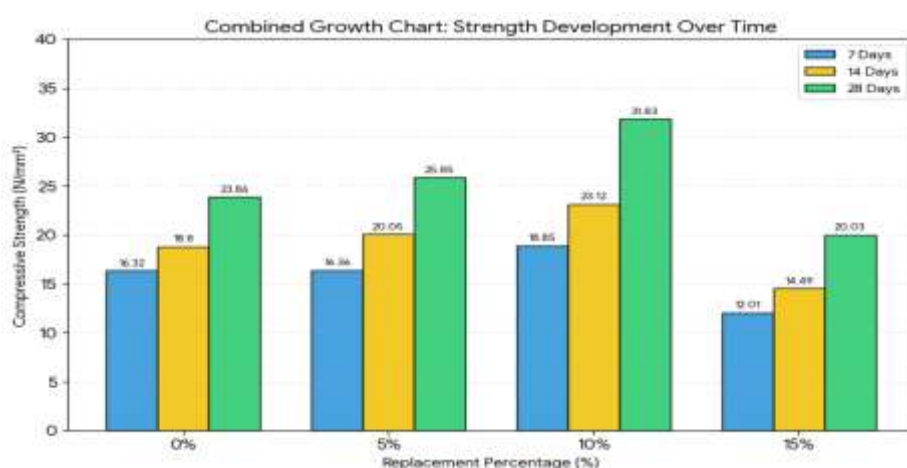


Fig. 8. Combined Growth Compressive Strength Analysis

The compressive strength results across 7, 14, and 28 days show a continuous increase for all concrete mixes, indicating that the hydration process is progressing effectively regardless of the replacement level. This steady upward trend confirms proper curing and consistent strength development in all specimens. Among all mixes, the 10% replacement level consistently demonstrates superior performance at every stage, making it the most effective proportion for enhancing concrete strength. A significant observation is the late-stage strength gain between 14 and 28 days. The 10%

mix exhibits a substantial increase of 8.71 N/mm^2 , which is considerably higher than the 5.06 N/mm^2 gain observed in the control mix. This clearly highlights the pozzolanic activity of coconut shell ash (CSA), which contributes to additional strength during the later stages of curing by forming secondary binding compounds. In contrast, although the 15% mix shows some strength improvement over time, its 28-day strength remains relatively low and is only comparable to the 14-day strength of the control mix. This indicates that 15% replacement is beyond the optimal limit, where excessive substitution begins to weaken the structural integrity of the concrete.

The results for 28 day-test compressive strength for all specimens tested and the average of the reading is shown in the table above. From the above results, it clearly shows that the addition of CS into cement composite does increase the compressive strength but the strength only increases up to certain percent CS content. Specimen with 10% CSA gave the highest compressive strength of 31.83 N/mm^2 and this optimum strength dropped when the CS content is further increased from 10-15%. Specimen with 15% CS gave the lowest compressive strength of 20.03 N/mm^2 .

5. Ansys Modeling Result

Case Study For 28 Days Compressive Strength At 10% Replacement

I chose this case study because Specimen with 10% CS of 28 days curing gave the highest compressive strength of 31.83 N/mm^2 and this optimum strength dropped when the CS content is further increased from 10-15%. Specimen with 15% CS gave the lowest compressive strength of 20.03 N/mm^2 .

Size Of Specimen

Size of cube- $150 \times 150 \times 150$

Material Data

Cement 90% + CSA 10% = 100%

Fine aggregate= 100%

Coarse aggregate 90% + CSC 10% = 100%

Density = $2.3 \times 10^{-6} \text{ kg mm}^{-3} = 2300 \text{ kg/m}^3$

Coefficient of thermal expansion = $1.4 \times 10^{-5} \text{ C}^{-1}$

Specific heat = $7.8 \times 10^5 \text{ mJ kg}^{-1} \text{ C}^{-1}$

Thermal conductivity = $7.2 \times 10^{-4} \text{ W mm}^{-1} \text{ C}^{-1}$

Youngs modulus MPa = 30000

Poisons ratio = 0.18

Bulk modulus MPa = 15625

Shear modulus MPa = 12712

Anslys Model

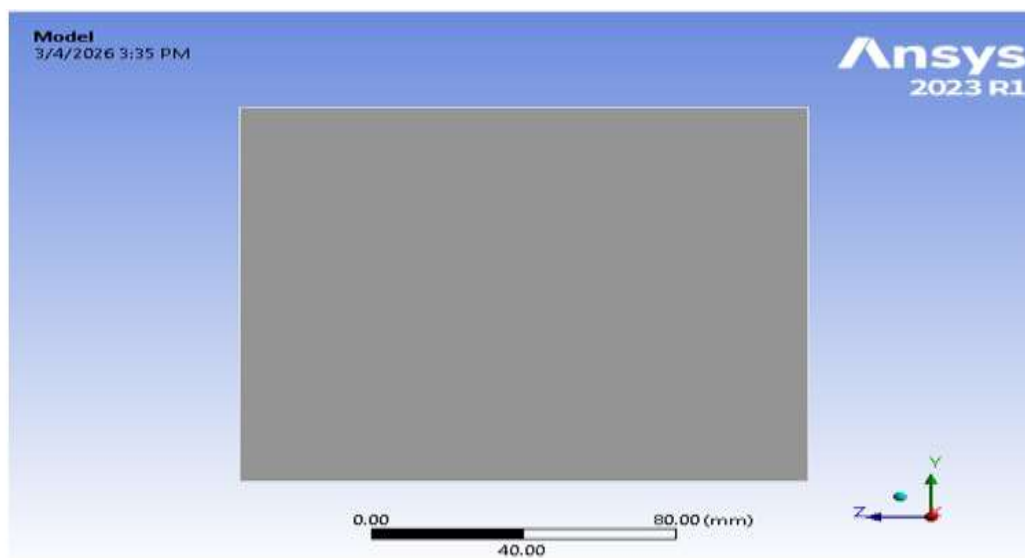


Fig. 9. ANSYS Model

Result Of ANSYS Model

Table 4: Result of Ansys

Time (s)	Grade of Concrete	Load (KN)	Minimum (MPa)	Maximum (MPa)	Average (MPa)
1.	M20	716.2	23.366	69.379	32.028

Comparison Of Experimental Results of Compressive Strength

The ANSYS result are attached in Annexure I

First the experimental work is carried out and corresponding failure load are calculated.

The same failure load is applied in ANSYS and stress are calculated.

The comparative statement of experimental and ANSYS modelling are prepared.

The comparative results are discussed by keeping in view of maximum compressive

Table 5: Comparison Result of Compressive Strength

Sr. No.	C/S Area (mm ²)	Grade of Concrete	Load (KN)	Experimental Compressive Strength (N/mm ²)	Anslys compressive strength (N/mm ²)
1	22500	M20	716.2	31.83	32.028

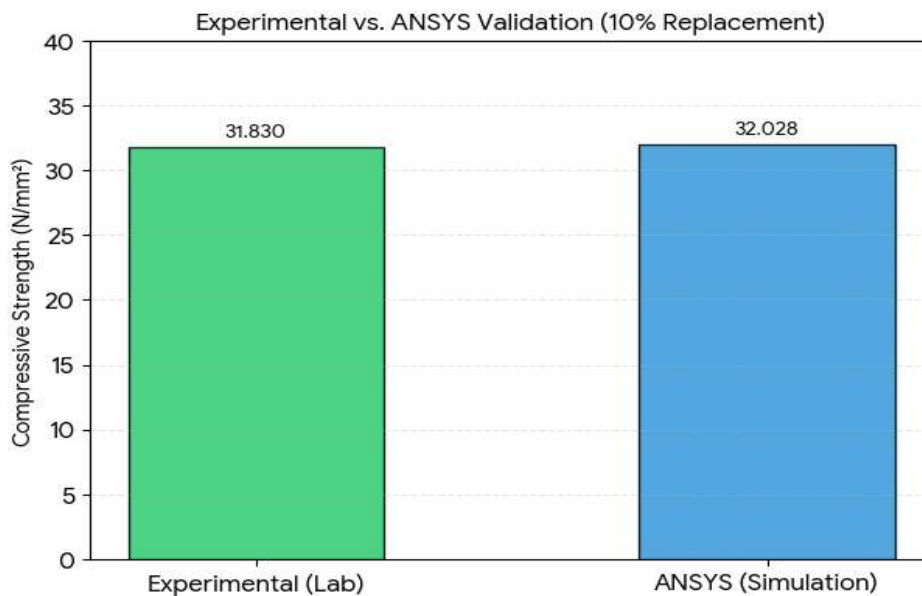


Fig 10. Experimental vs ANSYS Result

The fig presents a comparison between experimentally obtained compressive strength and the numerical results derived from ANSYS simulation for a concrete specimen with a cross-sectional area of 22,500 mm² and grade M20. The applied load of 716.2 kN resulted in an experimental compressive strength of 31.83 N/mm², while the ANSYS analysis predicted a slightly higher value of 32.028 N/mm². The variation between the two results is minimal, indicating a close agreement and high level of accuracy in the simulation model. This small difference may be attributed to assumptions in material properties, boundary conditions, or idealized conditions in the ANSYS model compared to real-world experimental conditions. Overall, the results validate the reliability of ANSYS as an effective tool for predicting compressive strength of concrete with acceptable precision.

Discussion

The experimental findings highlight the significant impact of coconut shell ash (CSA) and crushed coconut shell (CSC) on the mechanical and physical properties of concrete. A noticeable reduction in workability was observed with increasing CSA content, as indicated by decreasing slump values. This is primarily due to the higher water absorption capacity and finer particle size of CSA, which reduces the availability of free water in the mix. Despite this, mixes with 5% and 10% replacement maintained acceptable workability for practical applications. In terms of compressive strength, a progressive increase was observed up to 10% replacement, beyond which strength declined. The improved strength at 10% can be attributed to the pozzolanic properties of CSA, which enhance cement hydration and improve bonding within the concrete matrix. Additionally, better particle packing contributes to increased density and strength. The inclusion of CSC also reduces the overall weight of concrete, making it suitable for lightweight applications. However, at 15% replacement, the excessive reduction in cement content and increased porosity result in weaker bonding and reduced strength. The close agreement between experimental and ANSYS results further validates the reliability of the findings. Overall, the study demonstrates that moderate replacement levels provide an optimal balance between performance and sustainability.

Conclusion

This study demonstrates the feasibility of using coconut shell ash (CSA) and crushed coconut shell (CSC) as partial replacement materials in concrete production. The experimental results confirm that a 10% replacement level is optimal for achieving enhanced compressive strength and overall performance. At this level, the concrete not only meets but exceeds the strength requirements of conventional M20 grade concrete, reaching a maximum compressive strength of 31.83 N/mm² at 28 days. Additionally, the use of coconut shell materials contributes to the production of lightweight concrete, which can be advantageous in reducing structural load. From an environmental perspective, this approach significantly reduces dependence on cement and natural aggregates, thereby lowering carbon emissions and conserving natural resources. It also provides an effective solution for managing agricultural waste, promoting sustainable construction practices. However, replacement levels beyond 10% negatively impact strength due to increased porosity

and reduced bonding capacity. The strong correlation between experimental and ANSYS simulation results further supports the reliability of the study. In conclusion, the incorporation of coconut shell derivatives in concrete offers a cost-effective, eco-friendly, and sustainable alternative for modern construction, making it suitable for both structural and non-structural applications.

References

1. Afolayan, J.O., Ejeh S.P, Amartey Y.D. and Idris, A. published in Asian Journal of Science and Technology, September 2017 “Mechanical properties of coconut shell as coarse aggregate in lightweight concrete.”
2. Anviti Bhartiya and Manish Dubey (2018) published in international research journal of engineering and technology (IRJET) Issue:06 | June-2018 “Replacement of cement with coconut shell ash and egg shell powder for preparation of fresh concrete.”
3. Lavanya B.A, Sunitha M.S, Umesha P, Chetan H.H, published in International Research Journal of Engineering and Technology (IRJET) Issue:04| Apr-2018 “Experimental study on partial replacement of coarse aggregate with coconut shell in concrete”
4. Dr. B. Rajeevan, Shamjith K.M published in international journal of Engineering Research and technology (IJERT) Issue 07 july-2018 “A Study on the Utilization of Coconut shell as coarse aggregate in concrete.”
5. Thejaswi Prema raj M, Ranjith Kumar M G (2019) published in International Research Journal of Engineering and Technology (IRJET) Issue: 05 | May 2019 “Structural performance on partial replacement of cement by coconut shell ash.”
6. Rajesh Kumar, published in International Journal of Science and Research (IJSR) Issue: 8, August 2020 “Partial Replacement of Coconut Shell Ash with Cement in Concrete.”
7. Lohar Pandurang R, Patil Vikas J, Bedage Arjun B, Mane Amit R, Thorbole Shubham D. published in International Research Journal of Engineering and Technology (IRJET) Issue: 03 | Mar 2020 “Partially replacement of coarse aggregate with coconut shell in concrete.”
8. Utsev, J. T., Taku, J. K. Published in International journal of science and technology research (IJSTR) (2020) “Coconut Shell Ash as Partial Replacement of Ordinary Portland Cement in Concrete Production.”
9. K. Santhi, K. Candassamy, Dr. J. Sreerambabu, published in International Journal of civil engineering and technology (IJCIET) Issue 7, July 2020 “A study on partial replacement of coconut shell as coarse aggregate in concrete.”
10. Adajar, M. A., Galupino, J., Frianeza, C., Aguilon, J. F., Sy, J. B., & Tan, P. A. (2020). Compressive strength and durability of concrete with coconut shell ash as cement replacement. *GEOMATE Journal*, 19(73), 1–7.
11. Santosa, B., Ginting, A., Adi, P., & Manasye, E. O. (2023). Effect of partial replacement of cement with coconut shell ash on concrete performance. *Jurnal Teknik Sipil*, 19(2), 45–52.
12. Shanmuga Priya, S., & Padmanaban, I. (2023). Effect of coconut shell ash as an additive on the properties of green concrete. *Global NEST Journal*, 25(4), 112–120.
13. Herring, T. C., Thuo, J. N., & Nyomboi, T. (2022). Engineering and durability properties of modified coconut shell concrete. *Civil Engineering Journal*, 8(2), 345–356.
14. Yazid, M., Ningrum, P., Kurnain, A., Bagio, T. H., & Sinaga, S. M. T. (2024). The effect of coconut shell as a coarse aggregate substitute on concrete compressive strength. *Journal of Civil Engineering and Planning*, 5(2), 89–96.
15. Kumar, D., & Pawar, S. J. (2021). Compressive behaviour of green concrete using coconut shell as coarse aggregate replacement. *Indian Journal of Civil Engineering*, 5(1), 15–22.
16. Kambli, P. S. (2014). Compressive strength of concrete by using coconut shell as coarse aggregate. *IOSR Journal of Engineering*, 4(4), 1–7.
17. Bheel, N., Mangi, S. A., & Meghwar, S. L. (2021). Coconut shell ash as cementitious material in concrete: A review. *Jurnal Kejuruteraan*, 33(1), 27–38.
18. Gunasekaran, K., Kumar, P. S., & Lakshmipathy, M. (2012). Long-term study on compressive and bond strength of coconut shell aggregate concrete. *Construction and Building Materials*, 28(1), 208–215.
19. Kalbhor, S. H., Pisal, G. T., Amale, G. B., & Patil, P. S. (2024). Cocoblend concrete: Exploring concrete grades with recycled coconut shells for optimal durability. *International Journal of Research in Engineering, Science and Management*, 7(1), 55–60.