

# Enhancing Mechanical and Durability Properties of Coconut Shell Concrete Using Fly Ash

Gaurav Pandey<sup>1\*</sup>, Harsh Rathore<sup>2</sup>

## Abstract

*The increasing demand for sustainable and lightweight construction materials has driven research into alternative aggregates for concrete production. This study investigates the mechanical and durability properties of coconut shell (CS) concrete with varying percentages of fly ash replacement. The research evaluates compressive strength, split tensile strength, water absorption, and workability to determine the feasibility of CS concrete as a structural material. Experimental findings indicate that incorporating 10% fly ash (CSF10 and CSP10) significantly enhances compressive and split tensile strength at all curing ages (7, 28, and 56 days). The highest gain of strength was observed at 56 days due to the prolonged pozzolanic activity of fly ash. The CS-based mixes exhibited lower density than conventional concrete, highlighting their potential for lightweight construction applications. Water absorption was initially higher in CS concrete due to the porous nature of the aggregates but fly ash incorporation reduced absorption by refining the pore structure. Additionally, the partial replacement of CS with crushed granite aggregate (CSP mixes) further lowered water absorption, improving concrete durability. The study concludes that CS concrete with optimal fly ash replacement enhances mechanical strength and durability while maintaining sustainability. The results suggest its potential use in non-structural and semi-structural applications, with further research recommended for long-term performance evaluation and large-scale implementation. The integration of waste materials such as CS and fly ash in concrete aligns with sustainable construction practices, promoting resource efficiency and environmental conservation.*

**Keywords:** Coconut shell aggregate, fly ash, lightweight concrete, compressive strength, split tensile strength, water absorption, sustainable construction, pozzolanic reaction, durability, waste utilization

## INTRODUCTION

Sustainability is a fundamental aspect of modern construction, emphasizing the need to balance the consumption of renewable and non-renewable resources. For nations, organizations, and individuals committed to sustainability, it involves responsible resource management, economic stability, social progress, and poverty reduction. The construction sector in its current state is unsustainable. In response, researchers have explored the incorporation of recycled aggregates in concrete production [1–4]. The recycling process, however, requires substantial energy for crushing demolition waste, contributing to CO<sub>2</sub> emissions. This highlights the need for alternative coarse aggregates that are renewable and environmentally friendly. Agricultural solid waste has been identified as a potential solution to meet these criteria [5].

### \*Author for Correspondence

Gaurav Pandey  
E-mail: gauravpandey7797@gmail.com

<sup>1</sup>Research Scholar, Department of Civil Engineering, Sanjeev Agarwal Global Educational University, Bhopal, Madhya Pradesh, India

<sup>2</sup>Associate Professor, Department of Civil Engineering, Sanjeev Agarwal Global Educational University, Bhopal, Madhya Pradesh, India

Received Date: March 21, 2025

Accepted Date: April 21, 2025

Published Date: April 23, 2025

**Citation:** Gaurav Pandey, Harsh Rathore. Enhancing Mechanical and Durability Properties of Coconut Shell Concrete Using Fly Ash. Recent Trends in Civil Engineering & Technology. 2025; 15(2): 19–24p.

The cement and concrete industries significantly contribute to global warming due to their energy-intensive nature and high CO<sub>2</sub> emissions. Achieving

carbon neutrality in concrete production is challenging due to the substantial cement content, which can range from 200 to 1,200 kg/m<sup>3</sup> of concrete. The cement industry alone accounts for approximately 5% of anthropogenic CO<sub>2</sub> emissions, contributing to the 25% total emissions from the industrial sector. Research indicates that nearly 85% of CO<sub>2</sub> emissions throughout a concrete structure's lifecycle stem from cement production [6]. One viable strategy to mitigate this environmental impact is the partial replacement of cement with locally available byproducts and supplementary cementitious materials. Additionally, substituting traditional coarse aggregates with alternative materials can help reduce natural resource depletion, promoting environmental sustainability in concrete production.

## OBJECTIVES

- To analyze the compressive strength of CS-based concrete.
- To assess the water absorption characteristics and its effect on the long-term performance of CSC.
- To promote eco-friendly and sustainable construction practices by utilizing agricultural waste materials.

## MATERIALS

### Coconut Shell Aggregate

Coconut shells, sourced from local copra drying yards, are washed to remove iron and processed to eliminate fibers from the convex side before crushing [7]. The shell thickness varies between 2 and 5 mm. Due to high water absorption, they are used in an SSD condition after 24-h water immersion.

### River Sand as Fine Aggregate

Locally sourced river sand (Zone II, specific gravity 2.6) was sieved through a 4.75 mm mesh, ensuring uniformity. Testing was conducted per IS 383-1970.

### Coarse Aggregate

Crushed granite (3–12 mm) was used in CSP mixes. Key properties such as bulk density, specific gravity, water absorption, AIV, ACV, and abrasion value were assessed.

### Cement

53 Grade OPC (UltraTech) was used, conforming to IS 12269:2013. The specific gravity was 3.15.

### Fly Ash

Class F fly ash (specific gravity 2.08) from Mandideep, Madhya Pradesh, was used as a pozzolanic material to enhance durability and reduce OPC content, lowering CO<sub>2</sub> emissions.

### Water

Only potable water, free from harmful impurities, was used for mixing and curing to prevent adverse effects on concrete properties.

### Superplasticizer

Conplast SP430 (sulfonated naphthalene polymer) was added to improve workability, allowing water reduction and strength enhancement. The optimal dosage was 1.2% of the binder content.

## RESULTS

### Compressive Strength

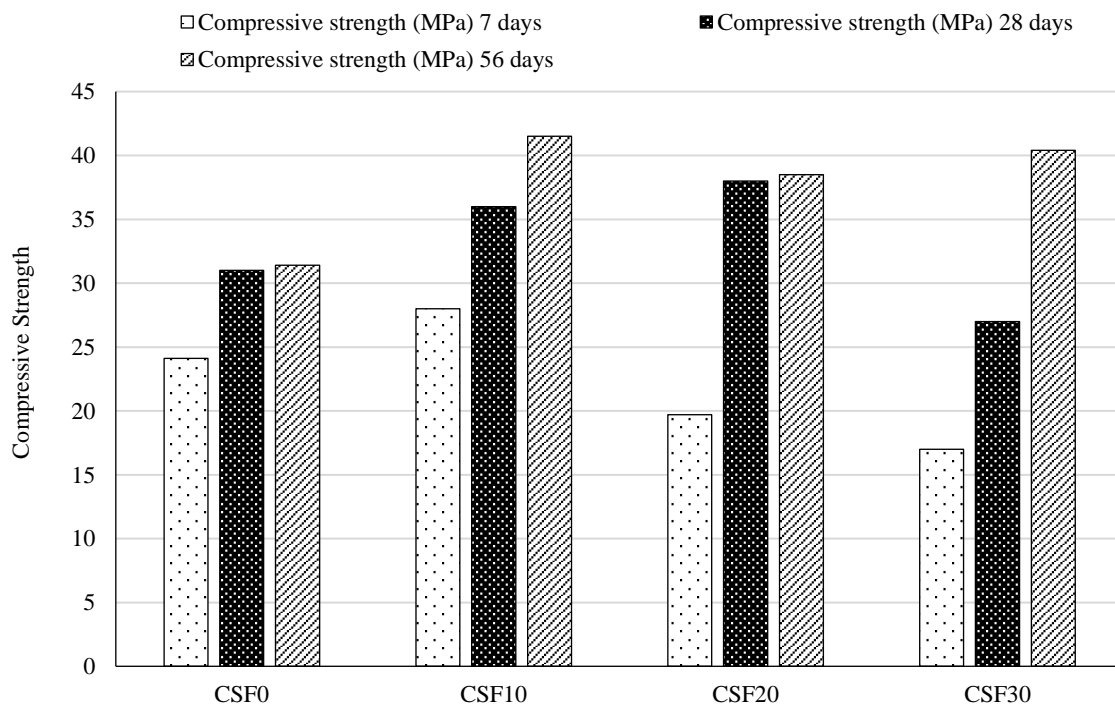
The compressive strength of various coconut shell concrete (CSC) mixes at 7, 28, and 56 days is summarized in Table 1. Among the different fly ash replacement levels, the mixes with 10% fly ash (CSF10 and CSP10) exhibited the highest compressive strength across all curing periods. These findings align with the research conducted on oil palm shell lightweight concrete incorporating fly ash. Figures 1 and 2 depict the compressive strength trends for CSF and CSP mixes, respectively.

The CSF10 mix demonstrated a compressive strength improvement of approximately 20, 16, and 32% at 7, 28, and 56 days, respectively, compared to the control CSF mix. Similarly, the CSP10 mix exhibited increases of 19, 15, and 25% at the same curing intervals compared to the CSP mix. The substantial rise in compressive strength at 56 days in both mixes can be attributed to the prolonged pozzolanic activity of fly ash, which continues beyond 28 days [8–12].

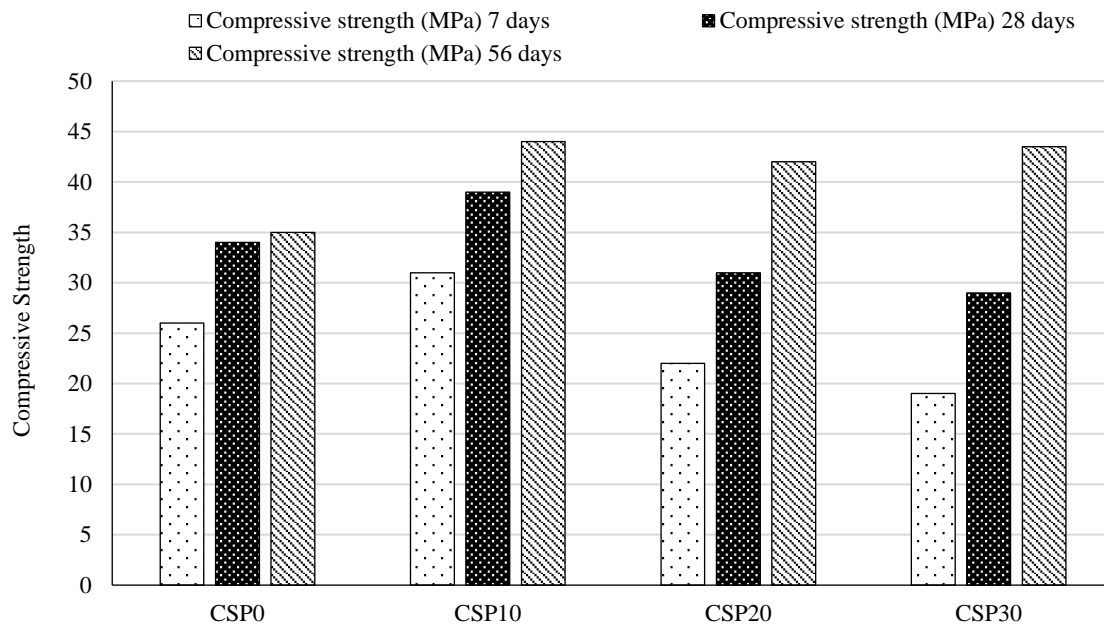
However, when the fly ash replacement exceeded 10%, a decline in 28-day compressive strength was observed. Specifically, with 20% fly ash replacement, the CSF mix experienced a reduction of 16 and 10% at 7 and 28 days, respectively, while increasing by 22% at 56 days. At a 30% fly ash replacement, compressive strength decreased by 27 and 14% at 7 and 28 days, respectively, but improved by 29% at 56 days. Similarly, for the CSP mix, a 20% fly ash replacement led to compressive strength reductions of 15 and 11% at 7 and 28 days, respectively, followed by a 20% increase at 56 days. At 30% fly ash replacement, strength declined by 26 and 15% at 7 and 28 days, respectively, but rose by 25% at 56 days (Table 1 and Figures 1 and 2) [13–16].

**Table 1.** Compressive strength of coconut shell concrete.

Mix Designation	Compressive strength (MPa)		
	7 days	28 days	56 days
CSF0	24.1	31	31.4
CSF10	28	36	41.5
CSF20	19.7	38	38.5
CSF30	17	27	40.4
CSP0	26	34	35
CSP10	31	39	44
CSP20	22	31	42
CSP30	19	29	43.5



**Figure 1.** Compressive strength of CSF mix.



**Figure 2.** Compressive Strength of CSP Mix.

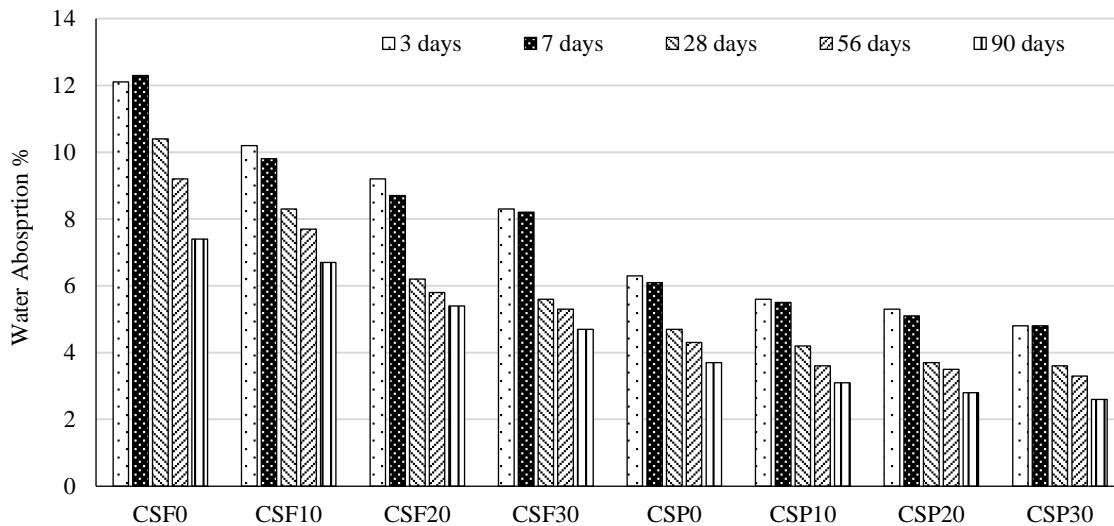
**Table 2.** Water absorption of different concrete mixes at various curing ages.

Mix Designation	3 days	7 days	28 days	56 days	90 days
CSF0	12.1	12.3	10.4	9.2	7.4
CSF10	10.2	9.8	8.3	7.7	6.7
CSF20	9.2	8.7	6.2	5.8	5.4
CSF30	8.3	8.2	5.6	5.3	4.7
CSP0	6.3	6.1	4.7	4.3	3.7
CSP10	5.6	5.5	4.2	3.6	3.1
CSP20	5.3	5.1	3.7	3.5	2.8
CSP30	4.8	4.8	3.6	3.3	2.6

Water absorption is a key indicator of concrete durability, representing the movement of liquids within porous materials due to surface tension in capillaries. The absorption values for different concrete mixes are detailed in Table 2, with comparisons made between conventional concrete and CSF and CSP mixes. The degree of absorption provides insights into the open pore volume of the specimens. Figure 3 illustrates CS concrete specimens placed in an electric oven for water absorption assessment [17–22].

For the CSF mix, the 28-day water absorption was recorded at 10.5%, which gradually decreased over extended curing periods (56 and 90 days). This reduction can be attributed to the gradual evaporation of moisture from the coconut shell (CS) aggregate, which initially retained water during the mixing process. Additionally, the inclusion of fly ash in CSF mixes led to lower absorption values compared to those without fly ash. A higher fly ash content corresponded to reduced water absorption, likely due to the fine particles filling pores within the concrete, thereby limiting water retention [23–27].

In the CSP0 mix, the 28-day water absorption was measured at 4.8%, equating to only 46% of the absorption observed in CSF0. Since CSP mixes incorporate 50% conventional crushed granite (CG) aggregate in the total coarse aggregate content, they exhibited significantly lower water absorption. The absorption values for CSP10, CSP20, and CSP30 were recorded as 4.1, 3.8, and 3.5%, respectively.



**Figure 3.** Variation in water absorption of concrete mixes over time.

The incorporation of fly ash further contributed to reducing absorption by minimizing pore spaces within the concrete matrix. A slight decline in absorption was observed over extended curing periods (56 and 90 days) in CSP mixes. Compared to CSF and CSP mixes, conventional concrete exhibited the lowest absorption levels, with its coarse aggregate absorbing just 0.2%, significantly lower than the 25% absorption capacity of CS aggregate (Table 1). This explains the minimal water absorption observed in conventional concrete [28–30].

## CONCLUSION

- The compressive strength results showed that a 10% fly ash replacement (CSF10 and CSP10) achieved the highest strength at all curing ages (7, 28, and 56 days). However, strength decreased beyond 10% replacement.
- A significant increase in compressive strength at 56 days was observed due to the continued pozzolanic reaction of fly ash, improving concrete durability.
- Water absorption was found to be higher in CS-based concrete compared to conventional concrete due to the porous nature of coconut shell aggregates. However, fly ash incorporation reduced water absorption by filling voids in the matrix.
- The use of 50% crushed granite aggregate in CSP mixes significantly reduced water absorption, improving the durability of the concrete.
- The findings suggest that incorporating fly ash up to 10% in CS concrete enhances strength and durability, making it a viable sustainable alternative for lightweight concrete applications.

## REFERENCES

1. Alduaij J, Alshaleh K, Haque MN, Ellaithy K. Lightweight concrete using local materials. *ACI Mater J.* 1999; 96(6): 776–780.
2. Alabadan BA. Agro-industrial residues in concrete technology. *Constr Build Mater.* 2006; 20(8): 658–664.
3. Basri HB, Mannan MA, Zain MFM. Concrete using waste oil palm shells as aggregate. *Cem Concr Res.* 1999; 29(4): 619–622.
4. Babu KG, Babu DS. Performance of fly ash concrete with lightweight expanded polystyrene aggregate. *Cem Concr Compos.* 2003; 25(6): 523–529.
5. Babu DS, Babu KG, Wee TH. Properties of lightweight expanded polystyrene aggregate concrete reinforced with steel fiber. *Cem Concr Compos.* 2006; 28(6): 556–565.
6. Chang JJ, Shieh MS. The use of lightweight aggregates in high-performance concrete. *ACI Mater J.* 1996; 93(5): 429–436.

7. Chandra S, Berntsson L. *Lightweight Aggregate Concrete: Science, Technology, and Applications*. New York: Noyes Publications; 2003.
8. Chen B, Liu J. Properties of lightweight expanded polystyrene aggregate concrete reinforced with steel fiber. *Cem Concr Res*. 2004; 34(1): 1259–1263.
9. Chen C, Liu T. Investigation of cenospheres as lightweight aggregates in concrete. *J Mater Civ Eng*. 2008; 20(6): 487–491.
10. Choi YW, Moon DJ, Kim YJ, Lachemi M. Characteristics of mortar and concrete containing fine aggregate manufactured from recycled waste polyethylene terephthalate bottles. *Constr Build Mater*. 2005; 19(6): 429–437.
11. Coatanlem P, Jauberthie R, Rendell F. Lightweight wood chipping concrete durability. *Constr Build Mater*. 2006; 20(9): 776–781.
12. Corinaldesi V, Gnappi G, Moriconi G, Montenero A. Reuse of ground waste glass as aggregate for mortars. *Waste Manag*. 2005; 25(2): 197–201.
13. Demirbas A, Aslan A. Utilization of agro-waste in concrete technology. *Resour Conserv Recycl*. 1998; 23(2): 83–93.
14. Ducman V, Mirtic B, Kopar T. Lightweight aggregates made from waste glass and fly ash. *Cem Concr Compos*. 2002; 24(2): 213–219.
15. Eko M, Riskowski G. Utilization of agricultural waste as building materials. *J Agric Eng Res*. 1999; 74(2): 211–219.
16. Ganesan K, Rajagopal K, Thangavel K. Rice husk ash blended cement: Assessment of optimal level of replacement for strength and permeability properties of concrete. *Constr Build Mater*. 2007; 22(8): 1675–1683.
17. Gesoglu M, Guneyisi E, Oz HO. Effect of lightweight aggregate properties on the behavior of lightweight concrete. *Cem Concr Compos*. 2004; 26(5): 455–465.
18. Gunasekaran K, Annadurai R, Kumar PS. Study on reinforced lightweight coconut shell concrete beam behavior under flexure. *Mater Des*. 2011; 32(2): 392–399.
19. Gunasekaran K, Kumar PS, Lakshmipathy M. Mechanical and bond properties of coconut shell concrete. *Constr Build Mater*. 2013; 34(3): 150–155.
20. Guneyisi E, Gesoglu M, Mermerdas K. Strength and permeability properties of self-compacting concrete with expanded perlite aggregate. *Constr Build Mater*. 2015; 74(1): 109–116.
21. Hassanpour M, Shafigh P, Mahmud HB. Lightweight aggregate concrete containing natural perlite aggregates. *Constr Build Mater*. 2012; 37(2): 516–521.
22. Jauberthie R, Rendell F, Walker P. The use of rice husk for making lightweight concrete. *Constr Build Mater*. 2000; 14(8): 419–424.
23. Khaiyat KH, Haque MN. Performance of high-strength lightweight concrete made with expanded clay aggregate. *ACI Mater J*. 1999; 96(5): 635–640.
24. Lai MH, Hwang CL, Lee HJ. The use of polystyrene beads for lightweight concrete. *Cem Concr Compos*. 1996; 18(3): 197–202.
25. Maiti R, Cordeiro GC, Sales A. Development of lightweight concrete using rice husk ash. *Mater Struct*. 2006; 39(9): 803–811.
26. Mannan MA, Ganapathy C. Concrete from an agricultural waste-oil palm shell as coarse aggregate. *Build Environ*. 2004; 39(4): 441–448.
27. Martirena H. Use of agro-industrial waste in construction. *Cem Concr Compos*. 1998; 20(3): 213–218.
28. Miled K, Sab K, Le Roy R. Particle size effect on EPS lightweight concrete compressive strength: Experimental investigation and modeling. *Mech Mater*. 2004; 36(4): 1031–1036.
29. Novoa FD, Pereira JD, Costa AC. Use of cork waste in lightweight concrete production. *Mater Sci Forum*. 2004; 455(6): 437–442.
30. Olanipekun EA, Olusola KO, Ata O. A comparative study of concrete properties using coconut shell and palm kernel shell as coarse aggregates. *Build Environ*. 2006; 41(3): 297–301.