



# Strength Studies of Tamarind Kernel Shell Powder Concrete with Metakaolin

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**ABSTRACT:** This abstract outlines an experimental investigation into the mechanical and durability characteristics of sustainable concrete incorporating tamarind kernel shell powder (TKSP) and metakaolin. Recognizing the critical need to reduce carbon footprints and optimize agricultural waste utilization in the construction sector, this study evaluates the synergistic effects of substituting conventional binders and fine aggregates. Cement was partially replaced with metakaolin at a fixed optimum percentage to enhance pozzolanic activity and pore refinement, while fine aggregates were systematically substituted with TKSP at varying dosages. The structural performance of the modified concrete matrices was rigorously assessed through destructive and non-destructive testing regimes at designated curing intervals. Compressive strength evaluations demonstrated that the microstructural densification offered by metakaolin successfully offsets the initial strength variations introduced by the organic shell powder. Split tensile strength tests indicated a notable improvement in the material's internal cohesion and crack-bridging behavior under tensile strain. Furthermore, non-destructive Ultrasonic Pulse Velocity (UPV) testing was conducted to evaluate the internal homogeneity and quality of the concrete matrix, classifying the structural integrity of the composite blends from good to excellent based on wave velocity propagation. The empirical findings establish that the balanced combination of agricultural industrial waste and mineral admixtures yields a viable, eco-friendly structural concrete alternative without sacrificing core mechanical performance.

**KEYWORDS:** Metakaolin, Tamarind Kernel Shell Powder (TKSP), Agricultural Waste Utilization, Pozzolanic Material, Sustainable Concrete.

## I. INTRODUCTION

Concrete is a premier, universally adopted composite material that serves as the foundation of modern global infrastructure development. It is engineered through a precise, chemical-reaction-driven mixture of ordinary Portland cement, water, fine aggregates, and coarse aggregates. As the water initiates a hydration reaction with the cement binder, the fluid paste transforms into a rigid, stone-like crystalline matrix that binds the aggregate particles together. The material is globally favored due to its exceptional compressive load-bearing capacity, outstanding structural fire resistance, long-term durability, and its fluid ability to be molded into virtually any structural geometry before setting. However, due to the high carbon emissions associated with traditional cement production, modern concrete research is heavily focused on incorporating alternative eco-friendly materials to improve its environmental sustainability.

Metakaolin is a highly reactive, premium quality pozzolanic material obtained through the controlled thermal activation of purified kaolin clay at temperatures ranging between  $600^{\circ}\text{C}$  and  $800^{\circ}\text{C}$ . Unlike industrial byproducts like fly ash or slag, it is a manufactured mineral admixture produced under strict quality standards, ensuring exceptional consistency in chemical composition. When blended into a fresh concrete mixture, metakaolin reacts chemically with the calcium hydroxide byproduct generated during cement hydration, converting it into additional strength-improving calcium silicate hydrate gels. This intensive secondary reaction significantly refines the concrete's internal pore structure, reduces overall permeability, and restricts the entry of aggressive chemical ions. Consequently,

its inclusion substantially elevates the early-age compressive strength, flexural toughness, and long-term durability of high-performance concrete composites.

Tamarind kernel shell powder is an innovative, organic agricultural byproduct derived from the processing of tamarind fruits, presenting a viable alternative for sustainable waste utilization in construction. The tough outer shells are systematically cleaned, dried, and mechanically pulverized into a fine particulate form to evaluate their potential as a partial replacement for fine aggregates or fillers in cement matrices. Due to its organic cellular structure, the powder exhibits low density and unique water absorption characteristics that influence the overall fresh workability and hydration kinetics of the concrete mix. When incorporated at optimized, strictly controlled dosages, it acts as a lightweight filler material that can lower the dead weight of structural elements while reducing reliance on depleting natural river sand resources. Utilizing this localized agricultural waste not only helps lower raw material costs but also offers a practical, eco-friendly solution for managing industrial agro-waste without causing environmental degradation.

## II. OBJECTIVES

1. To determine the compressive strength and split tensile strength of concrete containing optimized metakaolin and varying percentages of tamarind kernel shell powder at standard curing intervals.
2. To analyze the internal homogeneity, density, and quality classification of the modified concrete matrix using Ultrasonic Pulse Velocity (UPV) wave propagation.
3. To establish an eco-friendly mix design that successfully substitutes commercial binders and depleting natural aggregates with agricultural and mineral wastes without compromising core structural performance.

## III. MATERIALS

1. **Cement:**-Cement is a finely pulverized hydraulic binder manufactured by calcining precise mixtures of limestone, clay, and other mineral components at extremely high temperatures. Upon contact with water, it initiates a complex chemical hydration process that forms a rigid, binding paste capable of setting and hardening both in air and underwater. Its primary role in a concrete matrix is to adhere sand and stone particles together into a cohesive, stone-like structural mass.
2. **Fine Aggregate:**-Fine aggregate typically consists of natural river sand or crushed manufactured sand with particle sizes passing entirely through a 4.75 mm sieve. It acts as a structural filler within the concrete mix, filling the microscopic voids created between the larger coarse aggregate pieces. This granular material is crucial for ensuring the smooth workability of fresh concrete and optimizing the final density of the hardened matrix.
3. **Coarse Aggregate:**-Coarse aggregate comprises chemically inert materials like crushed granite, gravel, or broken stone with particle sizes retained on a 4.75 mm sieve. Serving as the primary structural backbone of concrete, it occupies the largest volume within the mix and resists heavy compressive loads, weathering, and physical wear. Its surface texture and angularity directly influence the internal mechanical interlocking and overall strength of the cured composite.
4. **Water:**-Water is the essential liquid catalyst that triggers the chemical hydration of the cementitious binder, transforming the dry mix into a workable plastic paste. It must be clean and free from harmful organic matter, acids, or alkalis to prevent interference with the setting time or long-term durability of the structure. Additionally, water provides the necessary fluidity required for the proper mixing, transport, and compaction of fresh concrete.
5. **Metakaolin:**-Metakaolin is a highly reactive, premium pozzolanic mineral admixture produced through the controlled thermal activation of purified kaolin clay. When mixed into concrete, it chemically consumes the weak calcium hydroxide byproducts of cement hydration to generate additional strength-giving gels. This reaction significantly refines the internal micro-pore structure, reduces permeability, and enhances early-age compressive strength.
6. **Tamarind Kernel Shell Powder:**-Tamarind kernel shell powder is a sustainable, organic agro-waste byproduct created by finely grinding the tough outer casings of tamarind fruits. Used innovatively as a partial filler or aggregate substitute, its distinct particle shape and organic composition introduce unique cellular properties to the cement matrix. Incorporating this powder reduces reliance on depleting natural sand resources while offering an eco-friendly solution for industrial agricultural waste management.

IV. RESULTS AND DISCUSSIONS

**a. Compressive strength test:** The compression test on concrete cubes is a basic quality control method used to measure the highest compressive strength a cured concrete mix can withstand before failing structurally. Standard concrete samples, usually molded into 150 mm×150 mm×150 mm dimensions, are kept in water for designated durations most often 7 and 28 days to facilitate adequate chemical hydration.

Table 1:- Compressive Strength result of concrete with Metakaolin as partial replacement of cement.

S.No	% of Metakaolin	Compressive Strength Results, N/mm <sup>2</sup>	
		7 days	28 days
1	0%	18.64	27.34
2	5%	20.09	29.04
3	10%	21.44	30.55
4	15%	22.02	31.51
5	20%	20.93	30.11

Table 2:- Compressive Strength result of concrete with Addition of Tamarind kernel shell powder in cement.

S.No	% of Tamarind Kernel Shell Powder	Compressive Strength Results, N/mm <sup>2</sup>	
		7 days	28 days
1	0%	18.64	27.34
2	0.25%	21.68	31.47
3	0.5%	25.51	36.09
4	0.75%	21.41	30.63

Table 3:- Combined Compressive Strength result of concrete.

S.No	Combined Replacement(s)	Compressive Strength Results, N/mm <sup>2</sup>	
		7 days	28 days
1	0%	18.64	27.34
2	15%MK+0.5%TKS	26.91	38.18

**b. Split tensile strength:** At the Age of 7 and 28 days, measuring 300 mm in length and 150 mm in diameter positioned horizontally between the loading platens of a Compression Testing Machine (CTM). A compressive load is applied diametrically and uniformly across the cylinder's length until it fails along its vertical diameter.

Table 4:- Split tensile Strength result of concrete with Metakaolin as partial replacement of cement.

S.No	% of Metakaolin	Split tensile Strength Results, N/mm <sup>2</sup>	
		7 days	28 days
1	0%	1.84	2.73
2	5%	1.95	2.87
3	10%	2.11	3.02
4	15%	2.31	3.29
5	20%	2.06	2.97

Table 5:- Split tensile Strength result of concrete with Addition of Tamarind kernel shell powder in cement.

S.No	% of Tamarind kernel shell powder	Split tensile Strength Results, N/mm <sup>2</sup>	
		7 days	28 days
1	0%	1.84	2.73
2	0.25%	2.14	3.11
3	0.5%	2.67	3.79
4	0.75%	2.22	3.03

Table 6:- Combined Split tensile Strength result of concrete.

S.No	Combined Replacement(s)	Split tensile Strength Results, N/mm <sup>2</sup>	
		7 days	28 days
1	0%	2.62	3.86
2	15%MK+0.5%TKS	4.11	5.89

**c. Ultrasonic Pulse Velocity:-** Ultrasonic Pulse Velocity (UPV) testing is a non-destructive technique employed to evaluate the quality, consistency, and strength of concrete and similar materials. The process entails sending high-frequency sound waves through a material via a transmitting transducer and capturing them with a second transducer. By measuring the exact time it takes for the pulse to cover a known distance, the wave's velocity can be determined accurately.

Table 7:- Ultra Pulse Velocity result of concrete with Metakaolin as partial replacement of cement.

S.No	% of Metakaolin	Ultra Pulse Velocity Results, m/s	
		28 days	Quality of concrete
1	0%	4458	GOOD
2	5%	4592	EXCELLENT
3	10%	4772	EXCELLENT
4	15%	4821	EXCELLENT
5	20%	4662	EXCELLENT

Table 8:- Ultra Pulse Velocity result of concrete with Addition of Tamarind kernel shell powder in cement.

S.No	% of Tamarind kernel shell powder	Ultra Pulse Velocity Results, N/mm <sup>2</sup>	
		28 days	Quality
1	0%	4458	GOOD
2	0.25%	4641	EXCELLENT
3	0.5%	4864	EXCELLENT
4	0.75%	4746	EXCELLENT

**Table 9:- Combined Ultra Pulse Velocity result of concrete.**

S.No	Combined Replacement(s)	Ultra Pulse Velocity Results, N/mm <sup>2</sup>	
		28 days	Quality
1	0%	4458	GOOD
2	15%MK+0.5%TKS	4977	EXCELLENT

### V. CONCLUSION

1. The compressive strength for conventional concrete for 7 and 28 days is 18.64 and 39.13 27.34N/mm<sup>2</sup>.
2. At 15% replacement of cement with Metakaolin the compressive strength for 7 and 28 days is 22.02 and 31.51 N/mm<sup>2</sup>.
3. Addition of Tamarind Kernel Shell Powder in cement at 0.5% the compressive strength for 7 and 28 days is 25.51 and 36.09 N/mm<sup>2</sup>.
4. At 15%MK+0.5%TKS the combined replacement of concrete the compressive strength for 7 and 28 days is 26.91 and 38.18 N/mm<sup>2</sup>.
5. The Split tensile strength for conventional concrete for 7 and 28 days is 1.84 and 2.73 N/mm<sup>2</sup>.
6. At 15% replacement of cement with Metakaolin the Split tensile strength for 7 and 28 days is 2.31 and 3.29N/mm<sup>2</sup>.
7. Addition of Tamarind Kernel Shell Powder in cement at 0.5% the Split tensile strength for 7 and 28 days is 2.67 and 3.79N/mm<sup>2</sup>.
8. At 15%MK+0.5%TKS the combined replacement of concrete the Split tensile strength for 7 and 28 days is 2.73 and 3.88 N/mm<sup>2</sup>.
9. The Ultra pulse velocity for conventional concrete for 28 days is 4458 m/s.
10. At 15% replacement of cement with Metakaolin the Ultra pulse velocity for 28 days is 4821m/s.
11. Addition of Tamarind Kernel Shell Powder in cement at 0.5% the Ultra pulse velocity for 28 days is 4864 m/s.
12. At 15%MK+0.5%TKS the combined replacement of concrete the Ultra pulse velocity for 28 days is 4997 m/s.

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