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MECHANICAL PROPERTIES OF CONCRETE WITH TAMARIND KERNEL SHELL AND METAKAOLIN

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ABSTRACT

Concrete, a fundamental composite material composed of cement, aggregates (sand, gravel, or crushed stone), and water, solidifies over time into a robust, rock-like substance. Its widespread use as a man-made building material stems from its exceptional versatility and strength. To further improve concrete's properties, metakaolin (MK), a highly reactive pozzolanic material produced from calcined kaolin clay, can partially replace cement. MK reacts with the calcium hydroxide generated during cement hydration, forming additional calcium silicate hydrate (C-S-H) gel. This process results in a denser microstructure, leading to increased compressive strength, decreased permeability, and improved durability of the concrete. Additionally, tamarind kernel shell powder (TKS), an eco-friendly and cost-effective additive derived from agricultural waste, can be incorporated into concrete mixes to enhance its characteristics. The optimal replacement percentage is determined through compressive strength tests and split tensile strength for 28, 56 and 90 days.

KEYWORDS: Metakaolin, Tamarind Kernel Shell, Pozzolanic, Agricultural waste Compressive strength and Split tensile strength

1. INTRODUCTION

As the world's most ubiquitous building material, concrete is an indispensable and versatile composite crafted from cement, aggregates, and water, which through hydration solidifies into a durable, stone-like substance that underpins modern infrastructure.

Metakaolin (MK) is an amorphous, calcined form of kaolin clay, produced by heating kaolinite to temperatures typically between 600°C and 800°C, which dehydroxylates the clay into a highly reactive aluminosilicate material.

Tamarind Kernel Shell (TKS), a byproduct of tamarind seed shell combustion, proves an effective additive

in concrete. Its pozzolanic nature enables it to react with calcium hydroxide in the cement paste, creating additional binding compounds that enhance strength. When finely ground, this agricultural waste also improves the packing density of the concrete mix, resulting in a denser microstructure.

2. OBJECTIVES

1. To investigate how varying percentages of metakaolin, when used as a partial cement replacement, affect the compressive and split tensile strength of concrete at different curing ages.
2. To evaluate the effect of varying percentages of tamarind kernel ash on the compressive and split tensile strength of concrete, both when used alone and in combination with metakaolin.
3. To identify the optimal combination of partial cement replacement with metakaolin and tamarind kernel ash addition that maximizes concrete's compressive and split tensile strength.

3. MATERIALS

3.1 Cement: Cement is more than just a binder; it's concrete's crucial chemical activator. When hydrated with water, cement undergoes complex chemical reactions, forming a microscopic, crystalline network of calcium silicate hydrates and other compounds.

3.2 Fine aggregate: More than just sand, fine aggregate acts as the essential granular filler in concrete; its finely graded particles fill voids between coarser aggregates, improving workability and preventing segregation.

3.3 Coarse aggregate: These larger, robust particles provide the bulk and structural integrity of concrete, transferring compressive forces through direct interparticle contact. Their shape, texture, and strength are critical to concrete durability by resisting deformation.

3.4 Water: Water is the indispensable chemical catalyst that initiates and sustains the hydration process in cement, acting as the medium for chemical reactions that allow cement compounds to dissolve and reform into a hardened paste.

3.5 Metakaolin: Metakaolin is an amorphous, highly reactive aluminosilicate material, produced by calcining kaolin clay, that acts as a pozzolan by reacting with calcium hydroxide to form additional C-S-H gel, thereby enhancing concrete strength and durability.

3.6 Tamarind kernel shell powder: Tamarind Kernel Shell (TKS) powder, derived from waste tamarind seed shells, can act as a filler or binding agent in concrete, potentially improving workability, strength, and contributing to sustainable waste utilization.

4. EXPERIMENTAL RESULTS

4.1 Compressive strength

The compressive strength test measures the maximum axial load a material, such as concrete, can withstand under compression before failure. This test is typically performed on standardized cube specimens at 7 and 28 days to assess strength development.

Table 1: Compressive strength results of concrete with Metakaolin used as a partial replacement of cement.

Sl.no	% of MK	Compressive Strength Results, N/mm ²		
		28 days	56 days	90 days
1	0%	49.67	54.01	57.84
2	5%	52.73	57.28	61.36
3	10%	55.19	60.07	64.51
4	15%	57.42	62.61	67.25
5	20%	54.87	59.78	64.18

Table 2: Compressive strength results On concrete by addition of Tamarind Kernel Shell Powder by weight of cement.

Sl.no	% of TKS	Compressive Strength Results, N/mm ²		
		28 days	56 days	90 days
1	0%	49.67	54.01	57.84
2	0.25%	57.12	62.23	66.68
3	0.5%	65.63	71.52	76.65
4	0.75%	54.75	59.65	63.83

Table 3: Combined Compressive strength of concrete with 15% of MK+0.5% of TKS

Sl.no	15% of MK+0.5% of TKS	Compressive Strength Results, N/mm ²		
		28 days	56 days	90 days
1	0%	49.67	54.01	57.84
2	15% of MK+0.5% of TKS	69.51	75.93	81.38

4.2 Split tensile strength

Split tensile strength is an indirect method to determine concrete's tensile strength, which is typically weak in direct tension. The test involves applying a compressive load along the diameter of a horizontal cylindrical concrete specimen until it splits into two halves, usually at 7 and 28 days to assess its strength development.

Table 4: Split tensile strength results of concrete Metakaolin used as a partial replacement of cement.

Sl.no	% of MK	Split tensile Strength Results, N/mm ²		
		28 days	56 days	90 days
1	0%	4.83	5.25	5.63
2	5%	5.17	5.61	6.04
3	10%	5.42	5.93	6.36
4	15%	5.68	6.18	6.67
5	20%	5.59	6.09	6.53

Table 5: Split tensile strength results On concrete by addition of Tamarind Kernel Shell Powder by weight of cement.

Sl.no	% of TKS	Split tensile Strength Results, N/mm ²		
		28 days	56 days	90 days
1	0%	4.83	5.25	5.63
2	0.25%	5.61	6.11	6.54
3	0.5%	6.49	7.07	7.54
4	0.75%	5.42	5.94	6.33

Table 6: Ccombined Split tensile strength of concrete with 15% of MK+0.5% of TKS

Sl.no	% of MK+0.5% of TKS	Split tensile Strength Results, N/mm ²		
		28 days	56 days	90 days
1	0%	4.83	5.25	5.63
2	% of MK+0.5% of TKS	6.91	7.59	8.03

5. CONCLUSION

1. The normal concrete compressive strength results for 28,56 and 90days is 49.67,54.01 and 57.84 N/mm².
2. At 15% partial replacement of cement with metakaolin which gives compressive strength result for 28,56 and 90days is 57.42,62.61 and 67.25 N/mm².
3. At 0.5% addition of cement with Tamarind Kernel Shell Powder which gives compressive strength result for 28,56 and 90days is 65.63,71.52 and 76.65 N/mm².
4. Compressive strength result for combined replacement of 15% partial replacement of cement with metakaolin and 0.5% addition of cement with Tamarind Kernel Shell Powder which gives compressive strength result for 28,56 and 90days is 69.51,75.93 and 81.38 N/mm².
5. The normal concrete split tensile strength results for 28,56 and 90days is 4.83,5.25 and 5.63 N/mm².
6. At 15% partial replacement of cement with metakaolin which gives split tensile strength result for 28,56 and 90days is 5.68,6.18 and 6.67 N/mm².
7. At 0.5% addition of cement with Tamarind Kernel Shell Powder which gives split tensile strength result for 28,56 and 90days is 6.49,7.07 and 7.54 N/mm².
8. Split tensile strength result for combined replacement of 15% partial replacement of cement with metakaolin and 0.5% addition of cement with Tamarind Kernel Shell Powder which gives compressive strength result for 28,56 and 90days is 6.91,7.59 and 8.03 N/mm².

6. REFERENCES

1. Khan, M. I., & Khan, I. A. (2020). Performance of High-Strength Concrete Incorporating Metakaolin as Partial Cement Replacement. *Construction and Building Materials*, 237, 117678.
2. Reddy, B. V., & Kumar, M. S. (2021). Influence of Metakaolin on the Mechanical and Durability Properties of Self-Compacting Concrete. *Journal of Building Engineering*, 39, 102280.
3. Zhang, L., Wang, Y., & Li, Q. (2022). Microstructure and Hydration Kinetics of Cement Pastes Containing Metakaolin. *Cement and Concrete Research*, 153, 106721.

4. Singh, S. P., & Prasad, R. (2019). Sustainable Concrete using Metakaolin: A Review of Properties and Applications. *Materials Today: Proceedings*, 18(Part 3), 1018-1025.
5. Al-Saleh, M. H., & Al-Amoudi, O. S. (2020). Permeability and Chloride Ion Penetration Resistance of High-Performance Concrete with Metakaolin. *Arabian Journal for Science and Engineering*, 45(7), 5797-5808.
6. Uchida, T., & Maekawa, K. (2013). Advanced Analysis of Hydration and Mechanical Properties of Metakaolin Blended Cement Pastes. *Journal of Advanced Concrete Technology*, 11(1), 1-13.
7. Dinakar, P., & Sethy, K. P. (2012). Study on Strength and Durability Aspects of Metakaolin Blended Cement Mortars. *Materials & Design*, 36, 375-381.
8. Brooks, J. J., & Megat Johari, M. A. (2010). Effects of Metakaolin on the Strength and Permeability of Concrete. *Cement and Concrete Research*, 40(11), 1438-1444.
9. Gruber, K. A., & Ramlochan, T. (2009). The Influence of Metakaolin on the Performance of Concrete. *Concrete International*, 31(8), 35-40.
10. Rahman, M. A., & Islam, M. S. (2023). Experimental Investigation on Concrete with Tamarind Kernel Shell Powder as Partial Replacement of Fine Aggregate. *Journal of Building Engineering*, 65, 105753.
11. Kumar, R., & Singh, J. (2022). Utilization of Tamarind Kernel Shell Ash as Supplementary Cementitious Material in Concrete. *Journal of Cleaner Production*, 345, 130421.
12. Devi, S., & Sharma, A. (2021). Effect of Tamarind Seed Ash on the Compressive Strength and Water Absorption of Concrete. *International Journal of Engineering Research & Technology*, 10(05), 589-593.
13. Prabhu, K. M., & Prakash, M. (2020). Investigating the Pozzolanic Potential of Tamarind Kernel Shell Ash in Cement Mortar. *Materials Research Express*, 7(9), 095501.
14. Rao, S. K., & Reddy, P. S. (2019). Strength and Durability Characteristics of Concrete with Partial Replacement of Cement by Tamarind Kernel Shell Ash. *Procedia Engineering*, 26, 1572-1579.
15. Kumar, V., & Gupta, A. (2023). Sustainable Concrete Development Using Tamarind Kernel Shell Powder as a Green Additive. *Construction and Building Materials*, 400, 132710.