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An Experimental inquiry into Concrete Properties with Partial Cement Replacement Using Alccofine and Metakaolin

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Abstract - In this research work, we delve into the pivotal role of concrete in modern construction practices and its indispensable nature across diverse structures. Concrete's widespread use underscores its significance in the construction industry, where economic considerations heavily rely on material cost efficiency. This study focuses on experimental investigations involving Alccofine and metakaolin, aimed at enhancing concrete strength while concurrently addressing environmental concerns such as CO2 emissions. These materials serve as substitutes for traditional cement in M20 grade concrete, with meticulous mix designs tailored to optimize performance. Metakaolin replaces cement at varying percentages (0%, 5%, 10%, and 15%), while Alccofine remains a constant 10% replacement in cement concrete. Specimens undergo rigorous curing and are subjected to comprehensive 28-day testing for compressive, split tensile and flexural strengths. This investigation aims to provide insights into the feasibility and effectiveness of using Alccofine and metakaolin as sustainable alternatives in concrete production, thus addressing both economic and environmental considerations.

***Key Words*:** Alccofine, Metakaolin, Cement, Concrete, Compressive Strength, Split Tensile Strength, Flexural Strength.

1. INTRODUCTION

The utilization of Alccofine and Metakaolin as substitutes for cement in concrete offers a dual benefit of enhancing concrete performance while addressing environmental concerns. Alccofine, characterized by its ultrafine particles and high reactivity, improves concrete strength and durability. Meanwhile, Metakaolin, derived from calcined clay, acts as a pozzolanic material, reducing cement demand and enhancing concrete properties like durability. By utilizing these materials, which are often industrial byproducts, concrete production becomes more sustainable, mitigating CO2 emissions from cement manufacturing and minimizing waste disposal. This approach aligns with global efforts to promote environmentally responsible construction practices. Continued research and development in maximizing the utilization of Alccofine and Metakaolin hold potential for further advancing sustainable construction methods and reducing the environmental impact of concrete.

Gunavant et al.[1] conducted an experimental study on High Strength-High Volume Fly Ash Concrete, emphasizing its sustainability potential. Their research delved into mechanical properties and durability of HSC incorporating fly ash, aiding in eco-friendly concrete development. Khan et al.[2] explored porosity and strength of ternary blended pastes with PFA, SF, and OPC. Their study optimizes mix designs with supplementary materials for improved concrete performance. Dave et al.[3] investigated Alccofine's influence on concrete, particularly for rigid pavement design. Using Kenpave software, they assessed Alccofine's impact on strength and durability, enhancing sustainable concrete mixes for infrastructure. Habel et al.[4] advanced concrete technology by enhancing UHPFRC's mechanical properties. Their study focused on fiber reinforcement to improve concrete strength and durability. Al Menhosh et al.[5] studied mechanical properties of concrete with Metakaolin and polymer admixture. Their research emphasized additive synergies, enhancing aspects like compressive strength and microstructure. Gupta et al[6]. offered a comprehensive review of Alccofine, discussing its properties and applications in concrete, adding insights into supplementary cementitious materials. Sabir et al.[7] reviewed Metakaolin and calcined clay as pozzolans, emphasizing their role in enhancing concrete properties and sustainability. Karthika et al[8]. conducted an experimental study on High Strength Concrete with Fly Ash and Alccofine, providing valuable insights for sustainable construction practices. Sawant et al.[9] investigated partial cement replacement with Alccofine and marble dust, evaluating mechanical properties and durability for sustainable concrete development.

2. MATERIAL INVESTIGATING

Cement is a vital building material, used in construction for its binding properties. It creates durable structures by binding materials like sand, gravel, and water, crucial for infrastructure development. In this project work we use Nagarjuna Cement. Specific Gravity is 3.15

Alccofine, an ultrafine, low calcium silicate product made in India, boosts concrete performance in both fresh and hardened states. Alccofine 1203, sourced from high-reactivity slag granulation, contains high glass content for enhanced properties. It originates from Chennai and was obtained from the Astrra Chemicals Factory.

Table-1: Chemical properties of Alccofine1203

Cao	SiO2	Al2O3	Fe2O3	MgO	SO3
30 -34%	30 -36%	18 -25%	1.8 – 3%	6 – 10%	0.1 – 0.4%

Table-2: Physical properties of Alccofine 1203

Form	Powder
Odour	Odourless
Colour	Grey
Density	2.7 – 2.9
Bulk density	Approx.700 KG/m³
% Volatiles	0G/L
Solubility in water	Insoluble
Solubility in other solvents	Slightly soluble

Metakaolin, a pozzolanic material, substitutes cement, enhancing concrete properties like strength and durability. It improves workability and reduces permeability, making it a sustainable construction solution.

Fine aggregates, like sand, are pivotal in concrete and mortar production, finer than a 4.75 mm sieve. The sand utilized in this study, with a particle size of approximately 0.07 mm, meets IS: 383-1970 Zone II standards, guaranteeing ideal concrete properties. Its specific gravity is 2.61.

Coarse aggregates, exceeding 4.75 mm, profoundly shape concrete properties. Their cleanliness and form affect adhesion to cement paste, crucial for strength and durability. Although angular aggregates enhance interlocking, they may hinder workability. This study employs graded aggregates sized at 20 mm and 10 mm, with a specific gravity of 2.81.

Water: Clean, pH-balanced tap water is essential in concrete production, hydrating cement to avoid voids or weak spots, ensuring optimal strength.

3. RESULTS AND DISCUSSIONS

Table -3: Compressive strength test results for 28 days

Mix No.	Mix Details	Compressive Strength (MPa)
M0	C100%+FA+CA	32.51
M1	C90%+AL10%+FA+CA	35.02
M2	C85%+AL10%+MK5%+FA+CA	38.51
M3	C80%+AL10%+MK10%+FA+CA	41.41
M4	C75%+AL10%+MK15%+FA+CA	31.37
M5	C70%+AL10%+MK20%+FA+CA	28.03

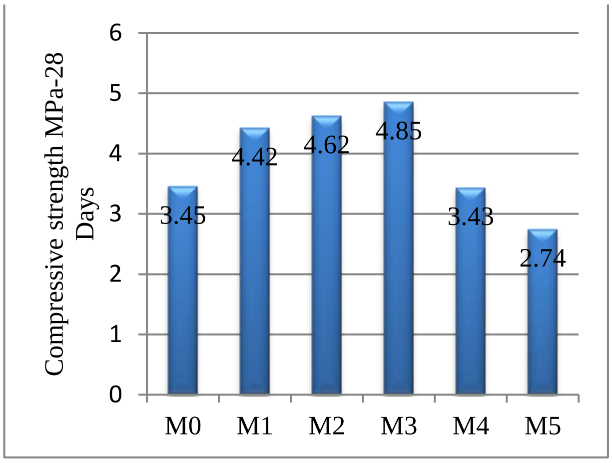

Fig -1: Compressive strength test results graph for 28 days

The comparison highlights the varied effects of incorporating Alccofine and metakaolin in concrete mixes. While Mix M1, with 10% Alccofine, exhibits a slight improvement in compressive strength compared to the control mix (M0), the addition of metakaolin yields mixed results. Mix M3, with 10% metakaolin, achieves optimal strength, indicating a balanced enhancement. However, excessive metakaolin content in M4 and M5 leads to diminishing compressive strength, suggesting the need for cautious use. These findings underscore the importance of precise mix design for concrete performance. Alccofine incorporation shows promising benefits, while metakaolin's impact is contingent on the replacement ratio. Further research is warranted to refine the utilization of supplementary materials in concrete production, ensuring optimized performance and sustainability.

Table -4: Split tensile strength test results for 28 days

Mix No.	Mix Details	Spilt tensile Strength (MPa)
M0	C100%+FA+CA	3.12
M1	C90%+AL10%+FA+CA	3.40
M2	C85%+AL10%+MK5%+FA+CA	3.83
M3	C80%+AL10%+MK10%+FA+CA	4.25
M4	C75%+AL10%+MK15%+FA+CA	2.98
M5	C70%+AL10%+MK20%+FA+CA	2.67

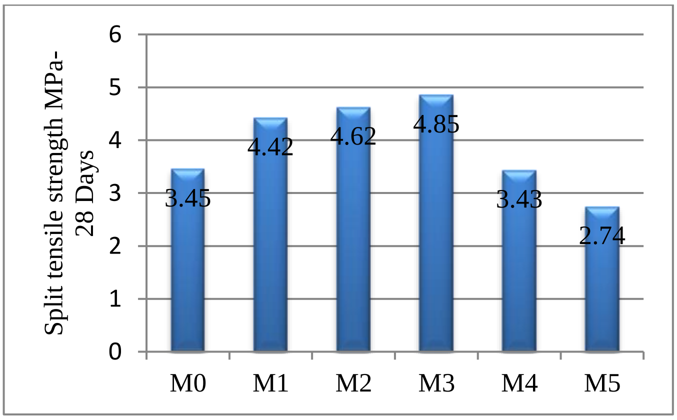

Fig -2: Split tensile strength test results graph for 28 days

The results for the 28-days period exhibit notable variations among concrete mixes incorporating Alccofine and metakaolin. Mix M1, with 90% cement and 10% Alccofine, displays a marginal increase in split tensile strength compared to the control mix (M0), suggesting a modest enhancement with Alccofine addition. As metakaolin content increases from 5% to 20% in mixes M2 to M5, a general trend of improved split tensile strength is observed. Mix M3, comprising 80% cement, 10% Alccofine, and 10% metakaolin, demonstrates the highest split tensile strength, indicating optimal performance. However, mixes M4 and M5, with higher metakaolin content, exhibit reduced tensile strengths compared to M3, suggesting potential diminishing returns with excessive metakaolin replacement. These findings underscore the importance of balanced mix designs and the potential benefits of incorporating supplementary materials like Alccofine and metakaolin in concrete production, with further research needed to refine their utilization for enhanced tensile properties.

Table -5: Flexural strength test results for 28 days

Mix No.	Mix Details	Flexural Strength (MPa)
M0	C100%+FA+CA	3.45
M1	C90%+AL10%+FA+CA	4.42
M2	C85%+AL10%+MK5%+FA+CA	4.62
M3	C80%+AL10%+MK10%+FA+CA	4.85
M4	C75%+AL10%+MK15%+FA+CA	3.23
M5	C70%+AL10%+MK20%+FA+CA	2.74

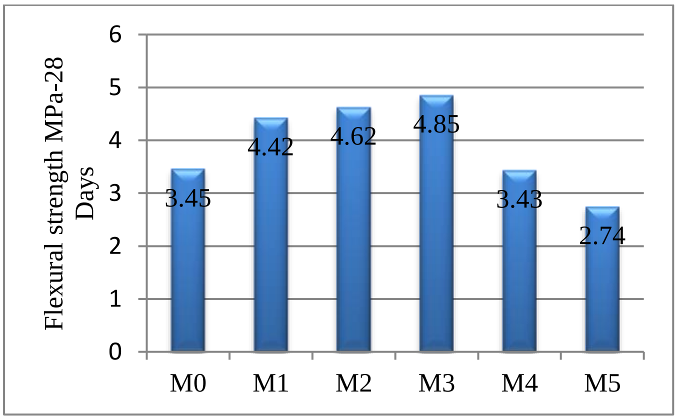

Fig -3: Flexural strength test results graph for 28 days

Flexural strength tests over 28 days show notable variances in concrete mixes with Alccofine and metakaolin. Mix M1, with 10% Alccofine, displays significantly higher strength than the control (M0), indicating Alccofine effectiveness. Metakaolin content increments from 5% to 20% in M2 to M5 show overall strength improvement. Mix M3, with 10% each of Alccofine and metakaolin, exhibits peak strength, while M4 and M5, with higher metakaolin, show diminished strength. Balanced mix designs are crucial, highlighting the potential benefits of supplementary materials in concrete, albeit further research is needed for optimal utilization.

4. CONCLUSIONS

The comparison of concrete mixes incorporating Alccofine and metakaolin reveals diverse effects on compressive, split tensile and flexural strengths. While Alccofine addition in Mix M1 shows slight enhancements in compressive strength, the impact of metakaolin varies. Mix M3 demonstrates optimal compressive, split tensile and flexural strengths, suggesting balanced enhancement. However, excessive metakaolin in M4 and M5 results in diminished strengths, emphasizing the importance of careful mix design. Future research should focus on refining the utilization of supplementary materials to maximize performance and sustainability in concrete production. Additionally, investigating the long-term durability and environmental impact of these mixes would be beneficial. Overall, while Alccofine shows promise, and metakaolin can enhance certain properties, their optimal use requires thorough understanding and precise control, ensuring optimized concrete performance for diverse construction applications. Continuing research efforts will contribute to advancing concrete technology towards more efficient and sustainable practices.

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