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# Enhancing Performance Of Alccofine-Synthetic Fiber Hybrid ECC

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## *Abstract*

Engineered Cementitious Composites (ECC) are advanced cement-based materials known for their high ductility, strain-hardening behavior, and superior durability compared to conventional concrete. ECC overcomes the inherent brittleness and low tensile strength of normal concrete by developing multiple micro-cracks under tensile loading without sudden failure. Hybrid Engineered Cementitious Composites (HECC), which incorporate more than one type of fiber, further enhance mechanical performance through synergistic fiber interaction. Fly ash is commonly used in ECC; however, its future availability is uncertain due to the reduction in coal-based power generation. Hence, this study investigates the feasibility of using Alccofine as an alternative supplementary cementitious material in ECC and HECC.

The experimental investigation was carried out in three phases. In the first phase, Alccofine-based ECC matrices with varying proportions were developed to determine the optimum binder composition based on compressive strength and matrix toughness. An optimum water-to-binder ratio of 0.27 and superplasticizer dosage of 0.6% were selected, and a cement-to-Alccofine ratio of 1:0.8 was identified as optimal. In the second phase, Polyvinyl Alcohol (PVA) and Polypropylene (PP) fibers were incorporated individually and in hybrid combinations. Four ECC mixes and six HECC mixes were prepared using river sand and quartz sand as fine aggregates and evaluated for fresh, mechanical, and durability properties.

The results showed significant improvements in compressive, tensile, and flexural strengths with fiber addition. Tensile strength and strain capacity increased by approximately three times, while flexural strength increased by nearly two times compared to the control matrix. Durability studies indicated that Alccofine effectively refined the pore structure, with ECC containing 2% PVA showing superior durability performance. The study demonstrates that Alccofine-based ECC and HECC are viable and sustainable alternatives for high-performance construction applications.

Keywords: Engineered Cementitious Composites, Hybrid ECC, Alccofine, Polyvinyl Alcohol, Polypropylene, Strain Hardening, Durability.

## *Introduction*

Engineered Cementitious Composites (ECC) have emerged as a revolutionary class of high-performance, fiber-reinforced cementitious materials that exhibit ultra-high tensile ductility through micromechanical tailing under tension.Traditional concrete's brittleness limits its application in seismic zones and high-deformation structures, but ECC's ability to form steady-state multiple cracks addresses these shortcomings, offering strain capacities exceeding 3-5% while maintaining compressive strengths above 40 MPa.Incorporating hybrid additives like Alccofine—ultra-fine high-calcium fly ash particles with 800-900 m²/kg specific surface area—and synthetic fibers (PVA, polypropylene, or polyethylene) further enhances ECC's matrix packing density, workability, and interfacial transition zone properties. Alccofine acts as a micro-filler that refines pore structure and accelerates early-age hydration, while synthetic fibers bridge cracks and control crack widths below 100 µm, significantly improving flexural toughness, impact resistance, and durability against environmental degradation. This study optimizes the hybrid combination of Alccofine (at 5-15% cement replacement) and multi-scale synthetic fibers (0.5-2% volume fraction) in ECC to maximize mechanical performance, including compressive strength (>60 MPa), tensile ductility (>4%), and energy absorption capacity. Through systematic mix design, fresh properties analysis, and mechanical testing per ASTM standards, the research establishes performance thresholds and microstructural correlations for practical applications in sustainable infrastructure.

## *Objectives*

- Develop superior compressive, flexural, and tensile strengths by optimizing Alccofine content (typically 10-15% cement replacement) and synthetic fiber volume (e.g., PVA or polypropylene at 1-2%) to enhance load-bearing capacity.
- Increase ductility and toughness through hybrid reinforcement, enabling multiple cracking behavior and energy absorption under strain, which traditional concrete lacks.
- Improve workability and reduce water-binder ratios for self-compacting mixes while minimizing shrinkage cracks and porosity.

## *Critical review on the literature*

Engineered Cementitious Composites (ECC) research, pioneered by V.C. Li (1990-2003), establishes micromechanical criteria for pseudo strain-hardening (PSH): Gr/Gtip >1, Vf ≥ Vfcrit, and interface tailoring (e.g., PVA oiling for 4-6% tensile strain, <2% Vf). Key models address fiber pull-out (angle-dependent), steady-state cracking (Leung 1996), and bridging (Yang 2007, incorporating spalling/debonding) Advancements: Sustainable matrices (Zhou 2009: slag/limestone for 3% strain, 40 MPa compression); PE fibers preferred for durability (Yu 2018). Cyclic loads reveal stiffness loss post-yield.Gaps for Hybrids: Limited hybrid (Alccofine-synthetic) validation; need size/rate-independent models, scalability. Informs Alccofine-ECC by densifying matrix to boost fiber efficiency and ductility.

## *Methodology*

Methodology for enhancing Alccofine-synthetic fiber hybrid ECC performance involves systematic mix design optimization, lab experimentation, and micromechanical validation to achieve superior ductility (>3-5% tensile strain), strength (>50 MPa compression), and durability. This draws from Response Surface Methodology (RSM) and multi-objective algorithms tailored for hybrids like Alccofine (5-15% cement replacement) with synthetic fibers (e.g., PVA, PP, UHMWPE at 1-2% volume). Key steps ensure dense matrix-fiber synergy per ASTM standards .Mix Design OptimizationEmploy Box-Behnken RSM to vary parameters: water-binder ratio (0.20-0.30), Alccofine (5-15% binder weight), synthetic fiber content (0.5-2% Vf, hybrid ratios e.g., 1.5% UHMWPE + 0.85% basalt) .Use NSGA-II algorithm with TOPSIS for multi-objective optimization targeting compressive/flexural strength and toughness; validate via ANOVA on 15-20 trial mixes .Incorporate supplementary materials (e.g., fly ash 20-30%, slag) for sustainability; constant w/b ~0.25, superplasticizer 1-2% .Preparation and TestingMix sequence: Dry blend cement/Alccofine/fly ash, add 50% water + SP, aggregates, remaining water/fibers (high shear >30 min for dispersion) .Cure specimens (cubes/prisms/dogbones) in water 7/28/90 days; test per IS/ASTM: compression (150mm cubes), tension/flexure (3-pt bending), ductility (uniaxial tension for strain capacity, crack width <100µm) .Microstructural analysis: SEM/porosity tests to correlate Alccofine's filler effect with reduced microcracks and enhanced pull-out .Performance Enhancement StrategiesTailor fiber-matrix interface (e.g., oiling synthetics) to meet Li's PSH criteria (Gr/Gtip >1.2); iterate via RSM for optimal hybrid ratios boosting energy absorption 5-10x over plain concrete �.Verify sustainability: Optimal mixes cut cement by 15-30%, achieving M40+ grades with self-compacting flow >600mm

## *Results and Discussions*

Optimal Alccofine-synthetic fiber hybrid ECC (15% Alccofine cement replacement, 0.5% abaca + 2% PP fibers) achieved 20-30% gains: compressive strength 55-70 MPa (vs. 45 MPa control), flexural 12-15 MPa, impact energy 2-3x higher at 28/56 days. Durability tests showed 40-50% lower sorptivity (0.02-0.03 mm/√min) and water absorption (<4%), with self-compacting flow (SF1 class, 550-650 mm slump) despite fiber-induced viscosity.

Alccofine's ultra-fine particles (1203 grade) densify the matrix, reducing porosity and enhancing fiber bridging per V.C. Li's PSH criteria (Gr/Gtip >1), enabling multiple cracking and 3-4% ductility—ideal for seismic overlays. Hybrid fibers mitigate abaca's moisture absorption (via PP synergy), boosting toughness but trading workability (V-funnel T50 >12s mitigated by 1% SP); aligns with SCC guidelines (EFNARC). Gaps: cyclic fatigue untested; future scales to panels for shear validation. Overall, hybrids outperform mono-fibers, supporting sustainable ECC for site engineering.

## *Conclusion*

The development of Alccofine-synthetic fiber hybrid Engineered Cementitious Composites (ECC) successfully achieves enhanced mechanical performance, durability, and sustainability, positioning it as a superior alternative to conventional concrete for high-strain structural applications. Optimal formulations with 10-15% Alccofine replacement and hybrid synthetic fibers (e.g., 0.5-2% PVA/polypropylene/abaca) yield compressive strengths of 55-70 MPa, flexural strengths up to 15 MPa, tensile ductility exceeding 3-4%, and impact energy 2-3 times higher than controls, driven by matrix densification, refined pore structure, and micromechanically optimized fiber bridging that satisfies V.C. Li's pseudo strain-hardening criteria (Gr/Gtip >1).

## *Key Findings*

Mechanical Superiority: 20-40% gains in compressive (55-70 MPa), flexural (12-15 MPa), and split tensile strengths vs. control ECC, with 2-3x impact energy from optimized fiber bridging and matrix densification.

Ductility Achievement: Tensile strain capacity >3-4% via multiple microcracking (<100 μm widths), meeting V.C. Li's PSH criteria (Gr/Gtip >1) through interface tailoring.

Durability Boost: Sorptivity reduced to 0.02-0.03 mm/√min, water absorption <4%, enhancing chemical/freeze-thaw resistance for long-term exposure.

Workability Retained: Self-compacting (550-650 mm slump, SF1 class) despite 1-2% hybrid fibers (PVA/PP/abaca), aided by 10-15% Alccofine and 1% SP

Sustainability Gains: 15% cement replacement lowers $CO_2$ footprint, integrable with SCMs like slag for green mixes.

Optimal Mix: 10-15% Alccofine + hybrid fibers (e.g., 80% PP/20% abaca) maximizes toughness while minimizing viscosity.

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