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An Experimental Investigation on M-30 Grade Concrete Prepared by Partial Replacement of Cement with Polypropylene Fiber, Coconut Shell Ash and Colloidal Nano Silica: A Review

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Abstract
The reviewed literature collectively highlights the potential of agricultural and industrial by-products—such as coconut shell ash, nano silica, polypropylene fibers, and glass powder—as partial cement replacements to produce sustainable concrete. Studies consistently show that coconut shell ash (CSA) possesses pozzolanic reactivity due to its high silica content, contributing to strength gain when used up to 10–15% replacement, beyond which dilution effects reduce performance. Nano silica (NS) accelerates hydration and refines the pore structure, significantly improving early-age compressive and tensile strengths, with optimal dosages generally in the range of 1–3% by weight of cement. Polypropylene fibers (PPF) are widely reported to enhance ductility, crack resistance, and post-cracking behaviour, though they tend to reduce workability at higher volumes. Combined use of CSA and NS achieves synergistic effects on mechanical properties and durability, while PPF further improves flexural toughness and resistance to chemically aggressive environments. Several researchers have noted that careful proportioning is crucial, as excessive amounts of any of these materials lead to strength reduction and workability loss. This review confirms that a hybrid blend of CSA, NS, and PPF is a promising pathway for developing sustainable, high-performance M-30 grade concrete.

Keywords: M-30 grade concrete; coconut shell ash; nano silica; polypropylene fibers; colloidal nano silica; sustainable concrete; pozzolanic reactivity

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1. INTRODUCTION

Concrete is essentially a heterogeneous composite material that is carefully constructed by combining water, hydraulic cement, and inert particles of different grades. When this combination undergoes the chemical process of hydration, it creates a sturdy, stone-like mass that is now the foundation of the world's infrastructure. However, there are serious environmental repercussions associated with the manufacture of regular Portland cement, which serves as the main binding agent in this matrix. Fossil fuels are used in high-temperature kilns to aid in the clinkerization process, which makes the production process very energy-intensive. Furthermore, significant amounts of carbon dioxide are chemically released into the environment during the calcination of limestone, a crucial raw material. The cement industry contributes significantly to the greenhouse effect and associated environmental contamination, accounting for around 8% of the world's anthropogenic CO_2 emissions. This calls for prompt corrective action.

The building materials industry has been aggressively looking for workable ways to lower the net cement content of concrete without sacrificing its structural integrity in response to these urgent environmental concerns. Using additional cementitious materials, especially those with pozzolanic qualities, is one of the most popular and successful tactics. Pozzolanas are siliceous or aluminosiliceous materials that have little to no cementitious value on their own. However, when they are finely divided and exposed to moisture, they react chemically with the calcium hydroxide released during cement hydration to form compounds that have binding properties similar to those of cement. Fly ash, an inorganic, mostly non-combustible fine particulate matter that is carefully collected from the flue gases of coal-burning thermal power plants using mechanical collection systems or electrostatic precipitators, is a prominent example of such an industrial waste. Chemically speaking, fly ash is rich in reactive silica and alumina, which are essential components needed for the pozzolanic reaction. Because of this, there is a noticeable and growing worldwide tendency to substitute fly ash for Portland cement in concrete mixes at ever-higher percentages, sometimes surpassing 30% to 50% by weight.

2. LITERATURE REVIEW

A literature study is required to get knowledge of the area of research, the present state of the work, and how it will be resolved in the future. A thorough literature assessment provides a solid foundation for a worthwhile research work. The first stage in beginning a research project is to identify the research's main problem and to narrow down the precise objectives that are required. Many studies and researches have been defined by experimenters to go along in order to get a specific conclusion on the research aims. In order to get at the conclusion of the problem's uniqueness and significance in a given region or subarea, a standard method will be followed in order to choose specific research objectives.

The broader domain of the respective topic of research will be the first thing to be considered while conducting a literature review. Once the domain has been narrowed down to a single point of issue, the decision will be made. It entails locating relevant articles from standard books, articles, case studies and research papers presented or published in different seminars, conferences, journals in the specific research area. Other than these scientific research articles, studying and analyzing the literature yields a well-condensed theory that is a little easier to comprehend. However, because it is not backed by adequate review by multiple academics working in the field, it does not provide a foundation for arriving at a conclusion of establishing research objectives. A research paper review is timeconsuming task. Research necessitates prior understanding of the research field. Research papers are well-organized, concise, and exact in their explanations.

2.1 Review of Literature Survey

Samuel, Abraham, et.al (2025) aimed to assess the viability of partially replacing cement with 2% nano-silica and coarse aggregate with 10% coconut shell in concrete mixes to identify optimal combinations for structural applications. Fresh concrete properties, including workability and slump, alongside hardened properties such as compressive and split tensile strengths at 7 and 14 days of curing, were systematically evaluated and compared against conventional concrete. The investigation also examines density reductions and weight savings from lightweight coconut shell incorporation, while promoting sustainable construction through waste material utilization to lower costs, minimize environmental impact, and advance nanomaterial and organic waste research in civil engineering.

Future research directions include exploring higher replacement levels of nano-silica beyond 2% and coconut shell beyond 10% to optimize performance while maintaining strength and durability. Long-term durability assessments against chemical attacks, freeze-thaw cycles, and chloride penetration are recommended, alongside structural applications in lightweight construction and integration with superplasticizers for improved workability. Comprehensive environmental impact analyses, economic feasibility studies, field trials under diverse climatic conditions, and bond strength evaluations with reinforcement would further validate the material's sustainability and practical utility in precast elements and reinforced concrete structures. [1]

Siddesha, Hanumanthappa et.al (2025) evaluated concrete in which coarse aggregate is partially replaced with coconut shell (CS) and cement is partially substituted with coconut shell ash (CSA). Owing to its high silica content, CSA exhibits pozzolanic activity by reacting with water and calcium hydroxide to form additional C-S-H gel within the matrix. Combined replacements of cement and coarse aggregate at 10%, 15%, and 20% levels were investigated, and it was observed that compressive strength decreased progressively as the proportions of CSA and CS increased.

The experimental results demonstrate modest enhancements in mechanical properties with 15% combined replacement of cement with coconut shell ash (CSA) and coarse aggregate with coconut shell (CS), yielding compressive strength increases of 2.48% at 7 days and 2.81% at 28 days. The incorporation of steel fibers further amplified these gains to 4.13% and 4.31% for the same curing periods, while split tensile strength improved by 1.62% and 3.31% at 15% replacement, rising to 4.06% and 8.09% at 20% replacement with fibers. At 20% substitution, concrete density decreased by 17%, and rapid chloride penetration test (RCPT) results indicated reduced chloride ion ingress, underscoring improved durability. [2]

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Sharma, A. et al. (2025) examined how the mechanical characteristics of M 30 grade concrete were affected by the combined effects of polypropylene (PP) fiber, coconut shell ash (CSA), and colloidal nano silica (CNS). The experimental matrix included PP fiber at a constant volume fraction of 0.5%, CNS at 1%, 2%, and 3% by weight of binder, and CSA at 5%, 10%, and 15% replacement of cement. Additional calcium silicate hydrate gel was formed within the capillary pores as a result of the pozzolanic reaction between CSA and CNS, and the fibers filled in microcracks. With compressive strength improvements of 8.4% at 7 days and 11.7% at 28 days in comparison to the control mix, the findings showed that the ternary blend of 10% CSA, 2% CNS, and 0.5% PP fiber provided the best performance. Flexural strength increased by 14.1% and split tensile strength by 16.3%. A significant increase in durability was shown by the two pozzolanic materials' combined action, which decreased water absorption by 32% and the fast chloride penetration test charge passed from 2540 to 1380 Coulombs. [3]

Rao, P. N. and Menon, G. (2025) investigated the durability properties of M 30 grade concrete made using polypropylene fibers, colloidal nano silica, and coconut shell ash. In addition to a set 2% CNS and 0.4% PP fiber by volume, the program included substituting CSA for cement at 0%, 5%, 10%, 15%, and 20%. The pore structure was greatly improved due to the nucleation impact of CNS and the pozzolanic reactivity of CSA, and the PP fibers offered micro-level fracture arresting capability. The results showed that the optimum durability indices were obtained using 10% CSA, 2% CNS, and 0.4% PP fiber. In comparison to the control, sorpitivity declined by 38% and the coefficient of water permeability by 44%. After 28 days, there was a 13.2% rise in compressive strength and a 15.8% increase in split tensile strength. The optimized mix lost just 1.3% of its weight after 90 days in a 3.5% sodium chloride solution, whereas the control group lost 3.1%, indicating improved resistance to chloride-induced degradation. [4]

Kumar, V. et al. (2025) examined the mechanical and microstructural behavior of M 30 concrete reinforced with PP fiber that included colloidal nano silica and coconut shell ash as ternary cementitious ingredients. While PP fiber was supplied at a constant dose of 0.6% by volume, the tests changed CSA from 5% to 20% and CNS from 1% to 4% by weight of cement. According to the test findings, the best combination of 10% CSA, 3% CNS, and 0.6% PP fiber enhanced the compressive strength after 7 and 28 days by 15.6% and 19.3%, respectively. After 28 days, split tensile and flexural strengths increased by 22.7% and 18.5%, respectively. Scanning electron microscopy revealed a continuous matrix with fewer microcracks in the dense interfacial transition zone caused by the simultaneous application of CSA and CNS. At 20% CSA, the density of the concrete dropped by around 6%, but the increased pozzolanic activity made up for the strength loss. For the ideal blend, rapid chloride permeability readings showed a 45% decrease in total charge passed. [5]

Babu, T. S. and Reddy, K. L. (2025) examined the response surface methodologybased optimization of M 30 concrete composed of polypropylene fibers, nano silica sol, and coconut shell ash. Compressive strength, split tensile strength, and sorpitivity were the responses to the independent variables of CSA content (5%–15%), CNS content (1%–3%), and PP fiber volume fraction (0.2%–0.6%). The optimal parameters were 9.8% CSA, 2.3% CNS, and 0.55% PP fiber, according to the statistical analysis. This resulted in a projected 28-day compressive strength of 44.5 MPa, which was just 1.4% less than the experimental value of 45.1 MPa. At the ideal combination, split tensile strength rose by 17.9% and flexural strength by 15.2%. Concrete density dropped by around 4% and the sorpitivity coefficient dropped by 35% without compromising durability. The investigation verified that a concrete with better mechanical and permeability qualities was created by the pozzolanic activity of CSA and CNS coupled with the reinforcing impact of PP fibers. [6]

Chatterjee, S. et al. (2025) described an experimental study on the long-term durability and strength of PP fiber reinforced M 30 concrete that included colloidal nano silica and coconut shell ash. The study adjusted the PP fiber concentration from 0.2% to 0.8% by volume while maintaining CSA at 10% and CNS at 2%. While the PP fibers enhanced the post-cracking toughness, the addition of CNS expedited early age hydration and offset the diluting impact of CSA. In comparison to the control, the 28-day compressive strength rose by 14.2%, split tensile strength by 21.3%, and flexural strength by 17.8% at 0.6% PP fiber. The strength increases rose by a further 6% to 8% after 180 days of continuous water curing, showing a persistent pozzolanic response. The water absorption decreased by 31% and the RCPT value decreased by 42%. The research found that the ternary system produced a low-density, long-lasting concrete with improved resistance to moisture and ion penetration that was appropriate for moderate strength structural applications. [7]

Rana Abhishek and Gupta Rahul Das (2024) investigated lightweight concrete formulations utilizing recycled coconut shells (CS) and glass pieces (GP) as partial substitutes for conventional aggregates, emphasizing sustainable construction practices. Further examined the combined effects of coconut shells (CS) and crushed glass pieces (GP) as partial coarse aggregate replacements in concrete, aiming to reduce environmental impact while meeting structural performance targets. A target compressive strength of 30 N/mm² was set for 28-day cured specimens across six M30-grade mixes (MCG00 to MCG30), incorporating CS and GP at substitution ratios of 0%, 6%, 12%, 18%, 24%, and 30%.

The experimental results revealed substantial increases in aggregate durability metrics for concrete mixes incorporating coconut shells and glass pieces compared to the control mix. Impact value rose by 55.55% to 34.05%, abrasion value by 42.07% to 42.68%, and crushing value by 45.57% to 41.14%. Workability declined, with slump reducing from 84 mm to 60 mm at 30% replacement, representing a 28.57% decrease. Compressive strength showed modest gains at optimal substitutions—reaching 22.18 N/mm² at 7 days with 18% replacement (7.04% below conventional) and 32.07 N/mm² at 28 days with 24% replacement (4.09% below conventional)—indicating viable performance with enhanced toughness. [8]

Parthiban, A. et al. (2024) examined the flexural behavior of M30-grade concrete incorporating fly ash and polypropylene fibers as partial cement replacements. Class F fly ash was used at replacement levels of 20%, 25%, and 30%, combined with polypropylene fibers at 1%, 1.5%, and 2%, with all mixes designed at a water-cement ratio of 0.4. Concrete cubes of 150 mm × 150 mm × 150 mm were cast and cured for 7, 14, and 28 days to evaluate compressive strength, enabling assessment of how varying fly ash and fiber contents influence the mechanical performance of the blended concrete.

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Results demonstrated substantial improvements in concrete properties when cement is partially replaced with fly ash and supplemented with polypropylene fibers. Specifically, the M30-grade concrete mix incorporating 30% fly ash replacement and 2% polypropylene fibers exhibited significantly enhanced compressive strength compared to conventional concrete, highlighting the synergistic benefits of these admixtures for improved mechanical performance. [9]

Ahda, Nu'man and Zulkarnain, Fahrizal (2024) investigated the partial replacement of cement with coconut shell ash and glass powder to evaluate their effects on the compressive strength and water absorption characteristics of concrete. The experimental program involved substituting cement with 5%, 7%, and 9% coconut shell ash and 10% glass powder by weight. Additionally, 5% of SikaFume, based on the total weight of concrete, was incorporated as a mineral admixture to enhance performance. The research aims to determine the optimal combination of these supplementary materials for achieving improved mechanical and durability properties of concrete.

Based on the experimental findings, the partial replacement of cement with a combination of coconut shell ash, glass powder, and SikaFume influences both the compressive strength and water absorption characteristics of concrete. The results indicate that the inclusion of coconut shell ash and glass powder produces a cementitious material with satisfactory absorption resistance, maintaining water absorption below 10%. The optimal absorption performance was observed in the BAS4 mix containing 5% coconut shell ash, 10% glass powder, and 5% SikaFume. However, increasing the coconut shell ash content to 7% and 9% led to a reduction in compressive strength, attributed to the reaction of finely ground ash with air and free lime, forming soluble compounds and initiating alkali-silica reactions—especially when glass powder particles exceeded 75 microns. The BAS1 mixture, composed of 10% glass powder and 5% coconut shell ash, yielded the optimum compressive strength value of 11.44 MPa. [10]

Patel, Akshay Kumar et.al (2022) This investigation explores the partial replacement of cement with waste materials, namely coconut shell ash (CSA) and glass powder (GP), at replacement levels of 0%, 2.5%, 5%, 7.5%, 10%, and 12.5%. Over 108 specimens were prepared and tested in the laboratory using a mix proportion of 1:2.03:3.10 (cement:sand:coarse aggregate by weight) and a water-to-cement ratio of 0.55. The study systematically evaluated key properties, including initial and final setting times, compressive strength, split tensile strength, and flexural strength, to assess the viability of these sustainable substitutions in concrete production.

Results concluded that incorporating coconut shell ash (CSA) and glass powder (GP) as waste materials enhances the compressive, split tensile, and flexural strengths of concrete, with negligible effects on mix density. Strength improvements across all curing ages were observed up to optimal replacement levels, beyond which an abrupt decline occurred due to impaired bonding at higher dosages. Notably, compressive strength exhibited a gradual increase at 7 days (2.844 N/mm²) and 28 days (2.902 N/mm²) with 10% CSA and GP addition, followed by reductions with further increases in replacement content. [11]

Yadav, Bikash K and Singh, H. Pratap (2022) employed waste materials, specifically coconut shell ash (CSA) and glass powder (GP), as partial cement replacements at levels of

0%, 2.5%, 5%, 7.5%, 10%, and 12.5% to develop sustainable concrete mixes. Over 108 specimens were prepared using a mix proportion of 1:2.03:3.10 (cement:sand:coarse aggregate by weight) and a water-to-cement ratio of 0.55. The investigation comprehensively evaluated key properties, including initial and final setting times, compressive strength (at 7 and 28 days of curing), split tensile strength, flexural strength, and workability assessed immediately after mixing.

Results revealed that incorporating coconut shell ash (CSA) and glass powder (GP) as waste materials enhances the compressive, split tensile, and flexural strengths of concrete across various curing ages, with minimal impact on mix density. Strength improvements were observed up to optimal replacement levels—10% for compressive strength (reaching 28.44 kg/cm² at 7 days and 29.02 kg/cm² at 28 days) and 7.5% for split tensile (3.81 kg/cm² at 7 days and 3.90 kg/cm² at 28 days) and flexural strengths (9.20 kg/cm² at 7 days and 9.22 kg/cm² at 28 days)—beyond which performance declined due to impaired bonding at higher dosages. The mix with 10% CSA and GP at a 0.55 water-to-cement ratio exhibited the highest compressive strength and is recommended for applications prioritizing maximum mechanical performance. [12]

Manasa, M. et.al (2022) evaluated glass fiber coconut shell concrete in comparison with conventional M30-grade concrete. It involves partially replacing 10% of coarse aggregate with coconut shells and adding glass fibers at 6% and 8% of the volume of cement, followed by casting and testing 15 cubes and 15 cylinders to determine compressive and split tensile strengths. The primary objective is to promote the use of coconut shells as a partial coarse aggregate replacement while assessing the resulting concrete's compressive strength and overall mechanical performance. The experimental investigation on glass fiber reinforced concrete (GFRC) cubes, incorporating 10% coconut shell as coarse aggregate replacement, demonstrated superior performance under forward cyclic loading compared to conventional concrete. The ultimate load-carrying capacity increased by 12.5% and 18.75% for specimens with 6% and 8% glass fiber content, respectively, accompanied by substantial improvements in load-deformation characteristics, energy absorption capacity, and ductility.

Additionally, compressive, tensile, and flexural strengths enhanced by 15-20% across varying glass fiber percentages. Overall, this GFRC formulation proves effective and economical for enhancing structural resistance to both static and dynamic loading conditions. [13]

Singh, Pankaj and Joshi, Rajesh (2022) investigated the strength characteristics of M30-grade concrete by partially replacing cement with varying proportions of NanoSilica liquid (0%, 5%, and 10% by weight) and incorporating Polypropylene fibers (0%, 0.5%, and 1% by volume). The experimental program focuses on evaluating the compressive and flexural strengths of the modified concrete mixes at curing ages of 7, 14, and 28 days. The performance of these mixes is systematically analyzed and compared with that of conventional concrete to assess the influence of Nano-Silica and Polypropylene fibers on overall strength development. Results concluded that incorporating Nano-Silica and Polypropylene fibers significantly enhances the mechanical performance of concrete. The addition of 10% colloidal Nano-Silica and 1% Polypropylene fiber yielded optimum results, increasing compressive strength by

9.58% and flexural strength by 16.34% compared to conventional concrete. The inclusion of Polypropylene fibers also improved deflection capacity, ductility, bond stress, and tension stiffening behavior, while reducing segregation and bleeding. However, workability decreased slightly due to fiber addition. The compressive strength continued to improve up to 28 days of curing but declined when Nano-Silica content exceeded 10%, indicating a threshold beyond which the material's performance diminishes. [14]

Karimipour, Arash et.al (2021) evaluated the effects of steel fibers (SF) and polypropylene fibers (PPF) on both fresh and hardened properties of high-strength concrete (HSC). A comprehensive experimental program involved 99 concrete mixes incorporating SF and PPF at volume fractions of 0%, 0.1%, 0.2%, 0.3%, 0.4%, and 0.5%, alongside nano-silica (NS) at 0%, 1%, and 2%, and silica fume powder (SP) at weight ratios of 0%, 5%, and 10%. Key properties assessed included slump for workability, compressive and tensile strengths, modulus of elasticity, water absorption, and electrical resistivity to determine the synergistic impacts of these admixtures on HSC performance.

The experimental results demonstrated substantial enhancements in high-strength concrete (HSC) properties through optimized admixture combinations. The incorporation of 1% nano-silica (NS) and 10% silica fume powder (SP) alongside 0.5% polypropylene fibers (PPF) increased compressive strength by approximately 123%. Steel fibers (SF) exhibited a more pronounced effect on tensile strength, with 0.5% SF combined with 2% NS and 10% SP yielding a 104% improvement. Additionally, increasing SF content reduced electrical resistivity, whereas PPF improved this property—particularly with 1% NS—achieving up to a 68% enhancement when combined with 0.5% SF and 10% SP. [15]

Gopu, G. N., et.al (2021) investigated the partial replacement of coarse aggregates with coconut shells and cement with glass powder in concrete mixes to promote waste material utilization. The primary objective is to reduce construction costs while mitigating environmental pollution through sustainable incorporation of these waste materials. By integrating such waste products, the study aims to achieve economic benefits alongside enhanced environmental cleanliness and resource conservation.

The experimental results demonstrate that partial replacement of coarse aggregates with 20% coconut shells and cement with 20% glass powder yields superior strength characteristics compared to conventional concrete mixes. This incorporation proves viable for recycling waste materials, enhancing workability and mechanical performance up to 20-30% replacement levels, beyond which strength declines progressively. The optimal range of 20-30% substitution is recommended to balance cost reduction, structural integrity, and environmental benefits by mitigating pollution through waste utilization in construction. [16]

Azunna, Sunday U. et.al (2019) comprehensively evaluated the properties of coconut shells and their integration into concrete as a partial replacement for fine aggregate, assessing suitability as a construction material. Concrete mixes targeting 35 MPa strength incorporated 10%, 20%, and 30% volume fractions of coconut shell substitution, with mechanical performance characterized through compressive and flexural strength tests on 72 cube specimens, alongside water absorption analysis. The resulting data were systematically

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analyzed to elucidate the impact of replacement levels on structural properties and overall concrete behavior.

The experimental findings confirm that incorporating coconut shells (CS) as a partial fine aggregate replacement enhances concrete workability, with slump increasing to 32 mm at 30% substitution, while reducing density to 2170 kg/m³. Compressive strength decreased by 9.10% to 41.07 MPa at 30% CS replacement compared to the control mix, yet remains suitable (>30 MPa) for structural applications. Flexural strength exhibited a modest 1.97% reduction (from 3.063 to 2.912 MPa), while sorptivity and initial surface absorption tests indicated higher water absorption with increasing CS content; however, production costs decreased by 5.87% at 30% replacement, supporting its economic viability. [17]

Saranya, K. et al. (2019) investigated M-30 grade concrete in which cement was partially replaced with coconut shell ash (CSA) and colloidal nano-silica (CNS). Owing to the high amorphous silica in both CSA and CNS, a pozzolanic reaction consumed calcium hydroxide and precipitated additional calcium-silicate-hydrate gel, densifying the matrix. The experimental programme considered CSA replacements of 0%, 5%, 10% and 15% by weight of cement, with CNS kept constant at 2% for the blended mixes. The results showed that 10% CSA with 2% CNS was the optimum combination, delivering a 28-day compressive strength of 42.3 MPa compared to 37.8 MPa for the control mix—a gain of 11.9%. Split tensile strength and flexural strength increased by 14.2% and 10.8% respectively at the same replacement level, while water absorption dropped from 3.9% to 2.6%, confirming a substantial refinement of the pore network. [18]

Zhang, P. et al. (2018) examined the combined influence of polypropylene (PP) fibre and nano-SiO_2 on the mechanical behaviour and durability of concrete. The experimental programme incorporated PP fibre at 0.6, 0.9 and 1.2 kg/m³ and nano-SiO_2 at 1%, 2% and 3% by weight of binder. Because of the nucleation and filler effects of nano-SiO_2, the interfacial transition zone was strengthened, while the PP fibres bridged micro-cracks and restrained their propagation. The findings demonstrated that the optimum dosage of 2% nano-SiO_2 and 0.9 kg/m³ PP fibre enhanced 28-day compressive strength by 17.6%, splitting tensile strength by 34.1% and flexural strength by 28.7% relative to the plain concrete. Furthermore, the chloride diffusion coefficient was reduced by approximately 40%, indicating a significant improvement in impermeability and long-term durability. [19]

Bathula, Srikanth and Suneetha P. (2018) The research involved characterizing raw materials and designing M20-grade concrete mixes using the ACI method, resulting in ten mix variations. Fine aggregate was partially replaced with rubber aggregate at 10%, 20%, and 30%, while silica fume replaced cement at 0%, 10%, and 15% for each rubber content, alongside a control mix without fine aggregate replacement for comparison. Concrete cubes, cylinders, and beams were cast from these mixes to evaluate their mechanical and durability performance relative to the control.

Results stated that control mix (CCM) records a failure load of 477.9 kN, equivalent to 21.24 MPa. For rubber-modified mixes without SF (CS10-SF0%, CS20-SF0%, CS30-SF0%), failure loads range from 436.7 to 378.5 kN (19.91 to 16.81 MPa), reflecting strength reductions of

8.6% to 20.8%. With 10% SF, optimal enhancements occur at 10% rubber (532.1 kN, 23.64 MPa, +11.3%) and 20% rubber (537.3 kN, 24.15 MPa, +13.7%), while 30% rubber yields 478.5 kN (20.26 MPa, -4.6%). At 15% SF, strengths decline across all rubber levels: CS10-SF15% (336.8 kN, 14.97 MPa, 29.5%), CS20-SF15% (412.4 kN, 18.33 MPa, -13.7%), and CS30-SF15% (425.2 kN, 18.9 MPa, -11.0%), indicating diminishing returns and suboptimal performance at higher SF dosages. [20]

Pannirselvam, Mouli, Chandra K et.al (2018) examined the combined influence of Nano-Silica (NS) and banana fibers (BF) on the mechanical performance of hardened concrete. Nano-Silica was incorporated as a partial cement replacement in varying proportions of 0%, 2%, 2.5%, 3%, 3.5%, 4%, and 4.5% by weight, while banana fibers were introduced as a volumetric replacement at levels of 1% to 6%. The study utilized banana fibers of 40 mm length to assess their reinforcement potential. The primary objective was to experimentally evaluate the compressive and split tensile strength of Nano-Silica concrete reinforced with Musa acuminata (banana) fibers at different curing ages. Comparative analysis was conducted between Banana Fiber Reinforced Nano-Silica Concrete (BFRNSC) and conventional concrete to determine performance variations across different mix proportions and ages, ultimately identifying the optimum fiber content for enhanced mechanical properties.

Results demonstrated that incorporating banana fibers into Nano-Silica concrete significantly enhanced its mechanical performance. The inclusion of banana fibers led to notable improvements in both compressive and split tensile strengths, as well as in the cracking resistance of the concrete, compared with conventional M30-grade concrete. The strength of the composite increased progressively with the addition of Nano-Silica and banana fibers up to an optimal combination of 3% NS and 3% BF, beyond which a slight decline in strength was observed. At this optimal level, the compressive strength exhibited maximum increments of 35.2% at 7 days and 41.25% at 28 days, while the split tensile strength improved by 26.9% and 43.03% for the same respective curing periods, indicating the synergistic effect of Nano-Silica and banana fibers on concrete performance. [21]

Hosanna, S et.al (2018) In this study, finely powdered waste glass is used as a partial replacement of cement in concrete and its performance is compared with conventional concrete. The work investigates the feasibility of using glass powder as a cement replacement material for new concrete. Glass powder is partially replaced at 0%, 25%, 35% and 50% of cement and the mixes are tested for compressive, tensile and flexural strength at 7 and 28 days, then compared with conventional concrete; from the results, glass powder is found suitable for use as a cement replacement material.

Results stated that incorporation of glass powder as a partial cement replacement in M20-grade concrete offers environmental benefits by mitigating the greenhouse gas emissions associated with cement production. This modification enhances compressive, split tensile, and flexural strengths compared to conventional concrete, with optimal performance observed at replacement levels up to 25%, beyond which strength declines at both 7 and 28 days of curing. Specifically, higher replacements of 35% and 50% result in reductions of compressive strength by 35% and split tensile strength by 50%, accompanied by decreased workability and increased water demand. The maximum viable replacement level is thus established at 25% for achieving balanced mechanical properties and sustainability. [22]

Umamaheswari, R. and Kumar, M. Vignesh (2018) evaluated the mechanical and durability properties of M50-grade concrete incorporating Ordinary Portland Cement partially replaced with coconut shell ash (5%, 10%, 15%) and silica fume (5%, 10%) at a water-cement ratio of 0.35. Material characterization included collection and testing of coconut shell ash and silica fume samples, alongside assessment of normal consistency and setting times for cement pastes with these replacements. Comprehensive performance testing encompassed compressive strength, flexural strength, split tensile strength, durability, and density to determine the efficacy of these sustainable admixtures.

The experimental results demonstrate that concrete mixes incorporating 15% coconut shell ash (CSA) and 10% silica fume (SF) exhibit superior compressive, split tensile, and flexural strengths compared to other combinations. The optimal replacement dosage was determined to be 10% CSA combined with 10% SF, yielding significant enhancements in mechanical properties relative to conventional concrete. This confirms the efficacy of partial CSA and SF substitution for improving concrete performance while promoting sustainable material utilization. [23]

3. CONCLUSION

Studies consistently show that coconut shell ash (CSA) possesses pozzolanic reactivity due to its high silica content, contributing to strength gain when used up to 10–15% replacement, beyond which dilution effects reduce performance. Nano silica (NS) accelerates hydration and refines the pore structure, significantly improving early-age compressive and tensile strengths, with optimal dosages generally in the range of 1–3% by weight of cement. Polypropylene fibers (PPF) are widely reported to enhance ductility, crack resistance, and post-cracking behaviour, though they tend to reduce workability at higher volumes. Combined use of CSA and NS achieves synergistic effects on mechanical properties and durability, while PPF further improves flexural toughness and resistance to chemically aggressive environments. Several researchers have noted that careful proportioning is crucial, as excessive amounts of any of these materials lead to strength reduction and workability loss. This review confirms that a hybrid blend of CSA, NS, and PPF is a promising pathway for developing sustainable, high-performance M-30 grade concrete.

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