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Influence of Chemical Admixtures on Properties of Structural Concrete

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Abstract

Chemical admixtures play a vital role in enhancing the strength and performance of concrete mixes. These admixtures modify various properties of concrete during the production stage as well as during the setting and hardening periods. The strength and durability of concrete structures significantly depend on the appropriate use of chemical admixtures. They contribute to early strength gain, adjust setting times, improve curing efficiency, and help achieve the desired mechanical properties as per design requirements. Chemical admixtures also interact with the cement hydration process over time, offering long-term protection to concrete against environmental factors. In coastal or high-rainfall regions, their application is especially beneficial, as they help safeguard reinforced concrete structures from corrosion and deterioration. This study focuses on the use of chemical admixtures in concrete incorporating coir fibers and Class C fly ash, using an M30 grade mix design. A PC-200 superplasticizer was employed as the chemical admixture during the experimental phase. PC-200 is a high-range water-reducing admixture based on polycarboxylate ether (PCE) technology. [9]. It is commonly used to improve the workability and strength characteristics of concrete without increasing water content. As a third-generation superplasticizer, PC-200 offers superior dispersion of cement particles, resulting in enhanced flowability, reduced water-cement ratio, and improved early and final strength development. The test results demonstrated that the inclusion of coir fibers effectively controlled cracking and improved tensile strength, while the addition of fly ash enhanced the long-term durability of the concrete. Comparative analysis between the nominal mix and the mix with chemical admixtures showed that the modified concrete mix exhibited superior performance in both strength and durability. These findings suggest that judicious use of fly ash and coir fibre that can contribute significantly to sustainable constructions, lowering construction costs, and minimizing environmental impact.

Keywords: Chemical admixture, Fly ash, Coir fibre and Sustainable concrete.

1. Introduction

Concrete is one of the most widely used and versatile construction materials in the modern world, with its usage expanding significantly over the past few decades. It is primarily composed of cement, natural aggregates (coarse and fine), and a calculated quantity of water. The mix design of concrete is carefully determined by engineers or designers based on several key factors, including the structural requirements, environmental exposure, site-specific conditions, and prevailing climatic conditions. These parameters guide the selection of appropriate material proportions to ensure a concrete mix that achieves the desired strength, workability, and durability.

A well-designed concrete mix not only ensures structural integrity but also contributes to reduced maintenance over the life of the structure. In regions experiencing heavy rainfall or coastal environments, the durability of reinforced concrete becomes a critical concern. Despite providing adequate cover to reinforcement bars, moisture ingress can lead to the initiation of corrosion in steel. The presence of chlorides, sulfates, or other aggressive agents accelerates this process. Once corrosion begins, it expands the steel, creating internal stresses that lead to cracking and eventual spalling of the concrete, severely compromising the structure's integrity.

Additionally, issues such as improper compaction during concrete placement can result in defects like honeycombing or voids within the concrete mass. These flaws not only weaken the structural load-bearing capacity but also increase permeability, allowing water and harmful agents to penetrate more easily. As a result, such deficiencies accelerate the deterioration of concrete structures and reduce their service life.

Ensuring proper compaction, mix design optimization, and the incorporation of advanced materials such as chemical admixtures and supplementary cementitious materials are essential to producing durable, long-lasting concrete structures. Modern concrete technologies also include the use of corrosion inhibitors, waterproofing agents, and fiber reinforcements to enhance performance in aggressive environmental conditions.

Apart from durability and performance considerations, the modern construction industry increasingly demands rapid construction techniques to meet tight project deadlines, reduce labor costs, and minimize disruption to the environment and surrounding infrastructure [1]. In such scenarios, achieving early strength in concrete becomes a critical requirement. Traditional concrete typically requires several days to attain sufficient strength for formwork removal, load application, or subsequent construction activities. However, in fast-paced construction environments—such as high-rise buildings, infrastructure projects, or precast concrete manufacturing—delays caused by slow strength gain can significantly impact project timelines and productivity.

To address this challenge, the development of concrete mixes capable of gaining strength at an accelerated rate has become a focus area. This is made possible through the use of chemical admixtures specifically designed to enhance early-age strength without compromising long-term performance. These admixtures interact with the hydration process of cement, accelerating the rate of reaction and improving the early strength development within the first 24 to 72 hours.

Various types of chemical additives are available in the market, each tailored to specific project requirements and environmental conditions. These include: Accelerators, which speed up the setting and early strength gain of concrete, Superplasticizers, which enhance workability at low water-cement ratios while contributing to strength development, Retarders, used to delay setting time in hot weather concreting, Shrinkage reducers, to control early-age cracking, and Corrosion inhibitors, especially in coastal and industrial environments [2]. The selection and dosage of these admixtures are typically based on factors such as ambient temperature, required workability, desired setting time, type of cement used, and structural application. The use of such admixtures enables contractors and engineers to design concrete that not only performs well under long-term loading but also meets the growing demand for speed and efficiency in construction. Ultimately, integrating these advanced materials into concrete technology is essential to meet the dual goals of rapid execution and structural longevity in today's dynamic construction landscape. The main purpose of this study is to investigate the effect of chemical admixtures on concrete properties with fly ash and coir fibres. Various tests were conducted to examine the variation in concrete micro structural properties and conclusions were drawn on the results.

2. Methods

Aggregates

Aggregates—both coarse and fine—are fundamental components of concrete, significantly influencing its strength, durability, and overall performance. Coarse aggregates are generally sourced from crushed stone obtained from quarries and must comply with specific gradation and quality criteria to ensure effective interlocking and uniform load distribution in the hardened concrete.

In the present study, coarse aggregates were procured from a nearby stone quarry and subjected to a series of standard laboratory evaluations to determine their physical characteristics. These tests included specific gravity, water absorption, aggregate impact value, and crushing strength. The results confirmed that the aggregates met the specifications outlined in relevant standards, with gradation falling within the permissible limits.[13]. This verified their appropriateness for use in concrete construction.

Fine aggregates, commonly known as manufactured sand (M-sand), were also sourced from the same quarry. For application in concrete, it is essential that fine aggregates be free from impurities such as silt, clay, organic matter, and other deleterious substances, as these can compromise the bond strength and durability of the concrete. In this investigation, M-sand was tested for critical physical properties including fineness modulus, specific gravity, silt content, and bulk density, following the procedures outlined in IS: 2386 (Part I & III).

The test results indicated that the fine aggregates were well-graded and free from harmful contaminants, confirming their suitability for use in concrete mixes formulated for rigid pavement applications. Ensuring the quality and compatibility of both coarse and fine aggregates laid a solid foundation for the development of concrete mixtures incorporating sustainable materials such as fly ash and coir fiber.

Cement

In this study, Ordinary Portland Cement (OPC) of 53 grade was used as the primary binding material for the preparation of concrete mixes. The selection of 53-grade cement was based on its high early strength characteristics, which are particularly beneficial in concrete applications where early load-bearing capacity is often desirable. The cement used conformed to the specifications of IS: 12269-2013, which outlines the requirements for 53-grade OPC in terms of chemical composition, physical properties, and performance criteria.[10]

A series of standard laboratory tests were conducted to evaluate the physical properties of the cement. The results, indicating its suitability for use in concrete mix design calculations, particularly for determining the mix proportions and unit weight of the mix.

Fly Ash

Fly ash is a fine particulate byproduct predominantly generated during the combustion processes in various industries, including paper mills. In the present study, fly ash was sourced from a paper mill located in Bhadravathi, Shimoga District, Karnataka. This industrial byproduct, collected through electrostatic precipitators or filter bags, was thoroughly tested to evaluate its suitability as a partial replacement for cement in concrete mixtures [12].

Known for its pozzolanic properties, fly ash reacts with calcium hydroxide in the presence of moisture to form additional cementitious compounds. This reaction contributes to enhanced workability, reduced heat of hydration, and improved long-term strength and durability of concrete. Moreover, the use of fly ash significantly lowers the environmental impact of cement production by reducing the demand for Portland cement, thereby minimizing associated carbon emissions.

The application of fly ash as a supplementary cementitious material is widely endorsed by national and international standards [14], and is well-supported by existing literature for its benefits in sustainable construction practices. In this study, fly ash was incorporated as an additive with cement to enhance both the environmental and economic efficiency of the concrete mix, without compromising its structural performance. This approach aligns with contemporary green building strategies and promotes the beneficial reuse of industrial waste in infrastructure development.

Coir Fibre

Fibres are commonly incorporated into concrete to improve its tensile strength, crack resistance, and post-cracking behavior. Their inclusion helps to control micro-crack propagation, enhances ductility, and contributes to the overall toughness of the composite material[3]. Among various types of fibres studied, natural fibres have gained increasing attention due to their environmental sustainability, cost-effectiveness, and availability. Numerous studies and case investigations have examined the performance of natural fibres such as coconut fibre, bamboo fibre, and banana fibre in combination with cementitious matrices. These investigations consistently demonstrate that natural fibres significantly enhance the mechanical performance of concrete, particularly in terms of flexural and tensile strength, impact resistance, and durability. In addition to their mechanical benefits, natural fibres also contribute to reducing the environmental impact of construction materials by promoting the use of renewable and biodegradable resources[4]. In the present experimental study, natural jute coir fibre—abundantly available and biodegradable—was selected as a reinforcing material in concrete. Jute coir was chosen due to its notable physical properties, including high tensile strength, lightweight nature, and strong bonding ability with cement paste. The fibre was incorporated in various proportions to evaluate its influence on the strength parameters of concrete, such as compressive strength and flexural strength. The results obtained from this investigation are discussed in detail and affirm the potential of jute coir fibre to enhance the structural performance of sustainable concrete composites.

Water

The quality of water used in concrete preparation plays a crucial role in determining its workability and strength characteristics. Ideally, the water should be potable—that is, safe and suitable for drinking—as it indicates the absence of harmful impurities that could adversely affect the hydration process or the long-term durability of the concrete.

Fig. 1. Fly ash, Coir fibre and Chemical admixture

Proportioning of Materials & Test results

In this research work, PC–200 superplasticizer was employed as a chemical admixture to investigate its influence on the compressive strength characteristics of concrete. A nominal M25 grade mix was designed in accordance with IS code specifications, with a water–cement (w/c) ratio of 0.4. All concrete mixes included coir fibre and fly ash as supplementary materials and were evaluated in comparison to the nominal mix without additives[5].

To assess the mechanical performance of the modified concrete, the proportions of coir fibre and fly ash were selected based on previous literature and relevant standard guidelines to ensure optimal performance. Concrete specimens were cast in standard cube moulds measuring 150 mm × 150 mm × 150 mm, adhering to the testing procedures specified in IS: 516 – 1959 for compressive strength evaluation.

After casting, all specimens were subjected to curing under controlled conditions to promote proper hydration and strength development. Curing was carried out for durations of 7, 14, and 28 days, reflecting typical field practices and allowing for comprehensive strength assessment over time. In addition to compressive strength tests, beam specimens were also prepared and tested for flexural strength, with results reported after 28 days of curing.

The chemical admixture (PC–200) was used in incremental dosages ranging from 0.0% to 2.2%, and its effects on the mechanical behavior of concrete were systematically studied. As the primary objective of this research was to evaluate the role of chemical admixtures in enhancing concrete performance, the results have been presented specifically in relation to the varying dosages of the superplasticizer [6].

The findings from this experimental study provide valuable insights into the mechanical behavior and practical feasibility of incorporating chemical admixtures along with coir fibre and fly ash in structural-grade concrete, with an emphasis on sustainable and performance-oriented mix design.

Compressive strength

Table 1 represents mix proportions considered for test purpose and obtained compressive strength test results for 7,14 and 28 days of curing. Fig. 2. represents the graphical representation of the compressive test results. Fig. 3. Represents graphical representation of effect of coir fibre and fly ash dosage on 28-day compressive strength.

Table. 1 Mix proportions & Compressive strength test results

Mix Design -ation	Materials	Dosage of PC – 200/100 kg cement	Compressive strength, N/mm^2		
			7 Days	14 Days	28 Days
M1	NM	0.0	16.2	24.2	29.4
M2	NM+CF+FA	1.0	17.5	24.5	29.8
M3	NM+CF+FA	1.2	17.8	24.8	30.1
M4	NM+CF+FA	1.4	18.2	25.1	30.2
M5	NM+CF+FA	1.6	18.5	25.6	30.5
M6	NM+CF+FA	1.8	18.7	25.8	30.6
M7	NM+CF+FA	2.0	18.9	26.1	31.2
M8	NM+CF+FA	2.2	18.6	25.8	30.9

NM – Nominal mix, CF – Coir Fibre, FA – Fly Ash

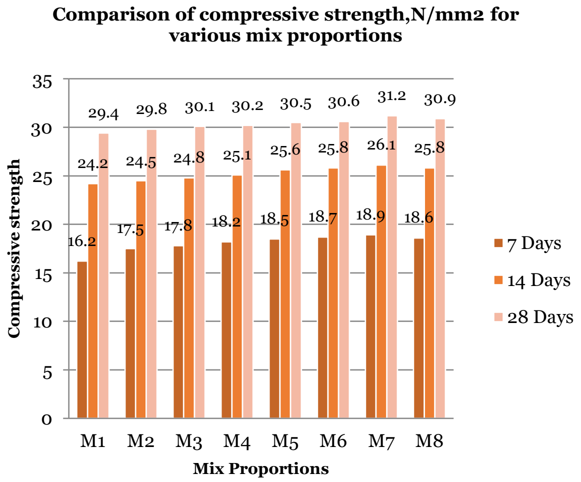

Fig. 2. Graphical representation of compressive strength of various mix proportions

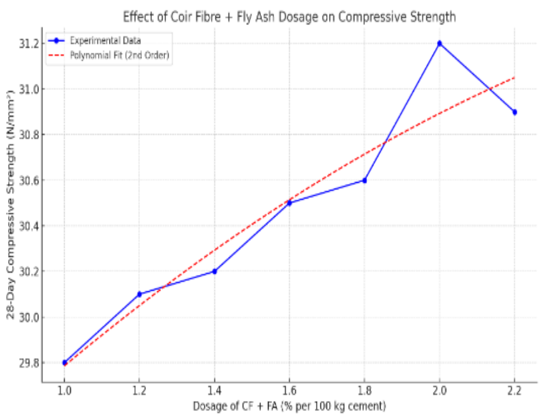

Fig. 3. Graphical representation of effect of coir fibre and fly ash dosage on 28-day compressive strength

From Fig.3. the curve clearly illustrates a peak strength at 2.0% dosage, confirming it as the optimal point, followed by a slight reduction beyond that level.

Discussions on compressive strength test results

The results indicate a consistent increase in compressive strength with the addition of coir fibre and fly ash up to a dosage level of 2.0%. Mix M7, containing 2.0% of CF+FA, exhibited the highest compressive strength at all curing ages, with a peak value of 31.2 N/mm² at 28 days. Beyond this dosage, a slight reduction in strength is observed, as seen in Mix M8, suggesting that 2.0% is the optimum dosage level for coir fibre and fly ash in this concrete mix. This enhancement can be attributed to the pozzolanic reaction of fly ash and the crack-bridging ability of coir fibres, which improve the microstructure and load-bearing capacity of the concrete.

The compressive strength results for concrete mixes M1 through M8, incorporating varying dosages of coir fibre and fly ash, were evaluated at 7, 14, and 28 days of curing. The key observations from the experimental data are as follows:

Control Mix (M1): The nominal mix without any fibre or fly ash achieved a 28-day compressive strength of 29.4 N/mm². Effect of CF and FA Addition (M2–M8): A progressive increase in compressive strength was observed with the addition of CF and FA up to a dosage of 2.0% (M7). Beyond this point, a marginal decline in strength was noticed at 2.2% (M8). Optimum Performance (M7): The highest compressive strength of 31.2 N/mm² was achieved at 2.0% dosage, showing a 6.1% improvement over the control mix. This enhancement is attributed to: The pozzolanic reaction of fly ash, which refines the microstructure and contributes to long-term strength gain. The bridging effect of coir fibres, which controls micro-crack propagation and increases the ductility of the matrix. Diminishing Returns (M8): At 2.2% dosage, the compressive strength slightly dropped to 30.9 N/mm². This indicates that excessive fibre content may lead to poor workability and inadequate compaction, resulting in decreased performance. Early Strength Development: All modified mixes showed slightly higher early-age strength (7 and 14 days) than the control mix, suggesting that coir fibre and fly ash do not delay early hydration significantly when used in optimum proportions.

Flexural Test

It is the ability of concrete to resist failure in bending. It reflects how well concrete can withstand tensile stress developed at the bottom fibers when subjected to bending, such as in beams, and slabs. Test is conducted as per IS 516:1959. Specimens of standard beam of 100 mm × 100 mm × 500 mm or 150 mm × 150 mm × 700 mm were casted for testing purpose. Two-point loading is used for loading pattern. Table 2 represents the split tensile test results for 28 days of curing. Fig. 4 represents the graphical representation of the split tensile test results. And Fig. 5. Graphical representation of the relationship between coir fibre + fly ash dosage

Table 2. Flexural test results

Mix Designation	Materials	Dosage of PC – 200/100 kg cement	Flexural strength, N/mm²
			28 Days
M1	NM	0.0	4.18
M2	NM+CF+FA	1.0	4.21
M3	NM+CF+FA	1.2	4.25

M4	NM+CF+FA	1.4	4.22
M5	NM+CF+FA	1.6	4.26
M6	NM+CF+FA	1.8	4.54
M7	NM+CF+FA	2.0	4.55
M8	NM+CF+FA	2.2	4.51

NM – Nominal mix, CF – Coir Fibre, FA – Fly Ash

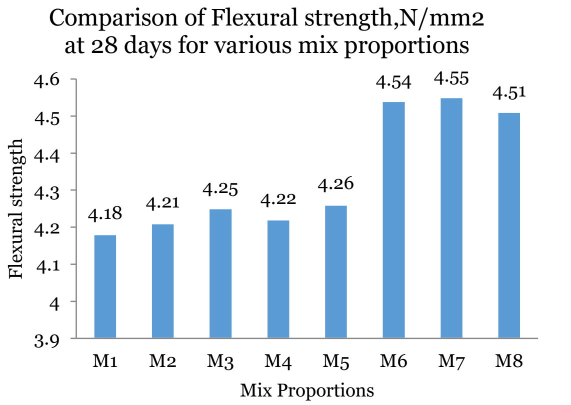

Fig. 4. Graphical representation of flexural test of various mix proportions

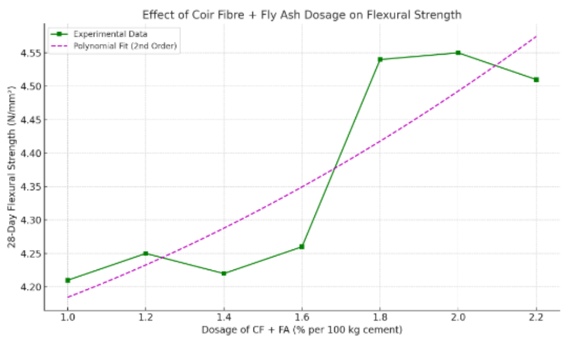

Fig. 5. Graphical representation of the relationship between coir fibre + fly ash dosage

Discussion of flexural test

Fig.4 showing the relationship between coir fibre + fly ash dosage and the 28-day flexural strength of concrete. The trend indicates a gradual increase in strength, reaching a peak at 2.0% dosage (M7) with a slight drop afterward, similar to the compressive strength pattern. This suggests that 2.0% is also optimal for maximizing flexural performance.

The flexural strength of concrete plays a vital role in evaluating its performance under bending loads, particularly in pavements and structural elements subject to flexural stresses. The 28-day flexural strength results for mixes M1 through M8, incorporating varying percentages of coir fibre (CF) and fly ash (FA), are summarized and analyzed as: Control Mix (M1): The nominal mix (NM) without any additives achieved a 28-day flexural strength of 4.18 N/mm². Modified Mixes (M2–M8): With the addition of CF and FA, there was a noticeable improvement in flexural strength across all mixes. The maximum flexural strength was achieved at 2.0% dosage (M7), reaching 4.55 N/mm², which reflects an 8.9% increase over the control mix.

Trend Analysis: A gradual increase in strength was observed from 1.0% to 1.2%, a slight dip at 1.4%, followed by a significant jump at 1.6% to 2.0%. Beyond 2.0% dosage, a marginal decrease was seen in M8 (4.51 N/mm²), indicating a potential saturation point beyond which additional fibre may begin to impair mix workability and homogeneity.

Effect of Coir Fibre and Fly Ash: The coir fibre improved crack-bridging and enhanced energy absorption, contributing to higher post-cracking performance and flexural strength. The fly ash, as a pozzolanic material, refined the microstructure and improved the matrix-fibre bond, further aiding in load transfer under bending.

3. Results

The incorporation of coir fibre and fly ash into nominal concrete mixes positively influences compressive strength, particularly at an optimal combined dosage of 2.0% per 100 kg of cement. A maximum strength gain of 31.2 N/mm² at 28 days was recorded for Mix M7, which is 6.1% higher than the control mix. Beyond the 2.0% dosage (M8), a slight reduction in strength was observed, likely due to fibre clustering or workability issues, indicating that excess fibre can be detrimental to compaction and strength development [7]. The results validate the potential of natural coir fibre and industrial byproduct fly ash as sustainable additives in concrete, offering both environmental and mechanical performance benefits [8]. This study supports the application of agro-industrial waste in concrete technology, promoting a circular economy approach and contributing to green construction practices.

Incorporation of coir fibre and fly ash into nominal concrete led to a consistent improvement in 28-day flexural strength, confirming their beneficial synergistic effect. The highest flexural strength was recorded at 2.0% dosage (M7), achieving 4.55 N/mm², which is approximately 9% higher than that of the control mix. This highlights the optimum dosage for maximizing bending performance. A slight reduction in strength at 2.2% (M8) suggests that excessive fibre content may hinder uniform dispersion and affect bonding, pointing to a practical dosage limit for optimal performance. These results confirm the feasibility of using agro-industrial waste (coir fibre and fly ash) in concrete not only for sustainability but also for enhancing mechanical properties. The observed trends in both compressive and flexural strength reinforce the selection of 2.0% CF+FA dosage as the optimal level for improved overall concrete performance in rigid pavement and structural applications.

Refrences

[1] Aggoun,S "Effect of some admixtures on the setting time and strength evolution of cement pastes at early ages". Construction and Building Materials. (2008) Vol 22(2): 106-110.

[2] F. Cassagnabre, G. Escadeillas, "Study of re-activity of Cement/matakoalin binders at early age for specific use in steam precast concrete", Construction and Building material 23 (2009) 775-784.

[3] J.M.L. Reis, "Fracture and flexural characterization of natural fiber-reinforced polymer concrete", Constr. Build. Mater. (2006)

[4] Marvila, M.T., Rocha, H.A., de Azevedo, A.R.G. et al. "Use of natural vegetable fibers in cementitious composites: concepts and applications". Innov. Infrastruct. Solut. 6, 180 (2021). https://doi.org/10.1007/s41062-021-00551-8

[5] Novinson T, Crahan J. "Lithium salt as set accelerator for refractory concretes: Correlations of chemical properties with setting time". ACI Materials Journal (1988). Vol. 85: 12-6.

[6] P. K. Mehta, and P. J. M. Monteiro, "Concrete Microstructure, properties and materials", 3rd Ed. Prentice Hall, NJ, 1998.

[7] Tattersall G.H. and P.F.G. Banfill, 1983, Rheology of fresh concrete, pitman advanced publishing program.

[8] Tae - Beom Min. et. al, "Experimental study on the development of compressive strength of early concrete age using calcium- hardening accelerator and high early strength cement", Construction and Building material 64 (2014): 208 - 214.

[9] V. S. Ramachandran, "Concrete admixtures handbook", Standard Publishers, New Delhi 2002.

[10] IS 8142 (1976): Method of test for determining setting time of concrete by penetration resistance.

[11] IS 7320 (1974): Specification for concrete slump test apparatus.

[12] IS: 6491-1972, Methods for sampling of Fly ash, Bureau of India standards, India.

[13] IS: 383 – Specification for Coarse and Fine Aggregates from Natural Sources for Concrete.

[14] IS: 3812 (Part 1) – 2013, Specifications for fly ash used in concrete.