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Performance of Sisal Fiber Concrete Using Fly Ash and Silica Fume Enhancements

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Abstract

The construction industry has advanced significantly in constructing innovative structures using diverse materials. Various waste materials such as fly ash, sawdust, and residues of natural fibers have been utilized in the construction industry. Addressing these concerns requires exploring low-cost, environmentally friendly, and sustainable materials. This paper aims to investigate mixing silica fume, fly ash, and sisal fiber into concrete to address waste disposal and global warming issues while creating stronger concrete. Using natural fibers and additional cement materials in concrete has become increasingly popular recently because they can enhance durability and tensile strength. In this study, several concrete mixtures were made with distinct proportions of sisal fiber and fly ash, and micro silica fume. The mechanical properties of the produced concrete were evaluated and compared to those of traditional concrete. Addition of silica fume into the concrete 5% by the weight of cement, fly ash replacement 5%, 10%, 15%, and 20% by the weight of cement, and addition of sisal fiber 0.5%, 1%, 1.5%, 2% in concrete (M30 grade) were studied. The samples were tested for compression, flexure, and split tension after 7 and 28 days of curing. The samples were subjected to tests to assess their compressive, tensile, and flexural strengths. An increase in compressive strength by 21.67%, tensile strength by 20.56%, and flexure strength 16.18% was observed for 1.5% addition of fiber, 15% replacement of fly ash, and 5% addition of silica fume in M30 grade of concrete. Incorporation of silica fume improves the bond strength whereas sisal fiber bridges the cracks developed in the concrete by increasing the ductility and decreasing the brittleness and offers resistance to impact loading.

Keywords: Sisal fiber, silica fume, fly ash, compressive strength, tensile strength, flexural strength, concrete, mix proportions, sustainability

INTRODUCTION

Concrete is a popular construction material made from a blend of cement, aggregates (like sand and gravel), water, and occasionally additional additives or admixtures. It is valued for its strength, durability, and versatility. Traditionally, concrete has been reinforced with materials like steel bars or mesh to improve its tensile strength and crack resistance.

Sisal fiber, derived from the *Agave sisalana* plant is used to enhance various strength properties of concrete, aiming for sustainability, and improved structural quality. Short, discrete vegetable fibers, such as sisal, have been evaluated for their suitability in cement concrete. These fibers show no deterioration when embedded in concrete. The leaves are dried, brushed, and baled to form the fiber.

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Concrete is a composite material made of binder and fillers, where cement and water act as the binder, and coarse and fine aggregates serve as the fillers. This material exhibits strong compressive strength but is approximately 8% to 10% weaker in tension. To improve these properties, reinforcement is added, and fibers have always been seen as a promising reinforcement option for cement. However, the main drawback of incorporating fibers into concrete is the high cost, and it also reduces the workability of the mix. Sisal fiber–reinforced concrete must be mixed by hand, with fibers randomly distributed throughout the mixture. The failure strength and modulus of elasticity of this concrete depend on the cellulose content and the orientation of the microfibers.

This study investigates the physical properties of both conventional concrete and sisal fiber-reinforced concrete, aiming to enhance the properties of concrete by incorporating sisal fiber. Sisal fiber, derived from the leaves of the agave species, is a strong and durable natural fiber commonly used in products such as rope, twine, carpets, mats, and paper. Sisal fiber is noted for its excellent tensile strength, abrasion resistance, and ability to maintain its shape. It is also a sustainable and renewable resource, as the sisal plant requires minimal water and can be harvested multiple times throughout its life span (Figure 1).


Figure 1. Agave species.

Additionally, sisal fiber as shown in Figure 2 helps to reduce the formation of plastic shrinkage cracks in concrete. These cracks occur when the concrete surface dries too quickly losing moisture faster than it can be replenished. By incorporating sisal fibers into the concrete mix, the fibers serve as reinforcement, decreasing the likelihood of cracking and enhancing the overall durability of the concrete. The use of sisal fiber in concrete can boost the material overall strength and longevity. Adding sisal fibers to concrete improves its resistance to cracking and shrinkage while also increasing its flexural and tensile strength. Sisal fibers exhibit good bonding properties with the cement matrix contributing to improved cohesion and durability of the concrete.


Figure 2. Sisal fiber.

AIM AND OBJECTIVES

1. The main objective of this research is to study mechanical properties such as compressive strength, tensile strength, and flexural behavior of reinforced concrete by introducing the sisal fiber, silica fume, and fly ash.
2. To evaluate the optimum percentage of sisal fibers, silica fume, and fly ash.
3. To provide a sustainable option in construction industry.

LITERATURE REVIEW

A literature review on sisal fiber would typically involve introducing the topic by providing an overview of sisal fiber, its characteristics, and its various applications. We also mention its significance in different industries, such as textiles, agriculture, and construction. Additionally, any challenges or advancements related to sisal fiber research and production are highlighted.

The outline below provides a broad framework, but it may need to be based on the specific focus and available literature on sisal fiber.

Vijayan et al. [1] conducted a study to manage solid wastes, particularly construction and demolition wastes. By converting these waste materials for new construction purposes, we can effectively utilize them. If not managed properly, the government would incur colossal losses, and the ecosystem would suffer greatly, degrading the sustainability of concrete. Therefore, the objective of this research was to recycle old concrete waste as coarse aggregate with different grades to prepare new mixes using the M30 mix design.

The impact of these wastes by strengthening and reutilizing demolished waste by adding sisal fibers and silica fumes as admixtures to the recycled aggregate concrete (RAC). This approach improves the mechanical properties of the RAC. effectively using demolished construction waste can significantly reduce environmental consequences and help overcome material scarcity in the construction field by transforming waste materials into aggregates.

Concrete is renowned for its rigidity and strength, so reusing concrete aggregate is cost-effective and beneficial in various fields. I concluded that the maximum compressive strength and splitting tensile strength were obtained with 15% silica and 1.5% sisal fibers added to the concrete as an admixture.

Hamid et al. [2] investigated the effects of incorporating silica fume and sisal fiber into concrete, which can address issues related to waste disposal and global warming while producing high-performance concrete. The use of natural fibers and supplementary cementitious materials in concrete has gained considerable attention in recent years due to their potential to enhance the durability and mechanical properties of concrete.

In this study, several cement mixtures were prepared with different proportions of sisal fiber and micro silica. The mechanical properties of the resulting concrete were then evaluated and compared to those of standard concrete. Silica fume was added to the concrete at 5% and 10% by the weight of cement, and the volume fractions of sisal fiber ranged from 0.5% to 2%. The incorporation of silica fume improves the bond strength between the particles of concrete, while sisal fiber bridges the cracks developed in the concrete, increasing ductility, decreasing brittleness, and offering resistance to impact loading.

According to Ahmad et al. [3], concrete is a widely used building material; however, it is prone to abrupt failure and limited energy absorption when yielding. The incorporation of short discrete fibers has shown significant potential in addressing these issues. Sisal, a natural fiber, is renewable, inexpensive, and readily accessible. Sisal fiber is a promising reinforcement for concrete due to its low cost, low density, high specific strength and modulus, negligible health risk, easy accessibility in certain regions, and renewability.

In recent decades, there has been growing interest in exploring new applications for sisal fiber-reinforced concrete, beyond its traditional uses in making ropes, mats, carpets, and other decorative items. This article provides an overview of the latest advancements in the use of sisal fiber and its composites. It examines the properties of sisal fiber, the interaction between sisal fiber and the concrete matrix, and the performance of sisal fiber-reinforced concrete, including its fresh properties, mechanical strength, and durability.

Okeola et al. [4] investigated, under monotonic loads, the impact of sisal fiber-reinforced concrete in exterior beam-column joints. Using the strong column–weak beam idea, 15 outside beam-column joints were developed in accordance with British regulations. In the concrete mixture, sisal fibers were added at weight percentages of 0.5%, 1.0%, 1.5%, and 2.0%. The joints' functioning was monitored while the load was steadily increased.

The findings demonstrated that external beam-column junctions with sisal fiber had better shear strength, reduced deflection, and higher yield and ultimate load when compared to the control specimen. The theoretical models put out by earlier research were compared to the shear strength of the joints. In order to increase the joint shear strength of sisal fiber-reinforced concrete in outside beam-column joints, a modification was suggested and tested because these models did not adequately represent the influence of the fiber.

Sabarish et al. [5] analyzed fiber-reinforced concrete (FRC), which is concrete that has been strengthened structurally by the addition of fibrous material. There are many different kinds of fibers available, including synthetic and natural fibers. The fibers' main contribution to the concrete is to make it harder under all loading conditions. FRC is most frequently utilized in India, although it still has very few structural uses. Slope stabilization, tunnelling operations, and heavy-duty industrial flooring are applications for FRC.

The mechanical and physical characteristics of fiber-mixed concrete were examined in a lab setting. The concrete mix utilized in this project was M30, and the dimensions of the beam were 1400 mm by 200 mm. The outcomes demonstrated the testing of both regular concrete and concrete mixed with M30 fiber. Comparing the fiber-mixed concrete to regular concrete, the latter showed lower ultimate flexural strength. Future research could involve comparing M30 and M40 FRC, and subsequently focusing on M40 using the same fiber-reinforced mix. The range of M30 to M40 may have different flexural strengths.

Naik and Sahoo [6] report that compared to manufactured fibers or even mineral asbestos filaments, sisal filament manufacturing experimental study uses a lot less energy and has advantages for the environment and society. The suitability of sisal, or short, discrete vegetal fibers, for inclusion in cement concrete was examined. In a concrete media, this fiber's physical characteristics did not degrade. The fibers were trimmed to a length of 3 cm after being combed and aligned.

With a slump value of 58 mm and an effective compaction factor of 0.97, the workability of the concrete mix with 0.2% superplasticizer and a water-cement ratio of 0.50 was found to be good. Materials were hand-mixed into cubes and cylinders using the M25 mix design, adding 0%, 0.5%, 1%, 1.5%, 2.0%, and 2.5%. When compared to conventional self-compacting concrete (SCC), the mechanical characteristics of SCC including sisal fiber were shown to be higher. The setting time was additionally prolonged by the superplasticizer.

de Souza Castoldi et al. [7] investigated how concrete reinforced with sisal and polypropylene fibers behaved mechanically. The two 51-mm-long fibers were mixed in fractions of 3, 6, and 10 kg/m^3 with the matrices. The composites underwent cyclic and monotonic three-point flexural stresses testing.

Extraction experiments were conducted to investigate the fiber-matrix interaction. As long as the fiber doses remained the same, sisal fiber was shown to be able to offer the same degree of residual strength as polypropylene fiber. Based on data derived from flexural tests, the composites were categorized in accordance with the fib Model Code 2010.

Bao et al. [8] investigated the use of different proportions of sisal fibers used to create sisal fiber concrete specimens. They underwent tests for dry shrinkage, flexural strength, tensile strength, and compressive strength. The results of the investigation showed that, although compressive strength was not affected, adding sisal fiber reinforcement to concrete at specific concentrations greatly increased its tensile, flexural, impact, and shrinkage resistance. Since sisal fibers and concrete have a contact surface that experiences several impact loads, this technique has the potential to be widely used in pavement construction and maintenance.

It was determined that the impact load is shared by the sisal fibers and the concrete. Effective failure prevention and improved impact resistance are achieved by the sisal fibers' absorption of part of the significant impact force applied to the specimen.

Thomas and Jose [9] reported that sisal fiber concrete is versatile and may be used for cladding panels, stiff equipment, and water containers. It is widely used in both building and agriculture, as demonstrated by experimental study on the material. The main goals of incorporating sisal fibers into the cement matrix are to improve the final composite's toughness, tensile strength, and bending properties. Sisal fibers have been used in concrete more and more recently as reinforcement, which has raised the profile of cementitious composites in contemporary industrial technology.

Several research studies evaluating sisal fiber performances are compiled in this study, showcasing the fibers' excellent tensile strength and other advantageous qualities for use in construction.

Krishna et al. [10] observed that because the building industry is under pressure to achieve enhanced growth and sustainable development, standard construction materials are getting more and more expensive. This has prompted developers to look for different building materials. Coir and sisal fiber are examples of natural fibers that were used in this study to improve the qualities of concrete. The efficiency of this natural fiber–reinforced concrete was assessed using the characteristics of regular concrete as a benchmark.

As a result, an increase in ductility and strength of concrete was achieved with the addition of 1.5% coir by weight of cement, which was found to be the optimum percentage. The improvement in load-carrying capacity of concrete cylinders was observed when wrapped with sisal fiber using the optimal percentage of coir. Enhancing ductility is a significant criterion for seismic-resistant design of structures to prevent catastrophic failure. Therefore, adding coir for concrete confinement can enhance the seismic resistance of structures in earthquake-prone areas.

Lima et al. [11] conducted studies on the structural performance of a new lightweight block for one-way precast concrete slabs. The block was constructed using short sisal fiber reinforced concrete (SSFRC) with recycled and natural aggregate. Experimental analysis of the effects of sisal fibers and recycled aggregate on the mechanical and physical characteristics revealed the distinct advantages of fiber reinforcement for post-cracking flexural capacity. Furthermore, the compressive strength of recycled aggregates was positively impacted by their increased water absorption, especially in FRC.

SSFRC blocks, as well as commercially available ceramic and expanded polystyrene (EPS) blocks, were subjected to flexural tests. SSFRC blocks had more ductile behavior, greater load and deflection capacities, and infrastructure could pass through them thanks to their advantageous shape. Four-point bending tests were performed on slab panels comprising SSFRC, ceramic, and EPS blocks in order to assess the benefits of the innovative. The tests' outcomes showed that SSFRC blocks outperformed other commercial alternatives in terms of structural performance, both initially and in terms of serviceability limit deflection.

Frazão et al. [12] reported that polypropylene fiber–reinforced lightweight concrete (PFRLC) is used as the core layer and thin outer layers of sisal fiber-cement composites (SiFCC) are used in the development of novel structural panels. Two methods were used to examine the impact of sisal fibers: long unidirectionally aligned sisal fibers (700 mm) applied by hand layup technique, and small sisal fibers (50 mm) dispersed randomly in the matrix. To improve the concrete layer that forms the core of the panel, lightweight aggregates and polypropylene fibers were used to lower its density and increase its ability to absorb energy and withstand tensile failure.

Four-point bending tests were used to assess the sandwich panels' behavior, and a number of failure mechanisms were noted and observed. Numerical simulations were conducted using the mechanical characteristics of SiFCC and PFRLC that were obtained.

The strength of the link between the outer SiFCC layers and the core was evaluated by pull-off tests. The outcomes showed that, in comparison to short sisal fibers, long sisal fibers were more successful in increasing the panel's flexural capacity. If short sisal fibers promoted the formation of numerous cracks after deflection hardening action, long fibers did the opposite.

Venkateshwara and Kalaiyarrasi [13] observed that reinforced concrete is an important area that is receiving a lot of interest, especially in terms of enhancing tensile qualities with fiber without sacrificing compressive strength. Their study examined the impact of using natural sisal fiber in place of some of the cement in concrete. For the best use in concrete, the sisal fiber underwent a chemical treatment. FRC was compared to standard M25 concrete in terms of mechanical parameters such compressive strength, split tensile strength, and flexural strength. The fiber replaced cement at volume fractions of 0.5%, 1%, and 1.5%, and the sisal fiber aspect ratio was 1:20.

The use of natural sisal fiber improves the strength of concrete, according to the results of this experimental inquiry. It was discovered that 1.5% for split tensile strength and 1% for compressive strength was the ideal proportion of sisal fiber to have for maximum strength. Workability falls off at 0.5%, 1%, and 1.5% of the cement volume as the fraction of sisal fiber substitution rises. Additionally, the flexural strength of sisal fiber-reinforced beams was higher than that of concrete with normal strength.

Izquierdo et al. [14] conducted research on the mechanical behavior of masonry pieces made of concrete and natural sisal fiber. Individual hollow blocks, as well as prisms and wallets constructed from these blocks, were subjected to compression tests. The mechanical reaction of plain concrete specimens was also assessed in order to offer a comparative comparison.

The tests' outcomes are shown, and a discussion of how sisal fibers affect the elements' mechanical characteristics follows. In order to forecast the nonlinear behavior of the blocks, numerical models were created. These models' parameters and boundary conditions were adjusted to correspond with the load-displacement curves obtained through experimentation. Using the smeared crack model, a qualitative explanation of the damage evolution in the elements was given.

Wei and Meyer [15] preformed experiments in an effort to improve the sustainability of reinforced concrete, using natural fibers like sisal fiber in place of synthetic reinforcement, combined with recycled concrete aggregate. Natural fibers require treatment to increase their longevity because they are susceptible to potential deterioration in the alkaline cement matrix, particularly in outdoor erosive conditions. To hasten aging, concrete sample were subjected to cycles of soaking and drying.

Evaluations were done on the sisal fibber's microstructure, tensile strength, Young's modulus, and weight reduction in the composite. The impacts on the sisal fiber–reinforced concrete's compressive and splitting tensile strengths were of particular interest. The sisal fibers' tensile strength, and Young's modulus were assessed, along with the composite's weight loss.

The initial strength and durability of sisal fiber were increased with thermal treatment, which also improved cellulose crystallization. On the surface of the Na_2CO_3-treated sisal fiber, a layer of calcium carbonate sediments developed to shield the inside of the fiber from the potent alkali solution produced during cement hydration. By filling in the pits and cavities on the fiber surface, this treatment increased the fiber longevity and resilience to corrosion while also lessening the negative impacts of Na^+ ions on concrete.

de Andrade Silva et al. [16] observed that fiber-reinforced cement composite laminates with long sisal fibers were manufactured using a cast hand lay-up technique. To enhance durability, a matrix with partial cement replacement by metakaolin and calcined waste crushed clay brick was utilized. The mechanical response was measured through tension and bending tests, while crack formation was investigated using high-resolution image capturing.

Crack spacing was analyzed through image analysis and correlated with applied strain under both tensile and bending conditions. Various stages of loading, including initiation, propagation, distribution, opening, and localization of cracks in the specimen, were examined. The effect of flexural cracking on the neutral axis location during bending tests was measured using strain gauges [17].

Materials Used

Cement: Ordinary Portland cement (OPC) with a specific gravity of 3.15 was used. UltraTech OPC grade 53, meeting BIS (Bureau of Indian Standards) specification IS:12269-1987, was selected.

Fine aggregate: River sand was utilized, and tests were conducted according to IS 2386 (Part I). The sand accessible locally passed through 4.75 mm I.S. sieve and was retained on 75 µm sieve. The specific gravity of 2.58. The fineness aggregates used in the sample was 2.65 and sand was falling under Zone II.

Coarse aggregate: 20-mm and 10-mm sized coarse aggregates were used with specific gravity 2.73 and 2.62, respectively. A total of 60% 20-mm aggregates and 40% 10-mm aggregates were used. The aggregates were passed through 40 mm and retained on 4.75 mm sieve [18].

Silica fume: Natural silica fume, also known as micro silica, and condensed silica fume consist of very fine particles of SiO_2. Due to its large specific area and amorphous nature, it becomes highly reactive pozzolanic material. It is composed of pure silica in a non-crystalline form. The specific gravity of silica fume is 2.23, and it was collected from Tulsi Buildcon RMC plant [19].

Fly ash: It was collected from Tulsi Buildcon RMC plant. The specific gravity of fly ash is 2.27.

METHODOLOGY

Mix proportions for grade of M-30 grade were designed by replacing cement with fly ash and addition of silica fume 5%, sisal fiber 0.5%, 01%, 1.5%, 02% by weight of cement, respectively, in different variations. Mix design was designed as per IS 10262:2019 with water cement ratio of 0.45, and 16 different proportions were designed [20].

Replacement of fly ash with cement and sisal fiber percentage: Four different sets of proportions were made with a total of 16 variations, 4 variations in each set with same cement percent replaced with different fly ash and sisal fiber variations, 5% silica fume addition constant for all variations [21].

- Set 1 [M01, M02, M03, M04]
- Set 2 [M05, M06, M07, M08]
- Set 3 [M09, M10, M11, M12]
- Set 4 [M13, M14, M15, M16]

Table 1 shows the variations with their full forms and percent variations.

Table 1. Abbreviations of variations

S.N.	Variations Abbreviations	Percent Variations
1	M0	0% sisal fiber, 0% fly ash
2	M01	0.5% sisal fiber, 5% fly ash
3	M02	1.0% sisal fiber, 5% fly ash
4	M03	1.5% sisal fiber, 5% fly ash
5	M04	2.0% sisal fiber, 5% fly ash
6	M05	0.5% sisal fiber, 10% fly ash
7	M06	1.0% sisal fiber, 10% fly ash
8	M07	1.5% sisal fiber, 10% fly ash
9	M08	2.0% sisal fiber, 10% fly ash
10	M09	0.5% sisal fiber, 15% fly ash
11	M10	1.0% sisal fiber, 15% fly ash
12	M11	1.5% sisal fiber, 15% fly ash
13	M12	2.0% sisal fiber, 15% fly ash
14	M13	0.5% sisal fiber, 20% fly ash
15	M14	1.0% sisal fiber, 20% fly ash
16	M15	1.5% sisal fiber, 20% fly ash
17	M16	2.0% sisal fiber, 20% fly ash

EXPERIMENTAL ANALYSIS

Compressive Strength Testing

concrete was prepared and poured in the cube specimen of 150 mm × 150 mm × 150 mm. Three specimens for 28 days and 3 specimens for 7 days for each variation were molded and cured. In total, 96 specimens were molded. Compressive testing machine was used for testing the specimens. The compressive strength was calculated using Equation 1 [22].

$$\mathrm{fc} = \mathrm{P/A}\frac{\text{Max. Load (N)}}{\text{Area of cross section of sample (mm2)}} \quad (1)$$

where, fc = compressive strength of concrete (N/mm^2)
P = maximum load (N)
A = area of cross section of sample (mm^2)

Tensile Strength Testing

Concrete was made and poured in the cylinder specimen of diameter 150 mm and length 300 mm. Three specimens for 28 days and 3 specimens for 7 days for each variation were molded and cured. In total, 96 specimens were molded. Automated universal testing machine was used for testing the specimens. The tensile strength was calculated using Equation 2 [23].

$$\mathrm{ft} = \frac{2\mathrm{P}}{\pi \mathrm{LD}} \quad (2)$$

where, ft = tensile strength of concrete (MPa),
P = load at the failure (N)
L = length of cylinder (mm)
D = diameter of cylinder (mm)

Flexural Strength Testing

Concrete was prepared and poured in the beam specimen of size 150 mm × 150 mm × 700mm. Three specimens for 28 days and 3 specimens for 7 days for each variation were molded and cured. A total of 96 specimens were molded for the study. An automated universal testing machine was used to test the specimens. The tensile strength was determined using Equation 3.

$$\mathrm{ff} = \frac{\mathrm{PfL}}{\mathrm{bd}^2} \quad (3)$$

where, ff= flexural strength of concrete (MPa)

Pf = central point through two-point loading (N)

L= span of beam (mm)

b = width of beam (mm)

d = depth of beam (mm)

RESULTS AND DISCUSSIONS

Six cubes for each variation were molded for 7 days and 28 days. Varying results were obtained with different percent combinations of replacing cement with fly ash and addition of fiber, respectively. The observations and readings of the different proportions are given below.

The third set of proportions were taken of 15% replacement of cement with fly ash and addition of fiber 0.5%, 1%, 1.5%, 2%, and silica fume 5%, respectively. Table 2 shows the readings of 7 days and 28 days compressive strength of the above variations. Figure 3 displays comparison of compressive strengths for 7 days and 28 days of set 3.

Table 2. Readings of 7 days and 28 days compressive strength set 3 variations.

Mix Proportions	7 Days Strength (MPa)	28 Days Strength (MPa)
M0	23.34	36.87
M9	27	41.8
M10	27.6	42.3
M11	28.9	44.86
M12	26.66	43.20

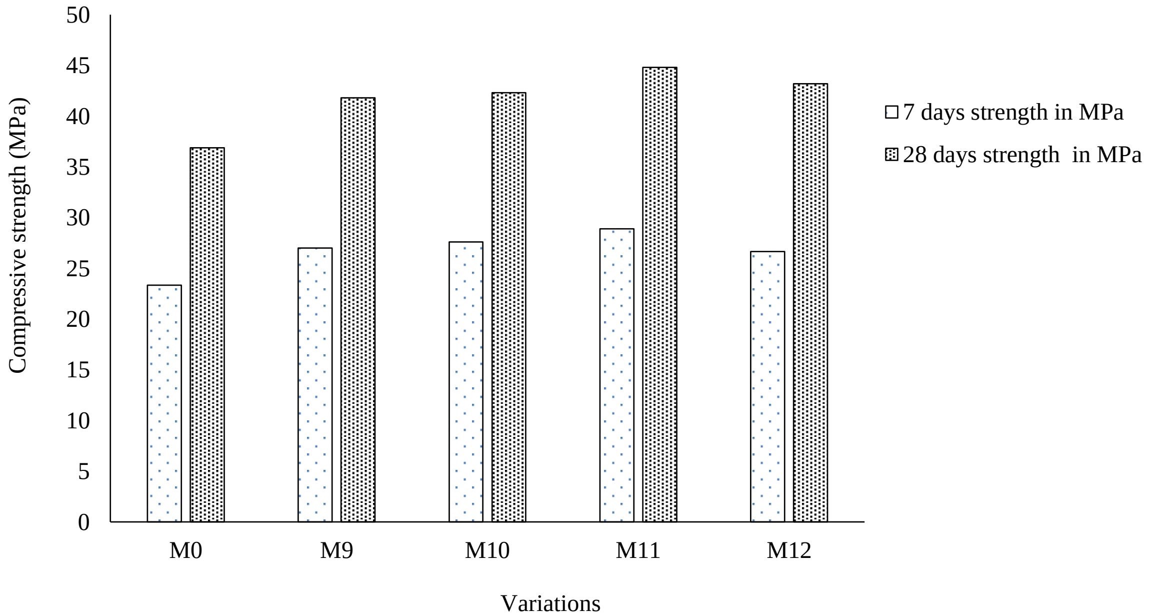

Figure 3. Comparison of 7 days and 28 days compressive strength of set 3 variations.

The third set of proportions was taken of 15% substitution of cement with fly ash and addition of fiber 0.5%, 1%, 1.5%, 2%, and silica fume 5%, respectively. Table 3 shows the readings of 7 days and 28 days tensile strength and Figure 4 show comparison of tensile strengths for 7 days and 28 days of set 3.

Table 3. Readings of 7 days and 28 days tensile strength set 3 variations.

Mix Proportions	7 Days Strength (MPa)	28 Days Strength (MPa)
M0	2.34	3.69
M9	2.5	3.65
M10	2.8	3.92
M11	3.1	4.246
M12	2.88	3.95

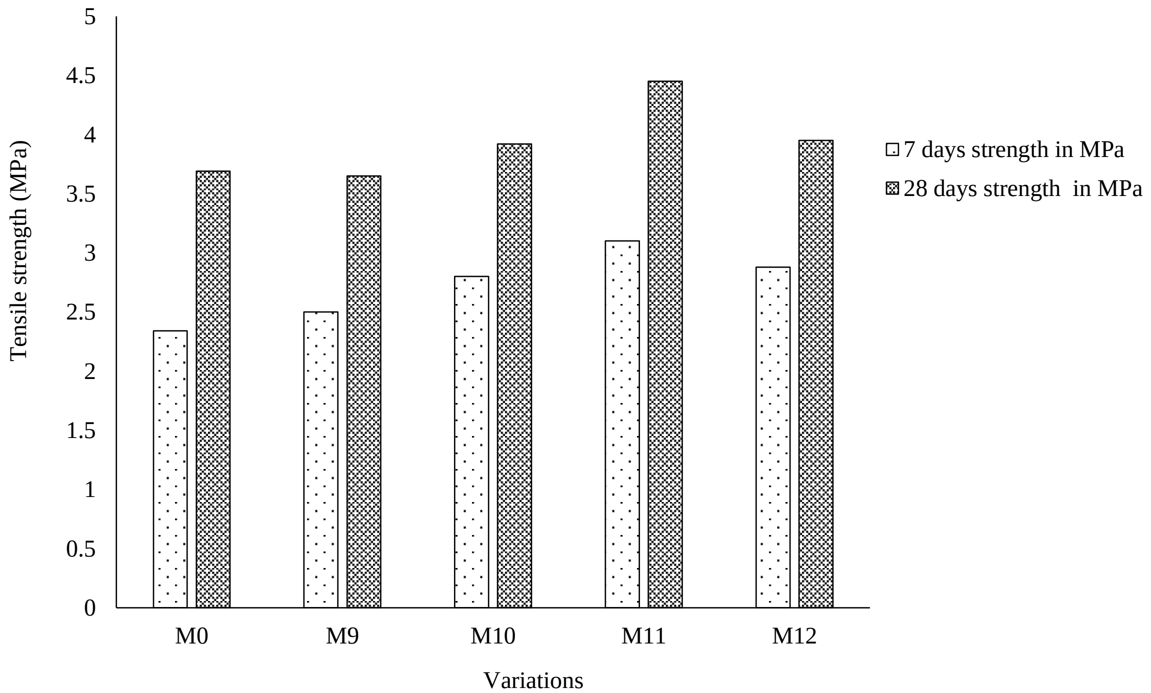

Figure 4. Comparison of 7 days and 28 days tensile strength of set 3 variations.

Third set of proportions were taken of 15% substitution of cement with fly ash and addition of fiber 0.5%, 1%, 1.5%, 2%, and silica fume 5%, respectively. Table 4 presents the readings of 7 days and 28 days flexural strength and Figure 5 displays comparison of flexural strengths for 7 days and 28 days of set 3.

Table 4. Readings of 7 days and 28 days flexural strength set 3 variations.

Mix Proportions	7 Days Strength (MPa)	28 Days Strength (MPa)
M0	2.29	3.83
M9	2.6	3.9
M10	2.78	4.1
M11	2.96	4.45
M12	2.8	4.3

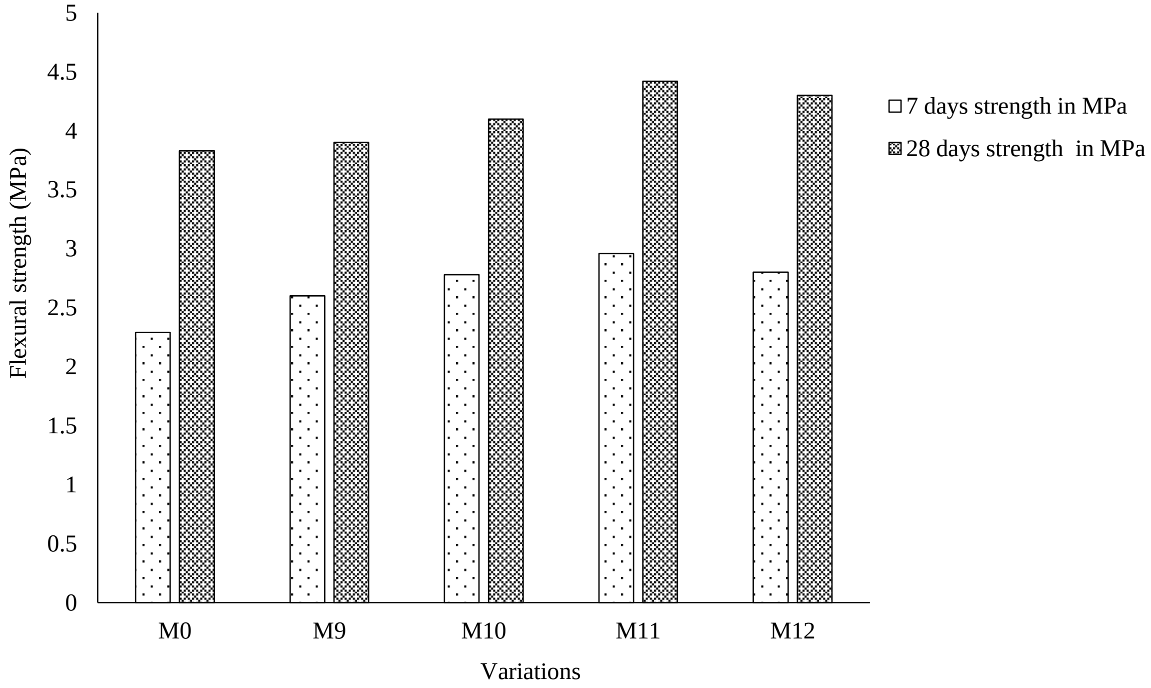

Figure 5. Comparison of 7 days and 28 days flexural strength of set 3 variations.

CONCLUSIONS

The experimental analysis was done on replacing cement with fly ash and addition of sisal fiber and silica fume in various proportions. Different specimens were molded and the compressive strength test was taken after 7 days and 28 days of curing. As per the IS10262:2019, the average compressive strength of cubes at 7 days should not be less than 65% and that at 28 days should not be less than 90%. The following conclusions are drawn form the results obtained:

1. All variations with fly ash replacing cement with 15% and silica fume 5% addition variations with sisal fiber 0.5%, 1%, 1.5%, 2% show an increase in the 28th day compressive strength of cubes.
2. A slight reduction in 7 days strength of variation with 5% fly ash replacement and 5% silica fume, 0.5% sisal fiber addition was observed.
3. Replacing fly ash 15% with cement and addition of silica fume 5%, sisal fiber 1.5%, the tensile strength significantly increases compared to conventional concrete.
4. On addition of silica fume 5%, sisal fiber 1.5%, and replacing fly ash 15% with cement, the flexural strength profoundly increases.
5. On replacing fly ash 20% with cement and addition of silica fume 5%, sisal fiber variation 0.5%, 1%, 1.5%, and 2%, the tensile compressive and flexural strengths decrease.
6. It is observed that increase in fly ash with silica fume improves the compressive strength of concrete.
7. A reduction in compressive strength is observed when percentage of fly ash above 15%.

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