# Study on Mechanical and Durability Properties of High Strength Coir Fibre Reinforced Concrete Blended with Silica Fume

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**ABSTRACT-** *In the construction field the utilization of industrial waste byproducts has increased. The use of pozzolanic materials is fundamental in developing low cost construction materials. By addition of pozzolanic materials, the various properties of concrete such as, workability, durability, strength, resistance to cracks and permeability can be improved and emissions of CO2 can be decreased. Among all the pozzolans, silica fume is more reactive due to the presence of amorphous silica in high content. Silica fume is known to improve the both mechanical characteristics and durability of concrete; also, it acts as perfect filler due to its fineness.*

*Concrete is strong in compression and weak in tension. The tensile strength of concrete, generally improved by steel reinforcement due to its ductility properties. But steel reinforcement exhibits micro cracks which cannot be avoided. To avoid these micro cracks additional fibre reinforcement is used. Coir fibre is a natural fibre and easily available everywhere. Usage of coir fibre is easy, flexible, cheap and eco-friendly.*

*Here an attempt has been made to study the performance of high strength coir fibre reinforced concrete blended with silica fume. M60 grade of concrete is used. Concrete mixes are planned to make using ordinary Portland cement alone as control and also replacing cement by 5%, 10%, 15% and 20% of silica fume. In all the concrete mixes 2% coir fibre is added. The strength and durability characteristics are studied and results compared with the control concrete. Based on the study it is found that the optimum level of replacement is 10% of cement by silica fume with addition of 2% coir fibre.*

***Keywords:*** Coir Fibre; Silica Fume; High Strength Concrete; Waste Disposal; Durability.

## I. INTRODUCTION

We know that concrete is strong in compression but brittle in tension and flexure. Due to this it is reinforced using steel bars. Even then micro cracks may occur. To avoid this secondary fibre reinforcement is required. These fibres are randomly distributed in concrete to improve the tensile and flexure strength of concrete. Fibres are of different types. They are steel fibre, glass fibre, synthetic fibre and natural fibre. Out of which natural fibres are flexible, cheap eco-friendly and more suitable. Here we are using coir fibre for reinforcement of concrete. It is a byproduct of agricultural waste. It enhances the properties of cement concrete and it also act as proper solution for disposing natural fibres. Coir fibres are in two colors, they are brown and white. Brown fibres are extracted from mature coconut which is strong, thick and have high tension and abrasion resistance. Whereas, white fibres are extracted from immature coconut which is soft, smooth and weak in tensile strength. Therefore, brown fibres are chosen for reinforcing the concrete. In previous study this is believed to be a cost-effective solution to earthquake-resistant housing. Beyond these advantages it is not used widely because of its embrittlement and balling effects. Embrittlement decays natural fibre in alkaline medium. Balling effect reduces the workability of concrete. To overcome this, pozzolanic material has been used to improve the durability of concrete.

Now a days, the construction of high rise building has been increasing and this is the only solution for increasing population. This increases the need of high strength concrete. In high strength concrete, cement content is high when compared to conventional concrete. Therefore the emission of CO2 is high and target strength is also not achievable. This is also achieved by the partial replacement of cement with pozzolanic material. There are various pozzolans available such as fly ash, silica fume, ground granulated blast furnace slag etc. Among all pozzolans silica fume is very effective due to high amorphous silica. Silica fume is a byproduct of producing silicon metal. It can have very high strength and can be very durable. The aim of the study is to conduct experimental investigation on mechanical and durability properties of high strength coir fibre reinforced concrete blended with silica fume. The following tests were done on the concrete specimen,

1. Workability
2. Compressive strength
3. Split tensile strength
4. Flexural strength
5. Durability

## II. METHODOLOGY

A well planned methodology is required for work progress. This flow chart gives a well-organized flow of work process.

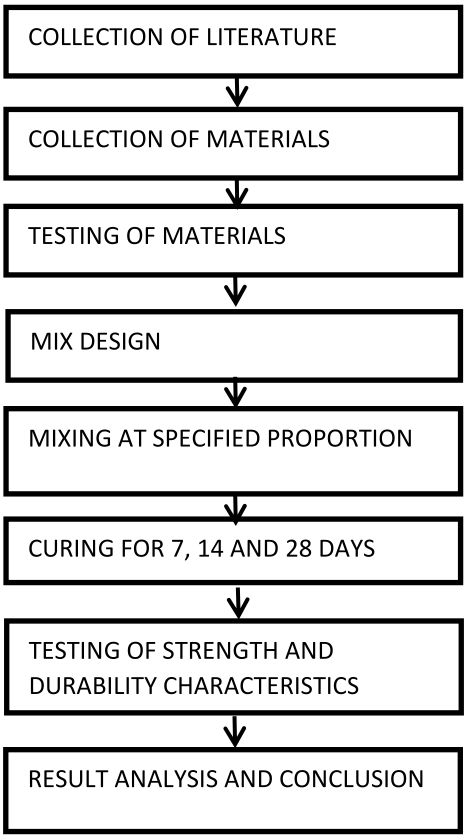


**Chart-1:** Schematic representation of methodology

## III. LITERATURE REVIEW

**Jaydeep Chowdhury (2016)** This is an experimental study on the use of coconut fibre as enhancement of concrete which can reduce conventional building material costs for the rural and urban development in India. Foamed concrete is a better option, but it is good in compression and weak in tension. The weakness in tension can be overcome by the addition of fibres. There is a comparative study on compressive strength, flexural strength and splitting tensile strength of coconut coir fibre with different percentages of coconut fibre (0%, 0.2% and 0.4%). The compressive strength, flexural strength and splitting tensile strength of the foamed concrete are increased as the fibre volume percentage of the coconut coir fibre increased in the concrete mix from experiments[1].

**Kshitija nadgouda (2015)** This paper is about the experimental investigation of coconut fibre reinforced concrete. The study comprises of comparative statement of properties of coconut fibre reinforced concrete with conventional concrete based on experiments performed in the laboratory. The use of coconut fibres will also lead to better management of these waste fibres. The addition of coconut fibres improved the flexural strength of concrete by about 12%, they also formed good bonding in the concrete. The study found the optimum fibre content to be 3% (by weight of cement). Further work is required by changing the fibre content and aspect ratio to determine the optimum range of fibre content so that fibre reinforced concrete can be used where high flexural strength is required[2].

**Majid Ali (2015)** This paper is about the use of coconut fibre reinforced concrete and coconut-fibre ropes for seismic-resistant construction. Of Earthquake-resistant and economical housing is the most desirable need in rural areas developing countries. These regions often suffer significant loss of life during a seismic event. To enable an efficient and cost-effective solution, a new concept of construction, i.e. a wallette of interlocking blocks with movability at the interfa ce and rope reinforcement, is investigated. The novel interlocking block is made of coconut fibre reinforced concrete (CFRC). The reason for using coconut fibre is their highest toughness amongst natural fibres. This paper describes the in-plane behaviour of the interlocking wallette under earthquake loadings. The wallette response is measured in terms of induced acceleration, block uplift, top maximum relative displacement and rope tension. The applied earthquake loadings cannot produce any damage in the structure, i.e. blocks and/or ropes. The response of the wallette is explained in detail along with correlation of materials aspect with structural behaviour[3].

**N. K. Amudhavalli and Jeena Mathew (2012)** This paper presents the effect of silica fume on strength and durability parameters of concrete. Large scale production of cement is causing environmental problems on one hand and depletion of natural resources on other hand. This threat to ecology has led to researchers to use industrial by products as supplementary cementations material in making concrete. The main parameter investigated in this study is M35 grade concrete with partial replacement of cement by silica fume by 0, 5, 10,15and by 20%. This paper presents a detailed experimental study on Compressive strength, split tensile strength, flexural strength at age of 7 and 28 day. Durability study on acid attack was also studied and percentage of weight loss is compared with normal concrete. Test results indicate that use of Silica fume in concrete has improved the performance of concrete in strength as well as in durability aspect[4].

**Anurag Jain (2015)** This is about the investigation of Characteristics of Silica Fume Concrete. Proper introduction of silica fume in concrete improves both the mechanical and durability characteristics of the concrete.

This paper reports the results of compressive strength data on 4- to 6-year-old cores obtained from well-documented field experiments where both silica-fume and non-silica fume concrete mixtures were used. The effectiveness of silica-fume concrete resist the damage caused by corrosion due to steel reinforcement. The compressive strength results obtained on concrete cores taken after a 4-year period from an experimental column built with a very high-strength concrete also confirmed that there was no tendency for strength loss in silica-fume concretes. The experimental program comprised six levels of silica-fume contents (as partial replacement of cement by weight) at 0% (control mix), 5%, 10%, 15%, 20%, and 25%, with and without superplasticizer. This result shows that there is a significant increase in strength and durability of concrete[5].

## IV. MATERIAL COLLECTION

Ordinary Portland Cement (OPC) – 53 grade cement

Coarse aggregate – aggregate passing through the 10mm sieve size taken 40% and 16mm sieve sized aggregates taken 60%.

Fine aggregate – river sand passing through 4.75mm sieve size.

Silica fume – collected from industries.

Coconut fibre – raw fibre collected from coir industries in the Viluppuram district.

Water – collected from local fresh water sources.

Super plasticizer - Conplast SP430.

### 4.1 Basic tests on materials

The material used in this project are tested according to the IS specifications. and the results are given below.

**Table 4.1** Properties of cement

| Properties | Result obtained | Requirements as per (IS 12269:1970) |
|---|---|---|
| Specific gravity | 3.15 | 3.1-3.15% |
| Normal consistency | 26% | 25-35% |
| Fineness | 3% | 3-7% |
| Initial setting time | 39 min | Not less than 30 min |
| Final setting time | 185 min | Not more than 10hrs |
| Soundness | 1.0 mm | Not more than 10 mm |

**Table 4.2** Properties of fine aggregate

| Properties | Result obtained | Requirements as per (IS 383:1970) |
|---|---|---|
| Specific gravity | 2.6 | 2.6-2.9 |
| Fineness modulus | 3.015 | 2-4 |
| Bulk density | 17.26 $KN/m^3$ | 14.50-18.50 $KN/m^3$ |
| Bulking of sand | 27.53% | 20- 40% |
| Grading of sand | Zone II | 100 |

**Table 4.3** Properties of coarse aggregate

| Properties | Result obtained | Requirements as per (IS 383:1970) |
|---|---|---|
| Specific gravity i)16mm-60% ii)10mm-40% | 2.64 | 2.6-2.85 |
| Fineness modulus | 2.08 | 2.5- 6.5 |
| Flakiness index | 18.96% | Not more than 30% |
| Elongation index | 24.64% | Not more than 45% |
| Bulk density | 16.38 $KN/m^3$ | 1520 – 1680 $KN/m^3$ |
| Impact value | 20.36% | 30% |

#### 4.1.1 Properties of silica fume

**Table 4.4** Physical properties of silica fume

| S.No | Physical Properties | Values |
|---|---|---|
| 1 | Specific gravity | 2.63 |
| 2 | $p^H$ | 6.9 |
| 3 | Colour | white |
| 4 | Physical state | Micronized powder |
| 5 | Moisture | 0.058% |

**Table 4.5** Chemical properties of silica fume

| S.No | Physical Properties | Values |
|---|---|---|
| 1 | Silica (SiO2) | 99.886% |
| 2 | Alumina (Al2O3) | 0.043% |
| 3 | Ferric Oxide (Fe2O3) | 0.040% |
| 4 | Titanium Oxide (TiO2) | 0.001% |
| 5 | Calcium Oxide (CaO) | 0.001% |

| | | |
|---|---|---|
| 6 | Magnesium Oxide (MgO) | 0.000% |
| 7 | Pottasium Oxide (K2O) | 0.001% |

**Table 4.6** Properties of coconut fibre

The fibres are tested only after it is soaked for 24 hours in water.

| S.No | Properties | Value |
|---|---|---|
| 1 | Specific gravity | 1.12 |
| 2 | Water absorption | 98% |
| 3 | Chopped length of fibre | 50 mm |
| 4 | Thickness of fibre | 0.05mm |
| 5 | Bulk density of coconut fibre KN/$m^3$ | 1825 |

## V. SPECIMEN DETAILS

The compressive strength of the concrete was determined by cubes of size 100mm × 100mm × 100mm. Split Tensile strength of the concrete was determined by the cylinder specimen 150mm diameter and 300mm length. Flexural strength was determined by the prism specimen 100mm × 100mm × 500mm. Durability was determined by the same size of cube given above. All the moulds corresponding to the specimen were prepared.

### 5.1 Mixes

Taking the control mix design (i.e. 0%silica fume&0% fibre). In all the concrete mixes silica fume was varied in the percentages of 5, 10, 15, 20 by the weight of cementitious material content and 2% coir fibre was incorporated for the w/b ratio 0.32.

### 5.2 Mix proportions ( As per IS 10262-2009)

#### 5.2.1 Mix Proportions for M60 grade of concrete

| Material | Water | Cement | Fine Aggregate | Coarse Aggregate |
|---|---|---|---|---|
| in kg/$m^3$ | 165 | 532 | 645 | 1181 |
| Ratio | 0.32 | 1 | 1.3 | 2.22 |

#### 5.2.2 Mix proportions for coir fibre reinforced concrete blended with silica fume (M60 grade)

| Material | Water | Cementitious Material | Fine Aggregate | Coarse Aggregate |
|---|---|---|---|---|
| in kg/$m^3$ | 144 | 511 | 598 | 1134 |
| Ratio | 0.29 | 1 | 1.17 | 2.22 |

Here, mix proportions for other mixes are calculated. The mix proportions for the mix in which 10% silica fumes and 2%fibre was incorporated are given in below table.

### 5.3 Casting the specimens

To know the hardening properties of concrete various tests are conducted on the specimens for 7, 14 and 28 days.

Mix 1: 0% silica fume and 0% fibre
Mix 2: 5% silica fume and 2% fibre
Mix 3: 10%silica fume and 2% fibre
Mix 4: 15%silica fume and 2% fibre
Mix 5: 20%silica fume and 2% fibre

## VI. RESULTS AND DISCUSSIONS

### 6.1 Workability test on fresh concrete

The workability of concrete is decreased than the control concrete because of the presence of coir fibres and absorption of moisture by silica fumes. The result of workability is given in table 6.1.

**Table 6.1** Results of Workability of mixes

| S.No. | Mix No. | Slump Value (mm) | Vee Bee time (sec) | Compaction factor |
|---|---|---|---|---|
| 1 | Mix 1 | 40 | 14 | 0.85 |
| 2 | Mix 2 | 0 | 18 | 0.70 |
| 3 | Mix 3 | 0 | 16 | 0.72 |
| 4 | Mix 4 | 0 | 14 | 0.74 |
| 5 | Mix 5 | 0 | 13 | 0.75 |

### 6.2 Compressive strength

The compressive strength test was conducted for cubes which are tested under compressive testing machine. Maximum compressive strength occurred at Mix 3(10%silica fume&2%fibre). The values obtained are tabulated. Table 6.2 represent the values obtained from compressive strength.

**Table 6.2** Results of Compressive Strength

| S.No. | Mix No. | Compressive Strength in N/$mm^2$ | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| 1 | Mix 1 | 45.35 | 51.19 | 63.93 |
| 2 | Mix 2 | 47.65 | 53.68 | 65.14 |
| 3 | Mix 3 | 49.72 | 56.90 | 69.30 |
| 4 | Mix 4 | 43.40 | 50.13 | 64.29 |
| 5 | Mix 5 | 37.74 | 43.18 | 54.77 |

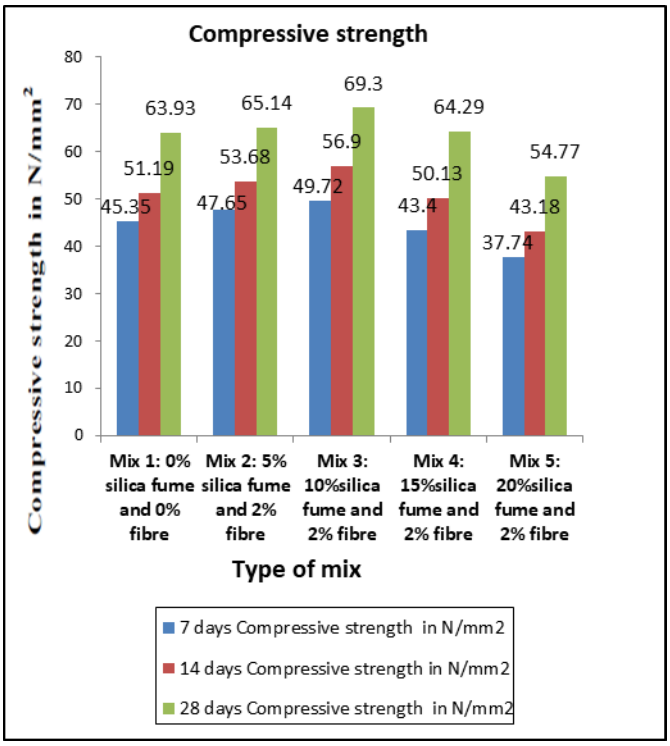


**Chart-2:** Variation of silica fume and coir fibre v/s compressive strength

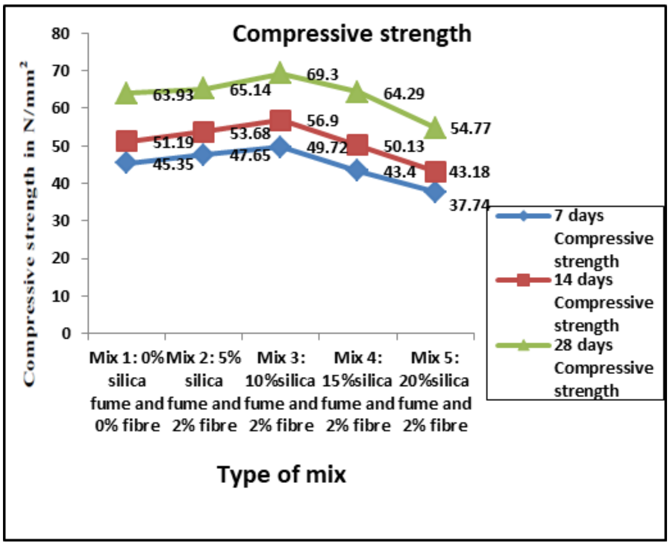


**Chart-3:** Variation of silica fume and coir fibre v/s Compressive strength at 7, 14 and 28 days

### 6.3 Split tensile strength

The split tensile strength of concrete is determined by testing the cylinders. The values obtained are given in table 6.3. The crack width is less and splitting of specimen into two pieces is also controlled.

**Table 6.3** Results of Split tensile strength

| S.No. | Mix No. | Split Tensile Strength in $N/mm^2$ | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| 1 | Mix 1 | 3.54 | 3.64 | 4.38 |
| 2 | Mix 2 | 3.56 | 3.92 | 4.43 |
| 3 | Mix 3 | 3.90 | 4.23 | 4.50 |
| 4 | Mix 4 | 3.64 | 4.03 | 4.41 |
| 5 | Mix 5 | 3.43 | 3.53 | 4.23 |

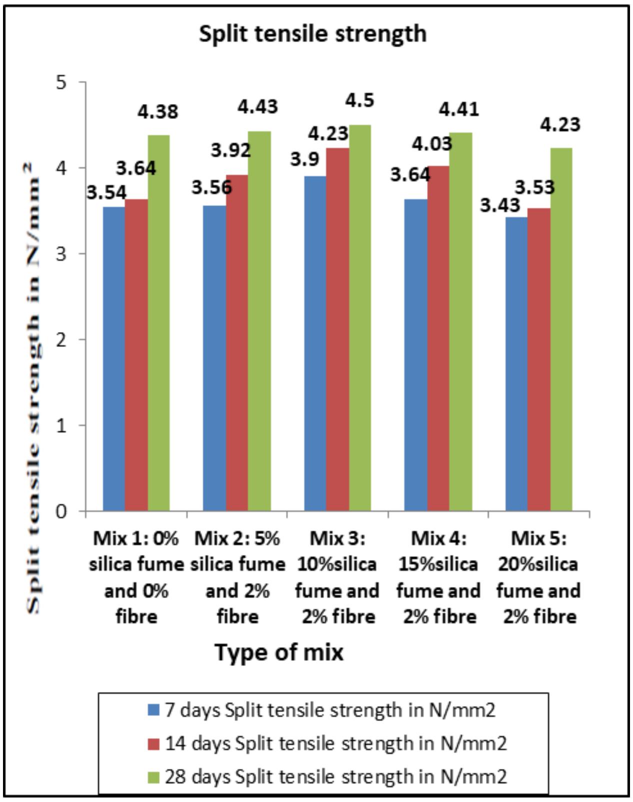


**Chart-4:** Variation of silica fume and coir fibre v/s Split tensile strength

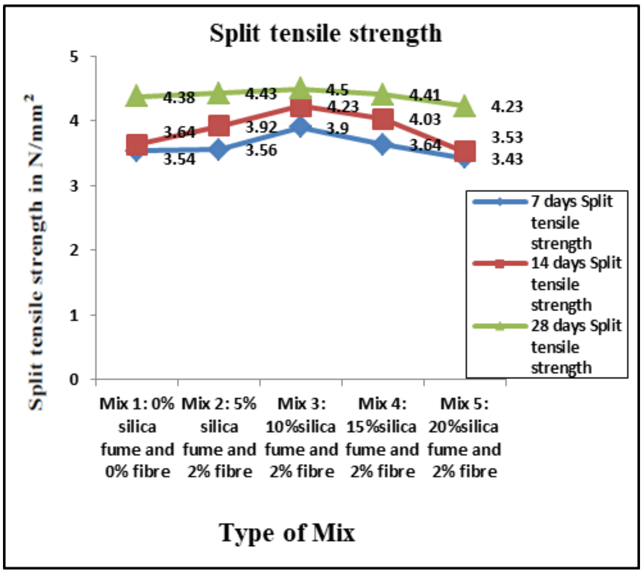


**Chart-5:** Variation of silica fume and coir fibre v/s Split tensile strength at 7, 14 and 28 days

### 6.4 Flexural Strength

Flexural strength of concrete was set on by testing the beam specimens under flexural testing machine and results are listed in table 6.4. When compared to control mix flexural strength of fibre reinforced concrete is increased. Breaking of concrete specimens into two pieces can be avoided by fibre reinforced concrete.

**Table 6.4** Results of Flexural Strength

| S.No. | Mix No. | Flexural Strength in N/mm$^2$ | | |
|---|---|---|---|---|
| | | 7 days | 14 days | 28 days |
| 1 | Mix 1 | 4.45 | 5.04 | 6.23 |
| 2 | Mix 2 | 4.75 | 5.56 | 6.32 |
| 3 | Mix 3 | 4.87 | 5.68 | 6.47 |
| 4 | Mix 4 | 4.72 | 5.47 | 6.27 |
| 5 | Mix 5 | 4.63 | 5.22 | 5.96 |

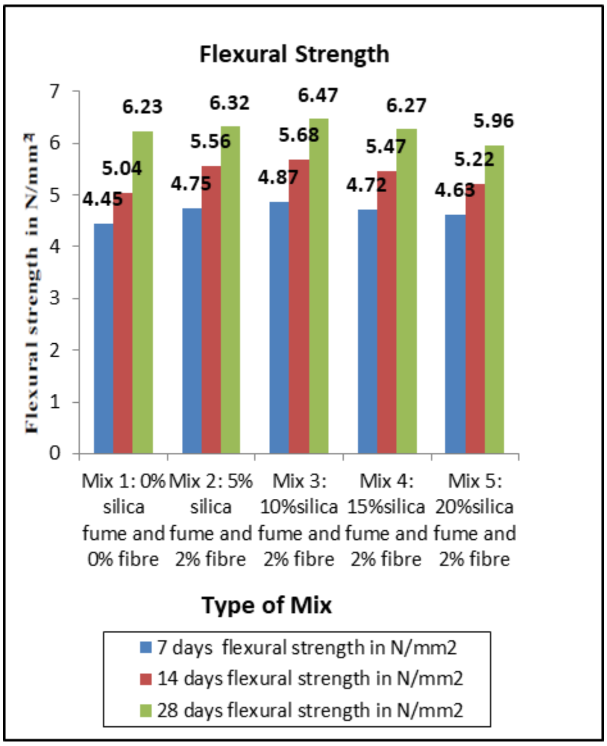


**Chart-6:** Variation of silica fume and coir fibre v/s Flexural strength

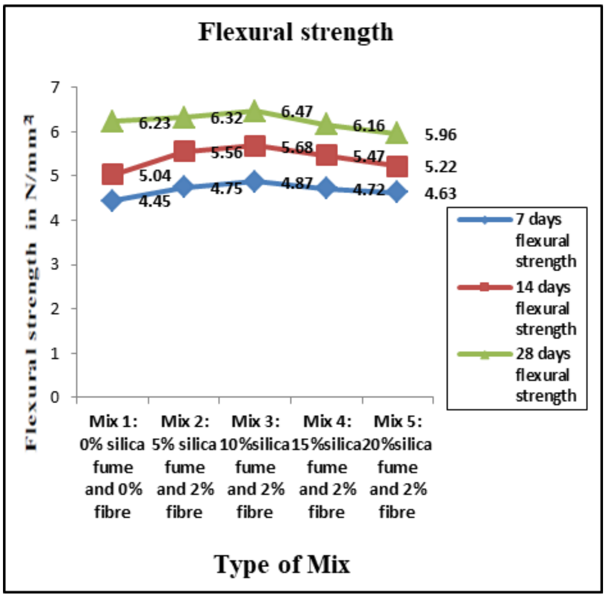


**Chart-7:** Variation of silica fume and coir fibre v/s Flexural strength at 7, 14 and 28 days

## VII. DURABILITY PROPERTIES OF CONCRETE

### 7.1 Water Absorption Test

Water absorption test is the amount of water absorbed in percentage which is the difference in weight of specimen and oven dried weight. Water absorption test was carried out according to IS 1124 (1974). The cube size of 100mm x 100mm x 100mm was casted and immersed in water for 28 days. The cubes were tested and at mix 3(10%silica fume& 2%fibre) lowest water absorption is obtained. Table 7.1 indicates the result of water absorption test.

$$\% \text{ water absorption} = \frac{w_2 - w_1}{w_2} \times 100$$

**Table 7.1** Result of Water absorption test

| Mix | Saturated weight in (gm) | Dried weight in (gm) | % Water absorption |
|---|---|---|---|
| Mix 1 | 2895 | 2820 | 2.65 |
| Mix 2 | 2854 | 2803 | 1.81 |
| Mix 3 | 2849 | 2802 | 1.67 |
| Mix 4 | 2890 | 2834 | 1.97 |
| Mix 5 | 2918 | 2839 | 2.79 |

### 7.2 Ultra-sonic pulse velocity test

Ultrasonic pulse velocity test is an in-situ, non-destructive test to check the quality of concrete by measuring the velocity of an ultrasonic pulse passing through a concrete structure. The highest ultrasonic pulse velocity obtained at 28 day is 4.49 km/sec. Table 7.2 indicates the result of ultrasonic pulse velocity test. Conforming to IS: 13311 Part 1, they were categorized as sound concrete with appropriate quality.

**Table 7.2** Result of Ultra-sonic pulse velocity test

| Mix | Velocity (km/sec) | Concrete quality grading |
|---|---|---|
| Mix 1 | 4.41 | Good |
| Mix 2 | 4.47 | Good |
| Mix 3 | 4.49 | Good |
| Mix 4 | 4.43 | Good |
| Mix 5 | 4.36 | Good |

### 7.3 Acid attack test

The presence of high concentrations of acid in water or in the environment that is in contact with the hardened concrete leads to the deterioration of concrete. The test was conducted on 100mm x 100mm x 100mm concrete specimens for loss in weight. The cubes are immersed in a 5% hydrochloric acid solution for 28 days. The effect of chloride attack on the properties of concrete was given in terms of weight loss and is shown in Table 7.3.

**Table 7.3** Result of Acid attack test

| Mix | Initial weight in (gm) | Final weight in (gm) | Loss in weight (%) |
|---|---|---|---|
| Mix 1 | 2847 | 2727 | 1.2 |
| Mix 2 | 2859 | 2770 | 0.89 |
| Mix 3 | 2865 | 2779 | 0.86 |
| Mix 4 | 2853 | 2758 | 0.95 |
| Mix 5 | 2750 | 2601 | 1.49 |

## VIII. CONCLUSIONS

Based on the experimental study, the Compressive strength, Split tensile strength and Flexural strength of concrete were obtained with the partial replacement of cement by varying percentages 5%, 10%, 15%, 20% of silica fume and 2% of coir fibre. The results are compared with conventional concrete. The maximum Compressive strength, Split tensile strength and Flexural strength had achieved at 10% of partial replacement with cement by silica fume with constant addition of 2% coir fibre.

Silica fume increases the strength and pore refinements of concrete. Coir fibre is incorporated in concrete to improve the ductility, resistance to cracks and shrinkage. The maximum strength obtained from our project is 69.30 N/$mm^2$ for Compressive strength, 4.50 N/$mm^2$ for Split tensile strength and 6.47N/$mm^2$ for Flexural strength.

The combined effect of silica fumes and coconut fibres upgrades resistance to acid attack and water absorption of concrete. The strength of the concrete is evaluated by non-destructive Ultrasonic pulse velocity test. The UPV test results of specimen with various proportions gave velocity within 4- 4.5Km/s rated 'Good' quality concrete which allows for an alternative to conventional concrete. The durability aspects of concrete for a mix proportion consisting of replacement of cement with 10% silica fume and 2% coir fibre was best among all other combinations.

## IX. RECOMMENDATION

I recommend my project for marine structures. Studies prove that it will be more suitable for aggressive environments. Since, marine structures have suffered from sea water attacks for decades the best approach to minimize the deleterious effects on these structures is to use high-strength concrete. Normally these concretes exhibit cracks. To overcome those cracks coconut fibres are used in high strength concrete. In addition to this silica fume is also used to improve the strength and durability parameter.

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