Effect of Blend of Silica Fume and Sisal Fiber on Performance of Concrete

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Abstract – India is a developing country, therefore Infrastructure development is necessary for our country and concrete plays a vital role in it. Concrete is the world's largest consuming material in the construction field. The emission of carbon-dioxide (CO2) in the atmosphere from the operation and maintenance of structures as well as production of building materials can be reduced by using renewable resources and construction materials. Conventional concrete is relatively strong in compression but weak in tension, in order to overcome the weakness the use of a sufficient volume of certain fibers such as sisal fiber is used in this experiment, which is easily available, renewable and economical. Micro silica, an industrial byproduct which is a very fine non-crystalline material is very good as filler material to provide good strength. By utilizing these waste materials in construction activities which solve the environmental pollution problems, also safer and economical construction.

The main objective of this project is to investigate effect of silica fume & fiber orientation of sisal fiber on performance of concrete, which ultimately solve the problems of waste disposal & reduces global warming. Here in the experiment an attempt has been made to increase the strength of concrete by replacing cement partially with silica fume and sisal fibers at varying percentage in a design mix of M30 and M40.

Keywords: Sisal Fiber, Micro Silica, Sustainable, Renewable, Economic.

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1. INTRODUCTION

1.1 Introduction

Nowadays, Concrete is a most widely used construction material around the world for various types of structures due to its structural stability and strength. Recent developments in civil engineering, with a fast population growth and a higher demand for housing and infrastructure, such as high-rise buildings and long-span bridges, higher compressive strength concrete is necessary. The world's carbon emission of approximately 8-20% is due to the manufacturing of building materials. Reducing the consumption of cement reduces the emission of CO_2 to the atmosphere and in turn reduces the effect of Global Warming. There is a need for sustainable development to mitigate the pollution, environmental degradation & to decrease global warming. For more sustainable structures, recycled materials and waste can thus be used in the manufacture of materials, the energy efficiency of buildings can be improved and renewable materials can be used to substitute conventional building materials.

For global sustainable development and lowest possible environmental impact, Supplementary cementitious materials can be used as an alternative for cement. Substantial energy and cost savings can result when industrial by products are used as a partial replacement of cement such as Silica fume, Fly ash, Ground Granulated Blast furnace Slag, Rice husk ash, Metakaolin. Silica fume is used in this experiment.

(Srivastava, et. al., 2014) The addition of silica fume reduces workability. However, in some cases it improves the workability. Silica fume inclusion increases the compressive strength of concrete significantly (6-57%). The increase depends upon the replacement level. The addition of silica fume improves the bond strength of concrete.

(Gowthami, et. al., 2013) The tensile strength of composite with silica is 1.5 times greater than that of composite without silica and 2.5 times greater than that of pure resin. Tensile modulus is significantly increased. The specific heat capacity of all samples increased with increase of temperature (30°C - 85 °C), and then decrease beyond 85 °C.

Natural fibers such as sisal fibers are preferred due to their greater advantages, which include low cost, high strength-to-weight ratio, better durability, environmental compatibility, bio degradability and recyclability. The mechanical properties of cement and concrete matrices improved are crack resistance, fracture toughness, compressive strength, flexural and impact strength.

(Balasubramanian, et. al., 2015) The weakness in tension in concrete can be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers. The use of fibers also alters the behavior of the fiber-matrix composite after it has cracked, thereby improving its toughness. By adding this sisal fiber it has been found that there is an increase in properties of both fresh and hardened concrete.

(Athiappan and Vijaychandrakanth, 2014) Modulus of rupture decreases with increase in percentage of sisal fibre. Workability decreases with increase in percentage of sisal fibre. The flexural strength of concrete with optimum percentage of sisal fibre increases the strength when compared with the conventional concrete.

(Toledo, et. al., 1999) The free plastic shrinkage is significantly reduced by the inclusion of 0.2% volume fraction of 25 mm short sisal fibres in cement mortar. Also, it was stated that the presence of sisal and coconut fibres promote an effective self-healing of plastic cracking after 40 days at 100% RH.

(Midhuna & Chandrasekeran, 2015) Significant improvements in the overall performance of the silica concrete with sisal fiber are observed at 10% silica replacement and 0.75% sisal fiber addition in M40 grade of concrete. In sisal-silica concrete strength increased gradually till 0.75% addition of fiber after that the strength is decreased than conventional concrete may be due to increase percentage of fiber which leads to voids formation. The strength of sisal fiber addition to silica concrete is higher when compared to conventional concrete.

It is observed that an effective increase in strength of concrete was found, due to the immersion of natural fibers in silica fume slurry before addition to the cement based composites. Also the natural fibers with improved durability were obtained by the partial replacements of OPC by undensified silica fume. In this experiment, durability of sisal fiber composites can be improved to some extent due to micro silica pozzolons in concrete.

1.2 Aim

To study the effect of silica fume and natural fibre (sisal) as partial replacement of cement on the performance of concrete.

1.3 Objectives

- To determine the optimum percentage of silica fume & sisal fibre, which enhances the concrete quality.
- To study the mechanical properties of silica with sisal fiber concrete.

1.4 Scopes

- This study focuses on the strength performance of concrete with sisal fibre, silica fume and its blend.
- The scope of this project is to find out the behavior of silica concrete with sisal fiber.
- For performance comparison study between silica fume and sisal fibre which is use as a supplementary cementite's materials.
- To develop a sustainable low-cost, nontoxic, renewable and durable construction materials with zero health risk.

2. MATERIALS

Materials used:

1) Silica fumes
2) Sisal fibers
3) Cement
4) Sand & Aggregates
5) Water

1) Silica Fume:

Fig. 1 Silica fume powder (Primary survey)

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Silica fume, also referred to as micro silica or condensed silica fume, is a byproduct material that is used as a pozzolan. This byproduct is a result of the reduction of high-purity quartz with coal in an electric arc furnace in the manufacture of silicon or ferrosilicon alloy. Silica fume rises as an oxidized vapor from the 2000°C (3630°F) furnaces.The escaping gaseous SiO oxidizes and condenses in the form of extremely fine spherical form of amorphous silica (SiO2); hence, it called as silica fume.

It is an airborne material like fly ash, it has a spherical shape. It is extremely fine with particles less than 1 µm in diameter and with an average diameter of about 0.1 µm, about 100 times smaller than average cement particles. The relative density of silica fume is generally in the range of 2.20 to 2.5. The bulk density (uncompacted unit weight) of silica fume varies from 130 to 430 kg/m3 (8 to 27 lb/ft3). It is used in applications where a high degree of impermeability is needed and in high strength concrete.

The chemical process is complex and it depends on the temperature of the producing. The Si formed, initially plays important intermediate roles.

At temperatures > 1520 ^{0}C

$SiO_2 + 3C = SiC + 2CO$

At temperatures > 1800 ^{0}C

$3SiO_2 + 2SiC = Si + 4SiO + 2CO$

The unstable gas diffuses in the furnace where it reacts with oxygen to give the silicon dioxide

$4SiO + 2O_2 = 4SiO_2$

Advantages:

- The slump loss with time is proportionally increased in concrete mix.
- Due to the high surface area workability and consistency of concrete decrease.
- Effective for increasing both damping capacity and stiffness.
- Increases the sound absorption ability.

Effects of Silica Fume:

- High compressive strength.
- Increase in the tensile and flexural strength.
- The bonding to the steel fibers is significantly increased.
- Enhances the freeze-thaw durability.
- Enhances the corrosion resistance of the reinforcing steel.
- Increases the concrete chemical attack resistance.
- Decreases bleeding significantly.

Table 1: Properties of Micro Silica

Property	Specifications
Particle Size	0.1micron
Bulk Density	670 kg/m3
Specific gravity	2.2
Specific surface	25000 m²/kg
Shape	Spherical
Colour	Light to Dark Grey
SiO2	90%-96%
Al2O3	0.5%-0.8%

2) Sisal Fibres:

Fig. 2 Sisal fibre plant

Agave sisalana Perrine (Agavaceae), popularly known as sisal in is a monocotyledonous plant from Mexico and is now mainly cultivated in India, East Africa, Brazil, Haiti and Indonesia.The reason for this is due to the ease of cultivation of sisal plants, which have short renewing times, and is fairly easy to grow in all kinds of environments. Sisal fibers are stiff, straight, smooth and yellow in colour. Strength, durability and ability to stretch are some of the important properties of sisal fibers. Concrete made with Portland cement is relatively strong in compression but weak in tension and tends to be brittle. The weakness in tension can be overcome by the use of sisal fibre. The use of fibers also alters the behaviour of the fiber-matrix composite after it has cracked, thereby improving its toughness.

Fig. 3 Hand Extraction

Table 2: Properties Sisal Fiber

Property	Specifications
Fibre length (mm)	50
Diameter (µm)	100-300
Density (g/cm3)	1.45
Specific modulus (Gpa)	6-15
Tensile Strength (MPa)	568-640
Modulus of elasticity (Gpa)	9.4-15.8
Moisture absorption	11%
Porosity (%)	17
Elongation at failure	2-4.5%
Cellulose content (%)	67-78
Young's modulus (Gpa)	9-22

3) Cement :

Cement may be defined as a material which possesses very good adhesive and cohesive properties which make it possible to bond with other material to form compact mass. Ordinary Portland Cement 53 grade was used in this experimental work. The cement properties were evaluated as per the IS: 4031-1996 and IS: 12269-1987.

Tests on Cement:

1. Fineness test
2. Standard Consistency
3. Initial and Final setting time

The cement used in this experimental investigation was 53 grade OPC manufactured by ACC Limited.

Table 3: Properties of Cement

Physical properties	Results
Standard Consistency	35%
Initial setting time	130 minutes
Final setting time	270 minutes
Finenessmodulus	98% passes through 90 micron sieve

4) Sand and Aggregate:

Fine aggregate:

The crushed sand used for experimental program was locally procured and conforming to Zone I. The fine aggregates were tested as per Indian Standard Specification IS: 383-1970. The specific gravity is 2.75.

Coarse aggregate:

Aggregates passing through 20mm sieve and retained on 4.75mm sieve were sieved and tested as per Indian Standard Specifications IS: 383-1970. The specific gravity is 2.85. FM was maintained throughout the experiment.

5) Water:

In this study, normal tap water was used. Fresh potable water, which is free from concentration of acid and organic substance, is use for mixing the concrete.

3. METHODOLOGY

Concept of using silica fume & sisal fiber in concrete was conceived. Based on the concept, various research papers & journals were referred and an idea about the supplementary cementitous materials such as silica fume & the natural fiber known as the sisal fiber being used in concrete was obtained. The knowledge on fiber reinforced concrete was also obtained by referring various journals. Literature review was done and the concept was finalized. Various tests on Cement, fine aggregate and coarse aggregates were carried out. The results obtain from the silica fume and sisal fiber reinforced concrete is compare with conventional concrete, in order to do find the merit or demerit of concrete.

The experimental work will be carried out in the following different phases:

- The first phase is the material testing in which all the materials properties for all ingredients of concrete were investigated.
- Second phase is mixing, placing of fiber and casting of the concrete mixes samples after which the curing of those samples were done.
- Third phase is Compressive strength testing of concrete mixes samples, in which the cured samples of 7 days and 28 days.
- Fourth phase of experiment is results, discussion & conclusion, which includes comparison of results obtain from silica fume and sisal fiber reinforced concrete blocks with conventional concrete blocks.

Also determining the optimum percentage of sisal fiber with micro silica in concrete, which enhances the concrete quality.

To avoid confusion of the concrete mix samples and grade of concrete, specific notations or coding system given in tables is used. Following notations were used for naming of concrete mix samples:

Concrete Mixes

Table 4: Grades of Concrete Use

Notation Used	A	B
Grades of Concrete	30	40

Table 5: The dry mixes composition of blended cement (wt.%)

For M30 & M40

M30			M40		
Concrete Mixes No.	Silica Fumes (SF)	Sisal Fibre (NF)	Concrete Mixes No.	Silica Fumes (SF)	Sisal Fibre (NF)
AM1	0.3%	10%	BM1	0.3%	10%
AM2	0.5%	10%	BM2	0.5%	10%
AM3	1%	10%	BM3	1%	10%
AM4	1.5%	10%	BM4	1.5%	10%
AM5	0.3%	15%	BM5	0.3%	15%
AM6	0.5%	15%	BM6	0.5%	15%
AM7	1%	15%	BM7	1%	15%
AM8	1.5%	15%	BM8	1.5%	15%

4. RESULTS AND DISCUSSIONS

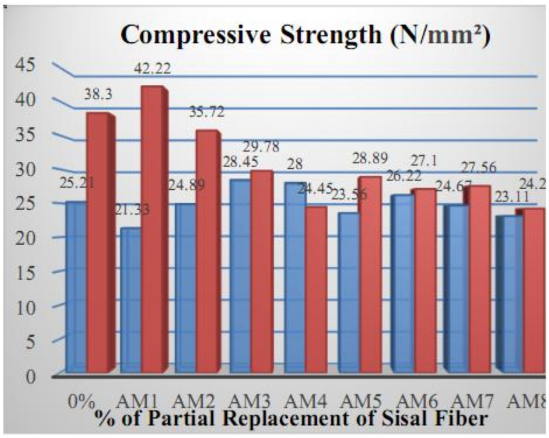
Compressive Strength, Split Tensile Strength &Flexural strength:

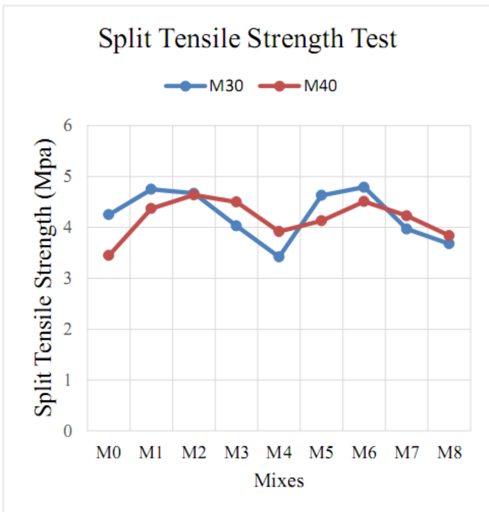
The test was conducted as per IS 516-1959 codal provision. For cube compression tests on concrete, cube of size 150 mm were employed. For split tensile strength, the cylinder of 150mm diameter and 300mm height were used. . Flexure strength was measured by loading 150mm x150 mm x 700 mm concrete beams with a span at least three times the depth. All the specimens were tested in saturated condition after wiping out the surface moisture from the specimen.

The tests were carried out at a uniform stress after the specimen has been centered in the testing machine. For all mixes compressive strengths were determined at 7 days.

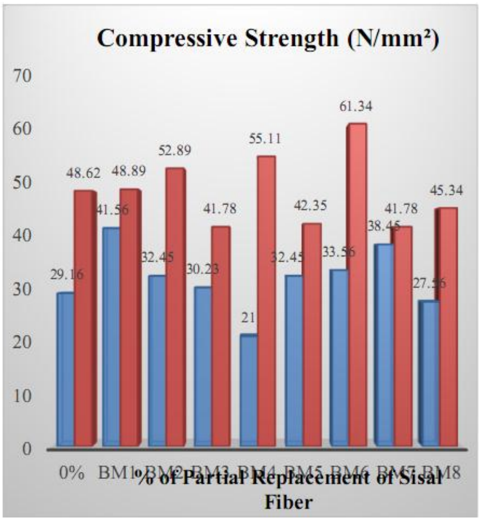
Results of test are as below:

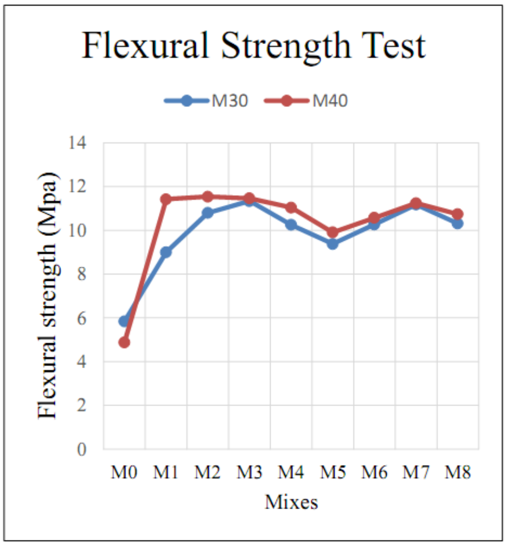
For M30:





M40:





From the above investigational work and test results, the following conclusions were arrived:

- The optimum percentage of sisal fibre and silica fume for maximum strengths (compressive) was found to be at AM4 and BM7 concrete mix.
- The optimum percentage of sisal fibre for maximum strengths (split tensile) was found to be 0.3% for M40 grade (BM6) of concrete and 0.5% for M30 grade (AM2).
- It is concluded that 10% replacement of Micro silica induces higher strength properties and good workability properties. This may be due to the filling effect of micro silica.
- At 15% replacement, the strength of concrete decreases due to excess fines and lesser cement content.
- Workability of concrete improves with addition of silica fume up to certain limit. Workability decreases with increase in percentage of sisal fibre as well as silica fume.
- The strength of sisal fiber addition to silica concrete is higher when compared to conventional concrete.
- Consistency of cement depends upon its fineness. Silica fume is having greater fineness than cement and greater surface area so the consistency increases greatly, when silica fume percentage increases.
- Increase in split tensile strength beyond 10 % silica fume replacement is almost insignificant whereas gain in flexural tensile strength have occurred even up to 15 % replacements. Silica fume seems to have a more pronounced effect on the flexural strength than the split tensile strength.

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