TO STUDY MECHANICAL PROPERTIES OF CONCRETE USING SILICA FUME AND STEEL FIBER

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ABSTRACT:

This study investigates the mechanical properties of concrete enhanced with silica fume and steel fibres. The integration of silica fume, known for its high pozzolanic activity, and steel fibres, recognized for their crack-bridging capabilities, aims to produce concrete with superior strength and durability. Various concrete mixtures were created with differing quantities of silica fume and steel fibres to evaluate their combined impacts on compressive, tensile, and flexural strengths, as well as workability and durability. Experimental results indicate that the inclusion of silica fume greatly enhances the compressive strength by refining the microstructure of the concrete, while steel fibres enhance tensile and flexural strengths by arresting crack development and distributing stress more uniformly. Even if the reduction in workability can be counteracted by applying superplasticizers, Using steel fibres and silica fume together is a very efficient way to make high-performance concrete. According to the study's findings, concrete with improved mechanical qualities and durability that is suited for demanding structural applications can be created by utilizing the synergistic effects of steel fibres and silica fume.

Keywords: Silica Fume, Steel Fiber, Concrete, Mechanical Properties, Compressive Strength, Tensile Strength, Flexural Strength, Workability, Durability.

1. INTRODUCTION:

Concrete's inherent compressive strength, durability, and versatility make it one of the most extensively used building materials. However, its mechanical qualities frequently need to be improved in order to satisfy the increasing needs of modern building. Additives like steel fibres and silica fume become essential at this point. The manufacturing of silicon and ferrosilicon alloys leaves behind silica fume, a highly reactive pozzolanic substance made up of extremely small particles with a high silica concentration. By producing extra calcium silicate hydrate (C-S-H) through a pozzolanic reaction with calcium hydroxide, silica fume greatly boosts the compressive strength of concrete. By decreasing permeability, this reaction not only increases strength but also improves durability, strengthening concrete's resistance to environmental deterioration and chemical attacks.

Steel Fibres, on the other hand, are tiny, distinct lengths of steel that are mixed into the concrete to improve its structural stability. By bridging cracks, steel fibres improve tensile and flexural strength while assisting in load redistribution and slowing the spread of cracks. Because of its increased toughness, ductility, and tensile and flexural strength, the concrete can absorb more energy and deform more before failing. Steel fibres also improve impact resistance, making concrete better capable of withstanding dynamic loads and fending off impact damage. By combining steel fibres with silica fume in concrete mixtures, one can maximize the advantages of both components and achieve notable gains in overall performance and mechanical qualities.

This research looks at how different ratios of steel fibres and silica fume affect concrete's compressive, tensile, and flexural strengths as well as durability characteristics like permeability and resistance to environmental influences. Through an examination of these improvements, the research aims to create concrete mixes that are designed to satisfy the exacting specifications of contemporary building, offering robust and long-lasting solutions for a variety of uses.

1.1 Materials

1.1.1 Cement

OPC 53 cement with a characteristic of compressive strength of 53 MPa after 28 days of curing process. It has widely used in construction because to its high strength and durability, making it suitable for various applications including construction of high-rise buildings, bridges, and dams, etc. OPC 53 cement has excellent strength and durability, its production can have high energy consumption and carbon dioxide emissions, raising environmental concerns.

1.1.2 Silica Fume

A fine pozzolanic byproduct of the manufacturing of silicon metal or ferrosilicon alloys is silica fume, also known as micro silica. Its minuscule particles, primarily composed of silicon dioxide, greatly improve the characteristics of concrete. Concrete gains strength and durability when silica fume is added because it combines with calcium hydroxide to generate more calcium silicate hydrate. It is perfect for hostile conditions since it decreases permeability, increasing resistance to chemicals, sulphates, and chlorides. Applications include industrial flooring, shotcrete for tunnel construction, and high-performance concrete for bridges and maritime buildings. By reducing the need for cement, using silica fume lowers carbon emissions and promotes sustainability. Because of its small particles, handling and storage must be done carefully. Construction standards such as EN 13263 and ASTM C1240 guarantee uniformity and quality.

1.1.3 Steel Fibre

Steel fibres are small pieces of steel added to concrete to improve its tensile strength, ductility, and crack resistance. Made from materials like cold-drawn wire, these fibres enhance concrete's performance by bridging cracks and evenly distributing loads, transforming it from a brittle to a more ductile material. This makes steel fibre-reinforced concrete (SFRC) ideal for applications needing high durability, such as industrial floors, pavements, and tunnels. The use of steel fibres reduces the need for traditional reinforcement, simplifying construction and reducing labour costs. Proper mixing and placement are essential for effective results.

Properties	Plain Concrete	Concrete With Silica Fume	Concrete With Steel Fibre	Concrete With Both Silica Fume And Steel Fibre
Compressive strength	Moderate (e.g., 20-40 MPa)	Significantly higher (e.g., 40-80 MPa)	Slight improvement (e.g., 25-45 MPa)	Maximized (e.g., 60-100 MPa)
Tensile strength	Low (e.g., 2-5 MPa)	Improved (e.g., 4-8 MPa)	Enhanced (e.g., 5-10 MPa)	Highest (e.g., 8-15 MPa)

Table 1 : Differentiation of Concrete Properties

2. MIX PROPORTIONS

2.1 Plain Concrete

Material	6 Cube	3 Cylinder	3 Beam
Cement (kg)	7.8	12.24	18.18
Water (kg)	3.198	2.49	7.44
CA (kg)	17.82	14.01	41.67
FA (kg)	4.445	3.498	1.38
Chemical Admixture (kg)	0.0306	0.0243	0.072

Table 2 : mix proportion for Plain Concrete

2.2 Concrete With Silica Fume

Material	6 Cube	3 Cylinder	3 Beam
Cement (kg)	7.02	5.49	16.35
Silica Fume (kg)	0.78	0.612	1.819
Water (kg)	3.198	2.49	7.44
CA (kg)	17.82	14.01	41.67
FA (kg)	4.445	3.498	1.38
Chemical Admixture (kg)	0.0306	0.0243	0.072

Table 3 : mix proportion for Concrete With Silica Fume

2.3 Concrete With Steel Fibre

Material	6 Cube	3 Cylinder	3 Beam
Cement (kg)	7.69	6	17.82
Steel Fibre (kg)	0.157	0.122	0.363

Water (kg)	3.198	2.49	7.44
CA (kg)	17.82	14.01	41.67
FA (kg)	4.445	3.498	1.38
Chemical Admixture (kg)	0.0306	0.0243	0.072

Table 4 : mix proportion Concrete With Steel Fibre

2.4 Concrete With Both Silica Fume And Steel Fibre

Material	**6 Cube**	**3 Cylinder**	**3 Beam**
Cement (kg)	6.911	5.38	16
Silica Fume (kg)	0.78	0.612	1.819
Steel Fibre (kg)	0.157	0.122	0.363
Water (kg)	3.198	2.49	7.44
CA (kg)	17.82	14.01	41.67
FA (kg)	4.445	3.498	1.38
Chemical Admixture (kg)	0.0306	0.0243	0.072

Table 5 : mix proportion Concrete With Both Silica Fume And Steel Fibre

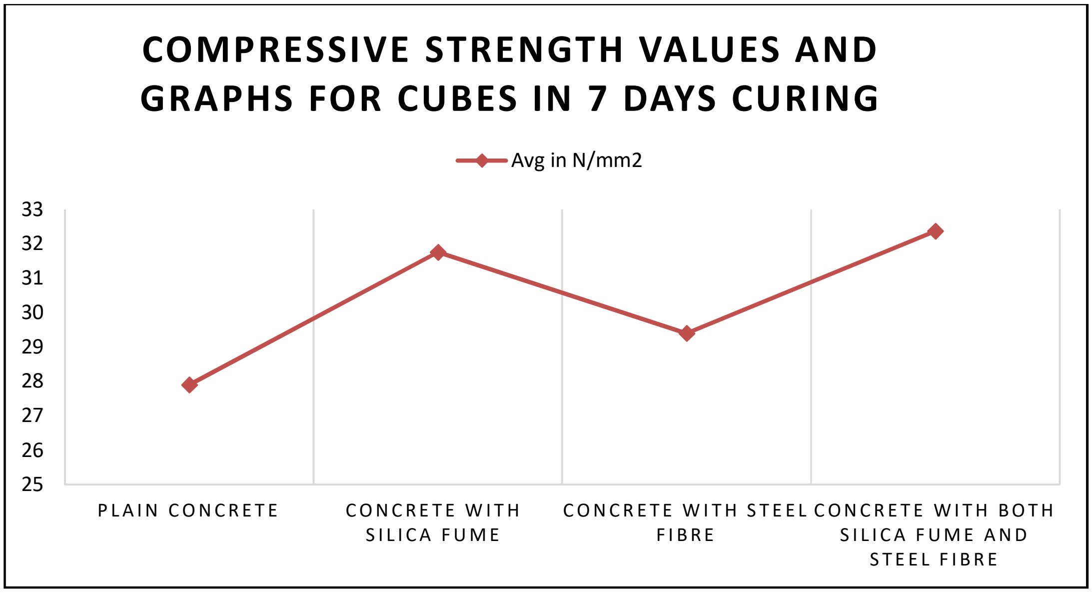
3. RESULTS

3.1 Compressive Strength Test Results

3.1.1 Test result for 7 days curing

Sr No	**Proportions**	**Specimen Designation**	**Age Of Concrete In Days**	**Compressive Strength In N/mm^2**	**Average Strength In N/mm^2**
1	Plain Concrete (100% concrete)	C1 C2 C3	7 7 7	26.8 27.9 29.0	27.9
2	Concrete With Silica Fume (90% - 10%)	C1 C2 C3	7 7 7	30.8 31.4 33.1	31.76
3	Concrete With Steel Fibre (98% - 2%)	C1 C2 C3	7 7 7	29.8 30.0 28.4	29.4
4	Concrete With Both Silica Fume And Steel Fibre (88%-10%-2%)	C1 C2 C3	7 7 7	31.9 33.01 32.22	32.37

Table 6 : Test Result Of Cube Specimen Of 7 Days Curing

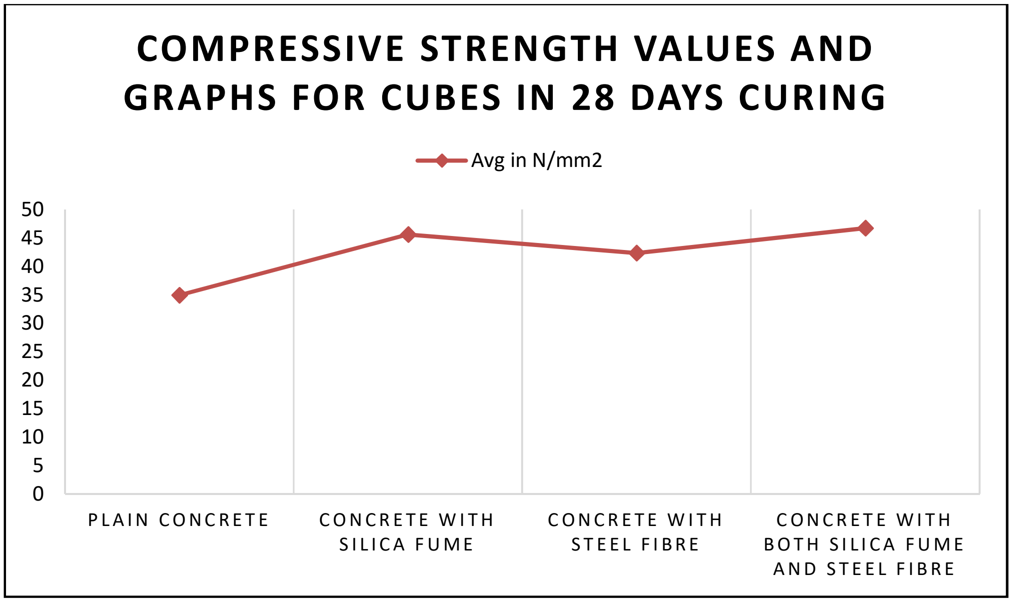


Graph 1 : Test Results Of Cube Specimen In 7 Days Curing

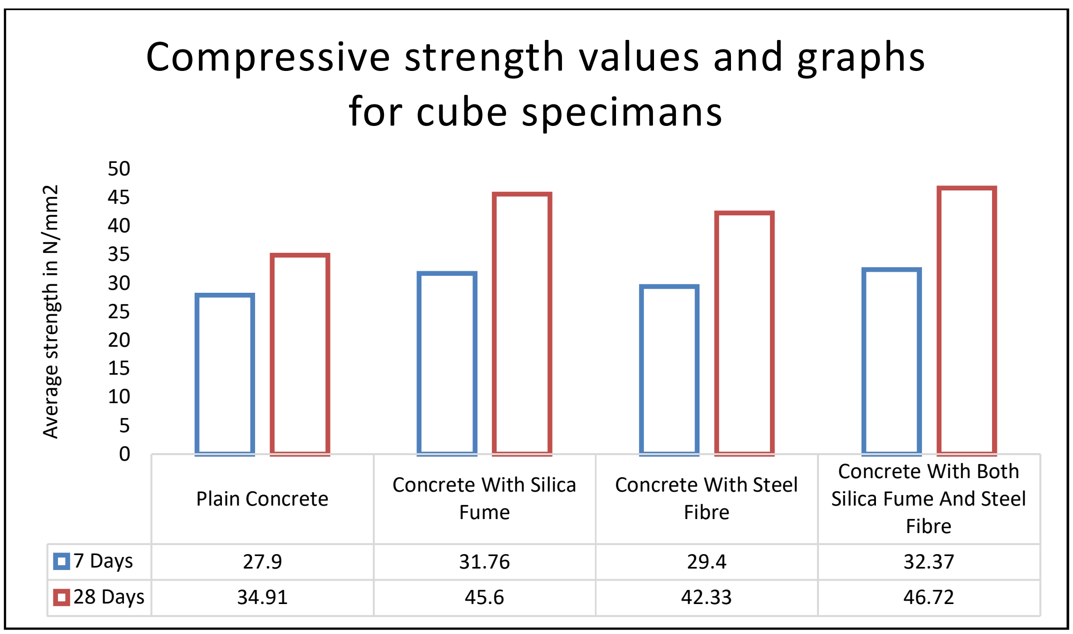
3.1.2 Test result for 28 days curing

Sr No	Proportions	Specimen Designation	Age Of Concrete In Days	Compressive Strength In N/mm²	Average Strength In N/mm²
1	Plain Concrete (100% concrete)	C1 C2 C3	28 28 28	34.31 35.44 34.98	34.91
2	Concrete With Silica Fume (90% - 10%)	C1 C2 C3	28 28 28	44.8 46.8 45.4	45.6
3	Concrete With Steel Fibre (98% - 2%)	C1 C2 C3	28 28 28	41.2 42.2 43.6	42.33
4	Concrete With Both Silica Fume And Steel Fibre (88%-10%-2%)	C1 C2 C3	28 28 28	46.98 46.69 46.21	46.72

Table 7 : Test Result Of Cube Specimen Of 28 Days Curing



Graph 2 : Test Results Of Cube Specimen In 28 Days Curing

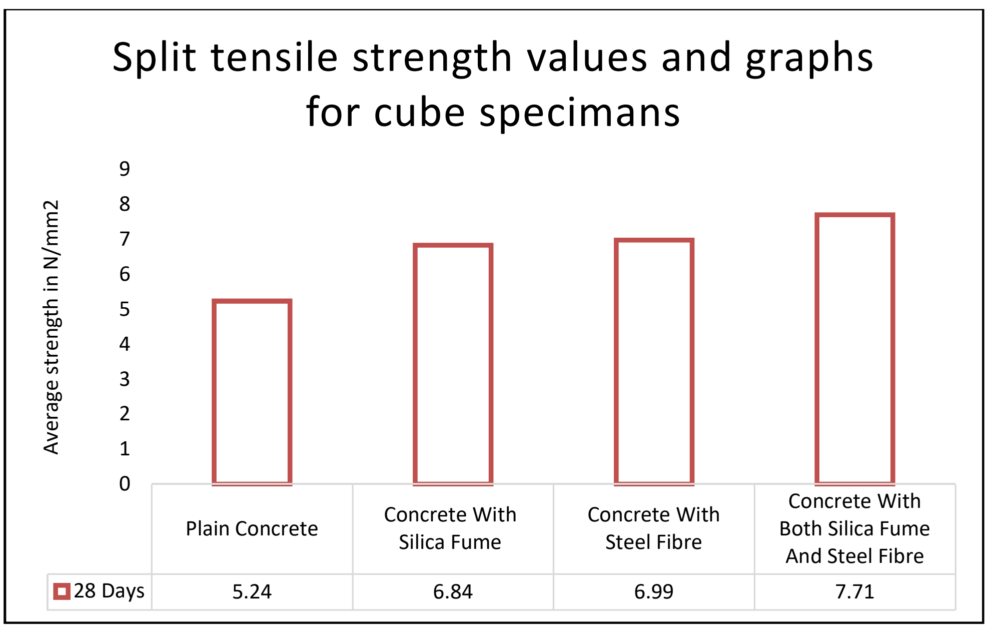


Graph 3 : Test Results Of Cube Specimen In 7 & 28 Days Curing

3.2 Flexure Test Results

Sr No	Proportions	Specimen Designation	Age Of Concrete In Days	Tensile Strength In N/mm^2	Average Strength In N/mm^2
1	Plain Concrete (100% concrete)	B1 B2 B3	28 28 28	5.52 4.98 5.24	5.24
2	Concrete With Silica Fume (90% - 10%)	B1 B2 B3	28 28 28	5.84 6.91 6.55	6.84
3	Concrete With Steel Fibre (98% - 2%)	B1 B2 B3	28 28 28	6.48 7.11 7.38	6.99
4	Concrete With Both Silica Fume And Steel Fibre (88%-10%-2%)	B1 B2 B3	28 28 28	7.28 7.91 7.84	7.71

Table 8 : Test Result Of Beam Specimen Of 28 Days Curing



Graph 4 : Test Results Of Beam Specimen In 28 Days Curing

4. CONCLUSION

The study shows that the mechanical qualities of concrete are greatly enhanced by the addition of steel fibres and silica fume. The plain concrete exhibited a tensile strength of 5.24 N/mm² after 28 days, and an average compressive strength of 27.9 N/mm² after 7 days and 34.91 N/mm² after 28 days. The 7-day compressive strength and 28-day compressive strength of concrete containing 10% silica fume increased by 13.8% and 30.6%, respectively, while the tensile strength improved by 30.5%. The 7-day compressive strength and 28-day compressive strength of concrete containing 2% steel fiber increased by 5.4% and 21.2%, respectively, while the tensile strength increased by 33.4%. The greatest gains were obtained with a mixture of 10% silica fume and 2% steel fiber: a 16% increase in 7-day compressive strength and a 33.8% increase in in 28-day compressive strength, and a 47.1% increase in tensile strength. Thus, combining silica fume and steel fibres produces concrete with superior strength and durability. while both silica fume and steel fibres individually enhance the mechanical properties of concrete, their combination yields the most significant improvements, demonstrating a synergistic effect that produces concrete with superior strength and durability. Additionally, the use of silica fume can reduce the heat of hydration, which helps in minimizing thermal cracking in large concrete structures, further enhancing the durability and performance of the concrete.

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