ASSESSMENT OF CONCRETE WITH SILICA FUME AS PARTIAL CEMENT REPLACEMENT

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ABSTRACT

Silica fume is a hazardous gas created as a residue of steel mills used to manufacture silicon metal and silicon alloys. It has excellent pozzolanic qualities, as well as other characteristics. Concrete that has been admixed with condensed Silica Fume has excellent strength and endurance, and it has proven to be particularly useful in places where structures are subjected to significant environmental damage. In contrast to the reactions using natural pozzolans and fly ash, the reaction involving Silica Fume is extremely fast. It is 100 times finer than cement and contains a high concentration of pozzolanic material. Despite the fact that Silica Fume does not have any binding qualities by itself, it combines with $Ca(OH)_2$ during the hydration of cement to generate a gel, known as calcium silicate hydrate, which has excellent binding properties. Because the heat of hydration for cement and Silica Fume is about the same, using this strategy of replacement minimizes the overall amount of heat created in the enormous pours that are normally utilized for dam construction. In the present assessment, an attempt has been made to study the mechanical characteristics of a few Silica Fume admixed concrete mixes, namely the compressive strength, split tensile strength, and modulus of rupture of the concrete. The purpose of the study is to determine the effect of increasing the percentage substitution of cement with silica fume in the mixes on the strength parameters of the mixtures under investigation. A commercially available Super Plasticizer, Conplast SP337, has been used to make the mixes tested here usable. Appropriate dosages of this Super Plasticizer have been added to the mixes tested here. It is the goal of this project work to investigate the effects of Silica Fume on the characteristics of concrete. The findings of an examination into the mechanical properties of hardened concrete that has been largely replaced by silica fume, including compressive, flexural and split tensile strength are presented. The optimal replacement of cement in concrete with Silica Fume is 9 percent, at which a strength fluctuation of up to 21.15 percent has been seen when compared to control concrete, according to the results.

Keyword: - *Silica Fume, Cement, Replacement, Concrete*

1. INTRODUCTION

Due to its strength, great dimensional stability, structural stability, and financial benefits, concrete is the most extensively utilized construction material on a global scale. Portland cement is the most significant element of concrete and is a flexible and relatively low cost material. On the one hand, large-scale cement manufacture creates environmental concerns; on the other hand, it results in the unfettered depletion of natural resources. This threat to the ecology has prompted numerous studies into the use of industrial by-products as supplementary cementitious material in concrete production. Fly ash, powdered pulverized blast furnace slag, and silica fume are all well-known industrial by-products that are frequently used as supplementary cementitious materials.

The use of high-strength concrete in high-rise skyscrapers, long-span bridges, offshore projects, and other mega structures necessitates smaller portions. This eliminates dead weight and allows for more cost-effective structure construction. The use of high-strength concrete raises both the compressive and tensile strengths of a structure. In high-rise buildings, increasing the strength of the columns reduces their size and so increases floor space. High strength concrete can be utilized in structures where self-weight is important. A great deal of attention is placed on Micro-Silica in concrete. In order to eliminate voids in the fresh concrete, ultra-fine spheres are injected between the cement grains. In this case, the tiny particles allow the concrete to flow more smoothly. Micro-Silica is a kind of pozzolan. It will react with the calcium hydroxide produced by cement hydration to produce calcium silicate hydrate, which will bind the concrete together. Bleeding and segregation will be decreased or eliminated. The crystalline structure created by this reaction is exceedingly fine and fills the vacant areas within the matrix due to the very fine size of the Micro-Silica particles. This densifies the entire concrete structure, increasing strength and decreasing permeability. Micro-Silica can be utilized in mass concrete buildings to minimize the heat of hydration. As a result, Micro-Silica serves as both filler and a pozzolan. Micro-Silica is widely utilized to produce concrete with improved qualities such as early strength and low permeability. Micro-fineness Silica decreases bleeding, preventing bleed water from being trapped beneath coarse aggregate particles. Silica fume is used to make high-strength and super-high-strength concrete. Fresh concrete with Silica Fume is more cohesive and less prone to segregation. Concrete with Silica Fume has less bleeding. The high surface area of Silica Fume being wet causes this action, leaving little free water in the combination for bleeding. Silica fume also minimizes bleeding by physically plugging holes in new concrete. Hydraulic constructions are now built with silica fume concrete. Abrasion resistance of dam sections such as overflow or stilling basins has been improved by using silica fume in dams. Using Silica Fume in place of cement decreases the overall heat generated in huge pours used for dam concrete. Recent research has focused on using Silica Fume in roller compacted concrete for dam construction. Shotcrete micro-silica concrete is utilized in hydropower tunnels and waste and water tunnels. Using Silica Fume to line steel water pipes with mortar will prevent leaching from the lining and enhance the connection between the mortar and steel. Because Silica Fume concrete has less permeability and less calcium hydroxide, it is more resistant to chemical assault and leaching than traditional concrete. Compared to sulphate resistant cement, Silica Fume offers superior resistance to sulphate assault, strength, acid attack, and mechanical attack such as impact or abrasion. For creating concrete, Silica Fume, also known as Micro-Silica or condensed Silica Fume, is superior. Silicon metal or silicon alloys are produced in electrically arc furnaces. It has remarkable pozzolanic properties. Concrete containing Silica Fume is strong and durable, and has proven useful in locations where construction is subjected to harsh climatic conditions. It comprises high amounts of ultrafine amorphous silicon dioxide particles, which often make up over 90% of the silica fume ingredients. Silica Fume comes in three forms: loose bulk, densified, and slurry. Blended Portland Silica Fume Cement is also available. Silica fume is a mineral additive used in cement to improve the quality of concrete and mortar while lowering the cost. Unlike natural pozzolans and fly ash, Silica Fume reacts quickly. High pozzolanic, 100 times finer than cement. While Silica Fume alone has no binding capabilities, it combines with $Ca(OH)_2$ during cement hydration to form a gel called calcium silicate hydrate, which does. Silica Fume is utilized in high strength concrete due to its high pozzolanicity.

2. METHODOLOGY

2.1 Properties of Admixtures Used

2.1.1 Properties of Silica Fume

S.No	Component	ASTMC 1240-99 Specifications (%)	Silica fume (Elkem) (%)
1.	SiO_2	85 Minimum	90.3
2.	Moisture content	3 Maximum	0.6
3.	Carbon	2.5 Maximum	0.8
4.	Greater than 45 micron	10 Maximum	0.4
5.	LOI (975^{o}C)	6 Maximum	2.1

2.2 Other Properties

Specific surface area	:	22,000 m^2 / kg
Bulk density	:	640 kg / m^3

2.3 Properties of Conplast Sp 337

Specific gravity	:	1.18 – 1.20 at 27°C
Chloride content	:	Nil as per IS: 456 and
Setting time	:	1 – 2 hrs
Air entrainment	:	Approx.1% additional air is entrained.

2.4 Design Stipulations

Required compressive strength - 28 days	:	60 N/mm^2
Maximum aggregate size	:	20mm (angular)
Quality control Degree	:	Very good
Workability Degree	:	Extremely low

2.5 Material test data

1.	Cement Type	:	OPC 53 grade as per IS: 269 - 1976
2.	Cement Specific gravity	:	3.15
3.	Coarse aggregate Specific gravity	:	2.60
4.	Fine aggregate Specific gravity	:	2.60
5.	Water absorption		
	(i) Coarse aggregate	:	0.5%
	(ii) Fine aggregate	:	1.0%
6.	Free surface moisture		
	(i) Coarse aggregate	:	Nil
	(ii) Fine aggregate	:	2.0%
7.	Compaction factor	:	0.81

3. EXPERIMENTAL RESEARCH

The experimental program entails casting and testing 108 concrete examples with and without Micro-silica. This study investigated 36 150mm side cubes for 7 days and 28 days cube Compressive Strength, 36 100 x 100 x 500mm size beams for 7 days and 28 days Flexural Strength, and 36 150mm diameter and 300mm length cylinders for 7 days and 28 days Split Tensile Strength. Cement was partially substituted with silica fume in increments of 2% between 3.0 and 11%. To obtain a workable concrete, Super Plasticizer was added to the mix, and the optimal amount was determined by a compaction factor test. It was possible to achieve a compacting factor of 0.81 by including a super plasticizer dosage of 1.5 percent by mass of cement in the concrete mixture. All concrete examples used in this study were cast using the dosage specified above. Prior to casting, machine oil was spread on the cast iron mold's inner surfaces. The components included 53-grade regular Portland cement, natural river sand, crushed granite coarse aggregate with a maximum particle size of 20mm, mixing and curing water, and a Super Plasticizing additive. The experiment used densified silica fume.

4. RESULTS AND DISCUSSIONS

4.1 Influence of Silica Fume on Mechanical Properties of Concrete

The compressive, flexural and split tensile strength of M60 Grade concrete are shown in Tables 4, 5, and 6. The data presented is an average of three specimens. These tables demonstrate that substituting Silica Fume up to 9% enhances the mechanical characteristics of concrete at both 7 and 28 days. The improvement might be described as a result of the combined action of the filler effect and the pozzolanic reaction, as follows:

4.2 Effect of Filler

It's more evident that silica fume has a greater specific surface area than cement. This clearly indicates that the Silica Fume particle size is less than that of cement. As a result, silica fume fills the spaces between the cement particles as well as between the cement particles and the aggregates when added to concrete. This physical phenomenon is referred to as the Filler-effect, and it is what causes the density of hardened concrete to increase, resulting in increased strength.

4.3 Reaction of Pozzolanic

Calcium hydroxide is liberated during the hydration process of cement. When Silica Fume is put on concrete, it chemically reacts with the free calcium hydroxide present in the concrete due to its inherent high pozzolanic property. This chemical process is referred to as the pozzolanic reaction, and it results in the development of calcium silicate hydrate from free calcium hydroxide. This calcium silicate hydrate gel functions as a binder and further strengthens the cured concrete. When compared to plain concrete, the compressive, split tensile and flexural strength all raise by 21.15 %, 13.18 %, and 12.91 % after 28 days.

Additionally, these statistics demonstrate that replacing Silica Fume above 9% results in a decrease in the mechanical properties of concrete at both ages. The decrease may be linked to the following explanation. The filling phenomenon, referred to as the filler effect, persists only up to a particular degree of Silica Fume addition. Further replacement will result in a reduction in the cement content of the concrete. This is why, when Silica Fume replacement exceeds 9%, the values of the hardened concrete's mechanical qualities decrease. During the production of the test specimens, it was discovered that replacing Silica Fume with more than 11% makes the concrete harsh, dry, and difficult to deal with. This could be because of the Silica Fume's hydrophobic characteristics, which means that, due to its finer particle size, it requires more water when used in concrete. As a result, concrete specimens containing more than 11% Silica Fume was not analyzed in this investigation. During specimen failure, it was observed that specimens prepared by substituting Silica Fume up to 5% failed in a manner comparable to that of the specimens prepared without Silica Fume. However, specimens made with more than 5% Silica Fume failed in a more brittle and noisy manner. This demonstrates that as the amount of Silica Fume replaced grows, the brittleness of the concrete increases as well.

TABLE: 1 Compressive Strength of M60 Conventional Concrete and Silica Fume Concrete At 7 And 28 Days

S.No.	Mix	Super Plasticizer Lit/100Kg of cement	W/C ratio	Silica Fume In %	7 Days Cube compressive strength (N/mm^2)	28 Days Cube compressive strength (N/mm^2)
1.	S1	1.5	0.30	0	51.01	72.6
2.	S2	1.5	0.30	3	53.77	76.44
3.	S3	1.5	0.30	5	56.30	81.45
4.	S4	1.5	0.30	7	58.27	85.21
5.	S5	1.5	0.30	9	59.84	87.96
6.	S6	1.5	0.30	11	54.72	78.96

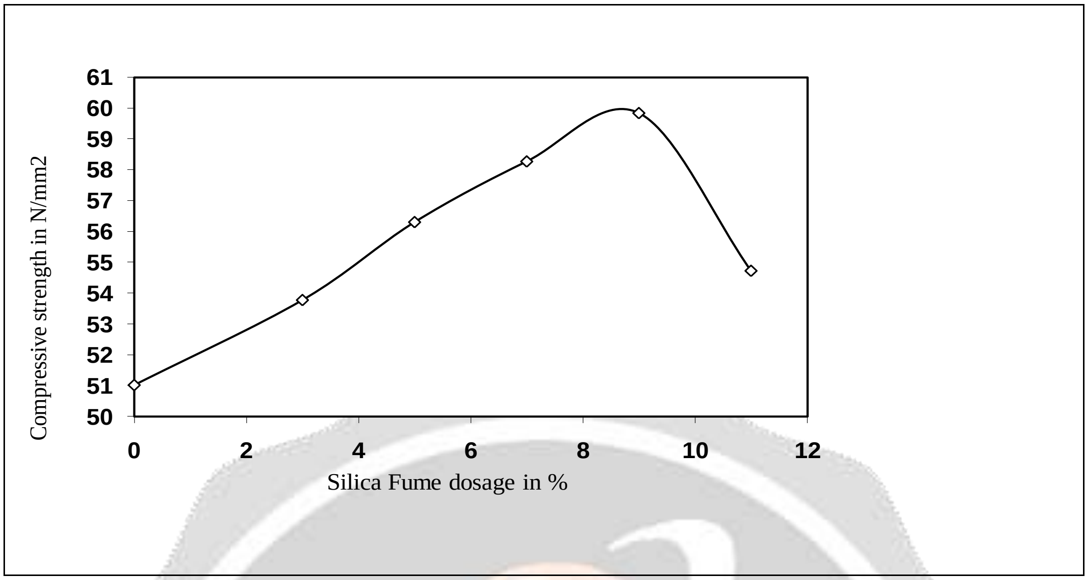

FIG: 1 7 Days - Concrete Compressive Strength

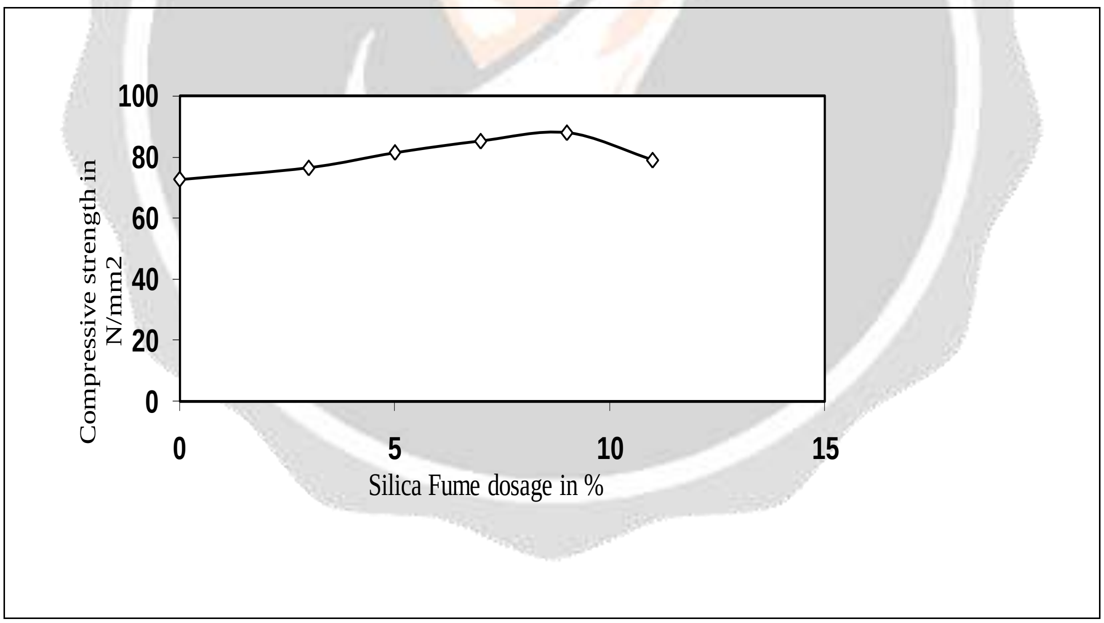

FIG: 2 28 Days Concrete Compressive Strength

TABLE: 2 7 And 28 Days, the Flexural Strength of M60 Grade Conventional Concrete and Silica Fume Concrete

S.No.	Mix	Super Plasticizer Lit/100Kg of cement	W/C ratio	Silica Fume In %	Flexural strength (N/mm^2) 7 Days	Flexural strength (N/mm^2) 28 Days
1.	S1	1.5	0.30	0	5.49	7.81
2.	S2	1.5	0.30	3	5.59	8.02
3.	S3	1.5	0.30	5	5.70	8.28
4.	S4	1.5	0.30	7	6.08	8.56
5.	S5	1.5	0.30	9	6.40	8.84
6.	S6	1.5	0.30	11	5.64	7.93

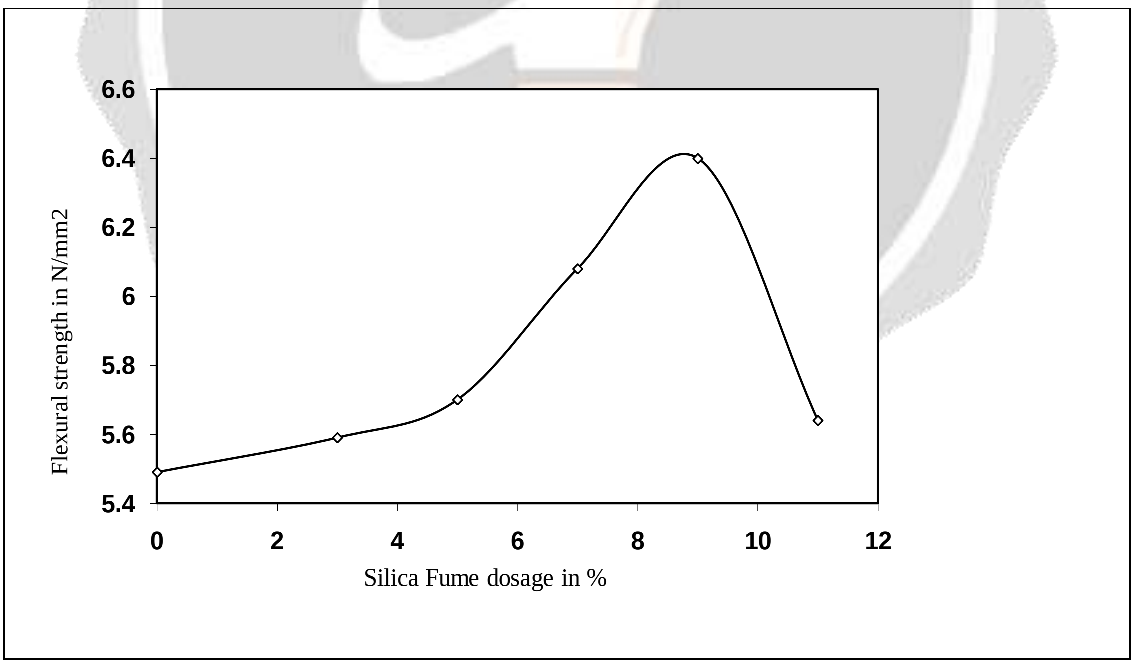

FIG: 3 7 Days Concrete Flexural Strength

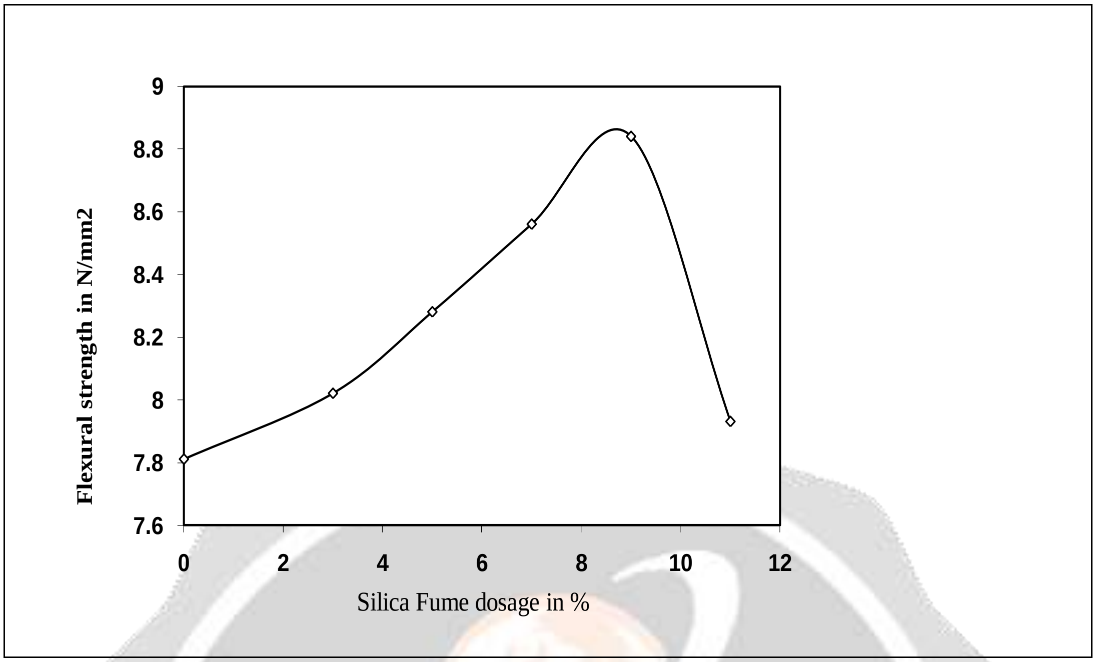

FIG: 4 28 Days Concrete Flexural Strength

TABLE: 3 7 AND 28 DAYS, SPLIT TENSILE STRENGTH OF M60 CONVENTIONAL CONCRETE AND SILICA FUME CONCRETE

Sl.No.	Mix	Super Plasticizer Lit/100Kg of cement	W/C ratio	Silica Fume In %	Split tensile strength (N/mm^2) 7 Days	Split tensile strength (N/mm^2) 28 Days
1.	S1	1.5	0.30	0	3.57	4.18
2.	S2	1.5	0.30	3	3.69	4.30
3.	S3	1.5	0.30	5	3.86	4.44
4.	S4	1.5	0.30	7	4.02	4.57
5.	S5	1.5	0.30	9	4.13	4.72
6.	S6	1.5	0.30	11	3.98	4.27

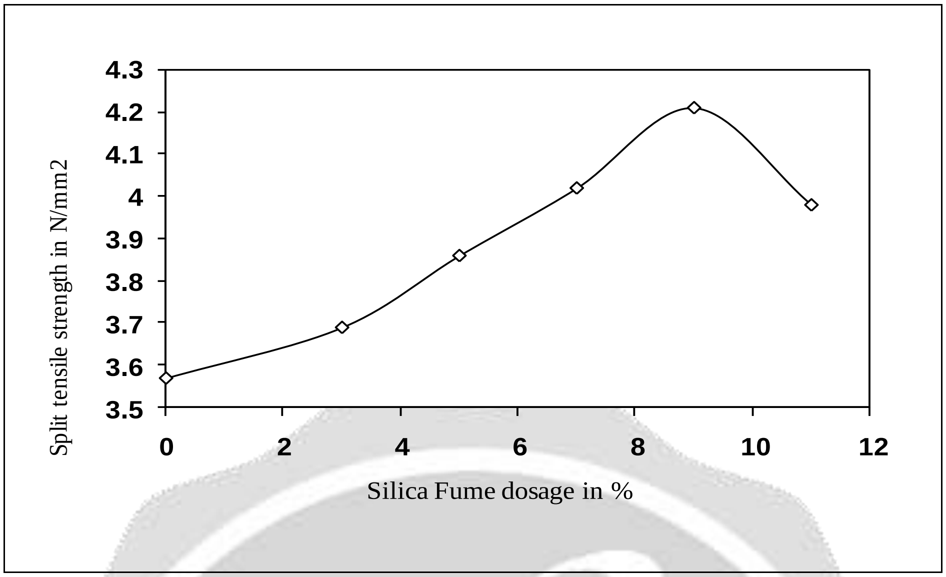

FIG: 5 7 Days Concrete Split Tensile Strength

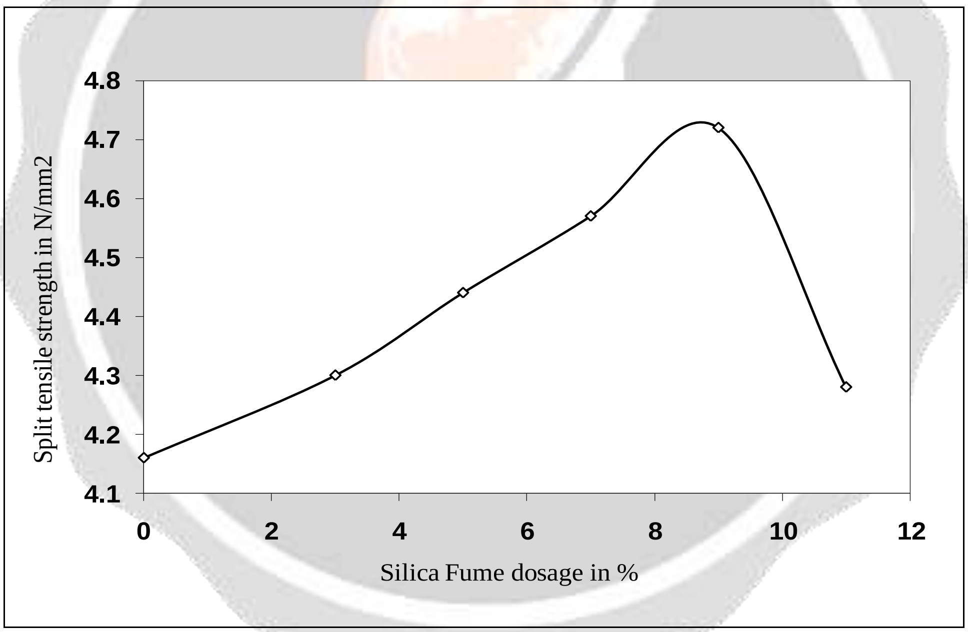

FIG: 6 28 Days Concrete Split Tensile Strength

Fig.7 illustrates the percentage increase in compressive strength above the control concrete. The graph demonstrates that Silica Fume concrete mixes generated greater strengths than control concrete at all ages. The optimal percentage of Silica Fume in concrete is 9 percent, at which point a strength fluctuation of up to 21.15 percent has been recorded when compared to control concrete.

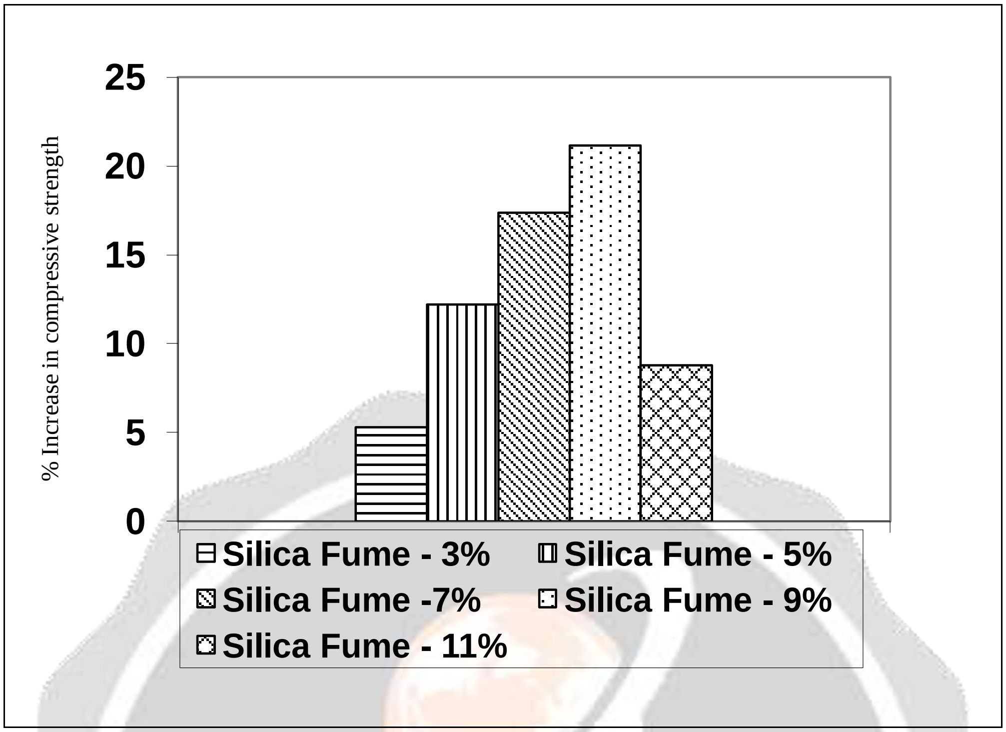

Fig: 7 Percentage Compressive Strength Improvements over Control Concrete

5. CONCLUSION

The final conclusion can be inferred from the test findings and discussions that have taken place throughout this investigation:

1. Silica Fume concrete's workability is inversely related to its Silica Fume content. As a result, partial substitution of Silica Fume for cement tends to diminish the workability of concrete.
2. It was discovered that adding 9% Silica Fume as a partial replacement for cement results in the greatest improvement in the mechanical properties of concrete.
3. The pozzolanic reaction appears to have a negligible influence on the strength gain of Silica fume after seven days when compared to control concrete. However, the Silica Fume concrete mixes demonstrated greater strength improvements over a 7–28 day timeframe, owing to the combination of sustained cement hydration and pozzolanic reaction.
4. The addition of Silica Fume as a partial replacement for cement in amounts more than 11% results in a harsh, dry, and difficult-to-work concrete.
5. The addition of Silica Fume as a partial replacement for cement in amounts greater than 5% results in a more brittle and noisy failure of the concrete.
6. When compared to ordinary concrete, the percentage increase in cube compressive strength achieved after 28 days by adding 9% as partial replacement is 21.15 % more.

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