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EXPERIMENTAL ATUSIES ON EFFECT OF SILICA FUME ON FRESH AND HARDENED PROPERTIES OF CONCRETE

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ABSTRACT
Silica fume, a byproduct of making silicon and ferrosilicon alloys, is used in concrete because its tiny particles fill gaps between cement, making concrete stronger and less porous. It reacts with calcium hydroxide in concrete to boost strength and durability. It's made during high-purity quartz production and is about 100 times smaller than cement particles. By using silica fume, we not only improve the mechanical and durability properties of concrete but also address environmental concerns by reusing industrial waste. Its impact is significant, enhancing workability, reducing water demand, and improving overall strength and durability of concrete structures. The objectives are to study how adding silica fume affects concrete workability, observe trends by varying its percentage, evaluate its impact on compressive strength over time, and compare concrete with and without silica fume to understand its benefits and drawbacks in terms of workability and strength.
Keywords: Silica fume, Compressive Strength, Workability.

1. Introduction
Silica fume, also referred to as micro-silica, is a valuable by-product derived from the production of silicon and ferrosilicon alloys. Comprising fine particles of amorphous silicon dioxide (SiO_2) with a notably high surface area, silica fume serves as a widely utilized admixture in concrete formulations due to its distinctive properties. Its minute particle size and expansive surface area facilitate the filling of interstitial spaces among cement particles, enhancing the overall packing density of concrete mixtures. This results in the creation of more uniform, denser concrete with reduced porosity. A key advantage of incorporating silica fume into concrete lies in its heightened reactivity as a pozzolanic material. Upon integration, silica fume undergoes a reaction with calcium hydroxide, generating additional calcium silicate hydrate (C-S-H) gel, a primary binding agent in concrete. Silica fume is procured as a by-product during the smelting process of high-purity quartz with coal or coke in electric arc furnaces, where temperatures can reach up to 2,000ºC. Subsequently, SiO_2 vapours are formed and subsequently oxidized and condensed into minute particles of non-crystalline silica in the cooler zones of the furnace. With particle sizes averaging less than 1 micron and an average diameter of about 0.1 microns, silica fume particles exhibit exceptional properties, efficiently filling voids between cement particles and thereby bolstering the strength and durability of concrete when employed as an additive. This material's significance was recognized following its discovery in Oslo, Norway, in 1947, observed during the exhaust gas filtration process. Since then, it has been widely acknowledged and harnessed as a valuable supplementary cementitious material in concrete production. Regulatory bodies such as AASHTO M 307 and ASTM C 1240 delineate guidelines for its use, with a recommended replacement range of 7% to 9% by mass of cementitious materials in concrete mixtures. This range ensures an optimal balance between reaping the advantages of silica fume and upholding the concrete's overall performance. In recent years, the construction sector's burgeoning demand for high-performance concrete has spurred increased utilization of silica fume as a substitute for cement, thereby augmenting concrete's strength and durability. However, determining the precise dosage of silica fume replacement remains a subject of variability among researchers, contingent upon diverse factors encompassing project specifics, concrete mix designs, curing conditions, and employed testing methodologies. Consequently, a comprehensive evaluation of individual project requisites alongside consultation of

pertinent research studies or expert guidance is paramount for ascertaining the optimal silica fume dosage for a given concrete application.

2. Materials

2.1 Silica Fume: Silica fume is a vital material used in concrete to enhance its strength, durability, and impermeability. It's a by-product of silicon and ferrosilicon production, consisting of fine particles of silicon dioxide. Silica fume fills gaps between cement particles, making concrete denser and less porous. Its high reactivity as a pozzolana reacts with calcium hydroxide to form additional binding agents, increasing concrete's strength and durability. It's produced through high-temperature processes and conforms to industry standards for optimal usage in concrete. Silica fume is commonly used in high-performance concrete mixes to achieve superior results.

2.2 Cement: Cement is a crucial material in concrete as per Indian standards. It serves as the binding agent that holds concrete together. As per Indian standards (IS 456:2000), cement used in concrete must comply with specifications regarding its chemical composition, fineness, setting time, compressive strength, and other physical properties. These standards ensure that cement contributes effectively to the strength, durability, and overall quality of concrete structures, meeting the requirements of various construction applications in India.

2.3 Coarse Aggregates: The coarse unit in IS Sieve at 4.75 mm is designated for coarse aggregates. Aggregates should be clean, strong, hard, durable and free from dirt, dust and impurities, etc. For this experimental project, locally sourced crushed granite with a size of 20 mm was utilized in the cement mix.

2.4 Fine Aggregates: These aggregates, commonly sourced from river sand, crushed stone, or gravel, play a vital role in concrete mixtures. They fill voids between coarse aggregates and cement particles, enhancing the overall strength and workability of concrete. Fine aggregates must conform to IS 383:2016 specifications, ensuring they meet the necessary criteria for use in concrete production.

2.5 Water: The water to be used shall be clean and free from salts, silts, etc. Only potable water shall be used for mixing concrete.

3. Methodology

3.1 Mix Design: For this study we designed concrete for M40 grade, resulting in a mix ratio of 1:2.12:2.56 (1 part cement, 2.12 parts fine aggregates, and 2.56 parts coarse aggregates.)

Table No. 1: Mix Proportion Of Concrete

Sr. No.	Raw Materials(kg/m^3)	Mass % of Silica Fume (M40 grade concrete)		
		0%	**5%**	**10%**
1	Cement	394	374.3	354.6
2	Fine Aggregates	835.71		
3	Coarse Aggregates	1010		
4	Water	0.50		
5	Silica Fume	0	19.7	39.4

3.2 Preparation of concrete: The materials are weighed according to the specified proportions and then mixed manually. Initially, cement, sand, coarse aggregates, and silica fume are dry mixed. Subsequently, the appropriate amount of water is added, and the mixture is stirred thoroughly in multiple directions until it achieves a uniform and homogeneous appearance in terms of colour and texture.

3.3 Casting and curing: Layer the concrete mix in the mould in three stages for uniformity. Fill the mould one-third full and compact it with 25 evenly distributed tamping rod blows. : Fill the mould to the top and again tamp 25 times. Add more concrete to reach two-thirds of the mould's height and tamp it 25 times. Smooth the top surface with a trowel for a flat finish. Cover the mould with a damp cloth or plastic to retain moisture. Allow the concrete to sit in the mould undisturbed for 24 hours in a stable environment without vibrations or direct sunlight. After this period, carefully remove the concrete specimens from the moulds. Place the specimens in a water tank with a temperature around 20°C (68°F) for curing. Keep them submerged throughout the curing period of 7, 14, and 28 days to achieve the desired strength.

3.4 Testing: Once the curing period is complete, take out the concrete specimens from the water and let them air dry briefly before proceeding with testing. Use a Compression Testing Machine (CTM) to evaluate the compressive strength of the concrete specimens.

4. Results and Discussion

4.1 Workability: Workability of the concrete is determined by slump cone test. It indicates how manageable the concrete is during construction processes such as pouring, spreading, and moulding. A concrete mix with good workability allows for efficient and effective placement and compaction while maintaining its desired properties and performance characteristics.

Fig.1. Decrease in slump

Fig.2. Slump cone mould

Table No.1: Results of slump cone test

Silica Fume (%)	W/C Ratio	Slump (mm)
0	0.5	60
5	0.5	45
10	0.5	30

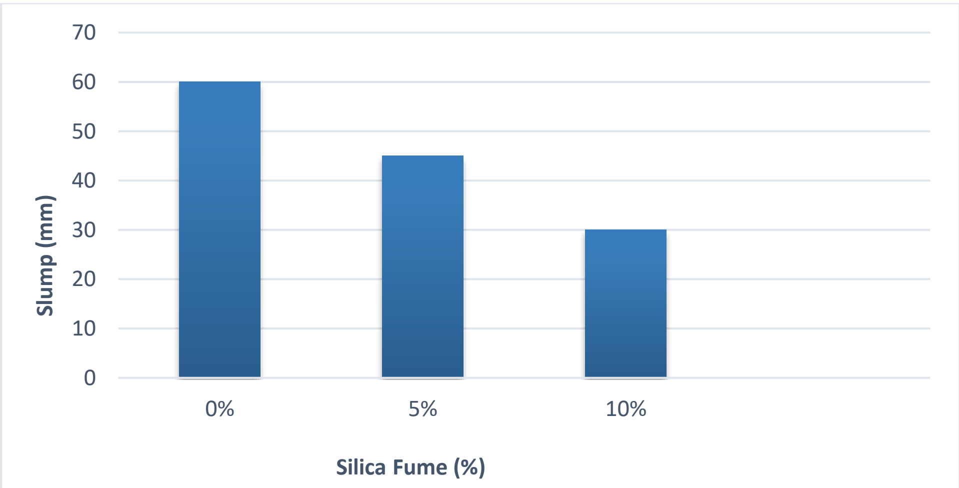

Fig.3. : Graph Showing Decrease In Workability Of Concrete

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4.2 Compressive strength: The compressive strength of concrete cubes was assessed using a Compression Testing Machine (CTM) with a capacity of 2000 KN. Testing was conducted at intervals of 7, 14, and 28 days to determine the compressive strength of the specimens.

Fig.4. Broken concrete cube

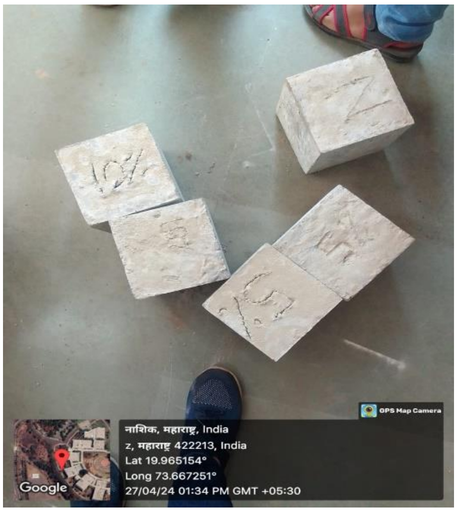

Fig.5. cubes for testing

Table No.3: Results after test on concrete cubes after certain time and curing

Silica Fume (%)	**Compressive Strength (for M40)**			**Average Compressive Strength (MPa)**
	S1	**S2**	**S3**	
0%				
7 Days	25.45	22.56	25.89	24.63
14 Days	36.8	38.03	35.25	36.7
28 Days	40.65	42.45	39.80	40.96
5%				
7 Days	29.78	31.47	29.98	30.41
14 Days	40.21	43.49	41.36	41.68
28 Days	45.32	45.9	47.21	46.14
10%				
7 Days	33.78	38.17	35.32	35.7
14 Days	44.12	46.22	44.97	45.10
28 Days	48.15	50.36	48.87	49.12

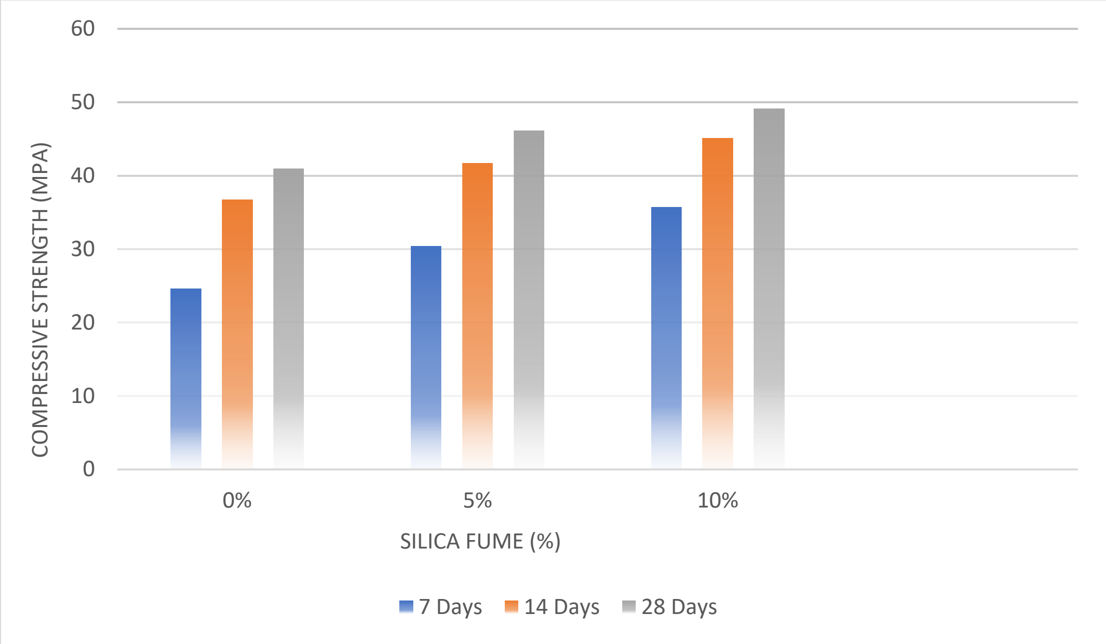

Fig.6. Graph Showing Increase In Compressive Strength In Concrete

5. Conclusion

The addition of silica fume enhances the strength characteristics of concrete. The workability of concrete containing silica fume is decreasing with the increase in percentage addition of silica fume. For the normal concrete the slump is 60mm. For the addition of 5% silica fume, the slump is 45mm, which decrease at 25%. For the addition of 10% silica fume slump is 30 mm, which decrease at 50%. The finer silica fume having higher surface area tends to absorb more water reducing the slump value of concrete. There is a clear trend of increasing compressive strength with increasing curing time for all mixes which is typical for concrete. This indicates that the concrete continues to gain strength as it matures. This is particularly notable in the case of concrete containing 10% silica fume, where there is a considerable increase in compressive strength at 7, 14, and 28 days compared to both normal concrete and concrete with 5% silica fume. In summary, the use of silica fume as a mineral admixture up to certain replacement level of cement in concrete offers certain decrease in workability and increase in compressive strength. The utilization of silica fume as a mineral admixture in concrete presents a dual advantage: enhancing material properties while promoting environmental sustainability through the reuse of industrial waste. Its multifaceted contributions underscore its importance in achieving high-performance concrete mixes that meet and exceed performance expectations in diverse construction applications.

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