International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

AN EXPERIMENTAL STUDY ON HIGH PERFORMANCE CONCRETE BY USING SILICA FUME IN M25 GRADE CONCRETE

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ABSTRACT :

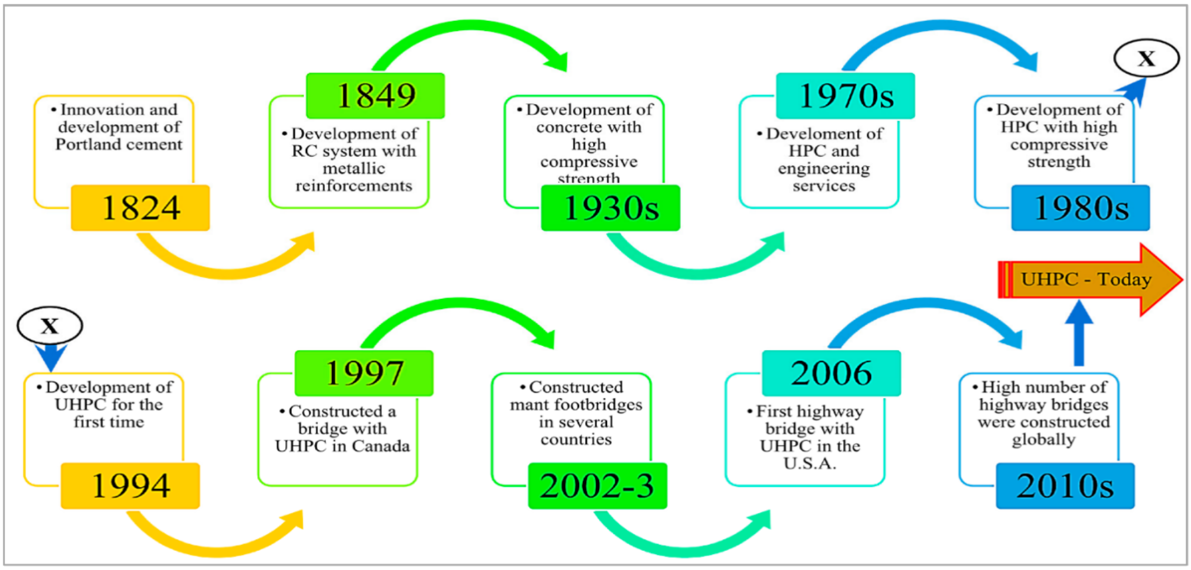
High Performance Concrete (HPC) now a days used widely in the construction industry worldwide. This paper presents an experimental study on the High Performance concrete with the partially replacement of silica fume and super plasticizer in the cement its influences on the properties of fresh and hardened concrete. This study aims to assess the efficacy of Silica Fume, an industrial byproduct, as a substitute for cement in concrete. The escalating market demand for cement has prompted large-scale production, causing environmental challenges and depleting natural resources, accompanied by rising prices. To address these issues, exploration into the utilization of industrial byproducts/waste has been undertaken. Silica fume, derived from the smelting process in the silicon and ferrosilicon industry, emerges as a promising cementitious material. The research focuses on the partial replacement of cement with silica fume in M-25 concrete mix, with varying proportions (0%, 5%, 10%, 15% and 20% by weight). The study investigates key parameters, including compressive strength, flexural strength, and split tensile strength at different curing periods (3 days, 7 days, 14 days, and 28 days). Experimental results reveal that the incorporation of silica fume enhances the strength and durability of concrete across all ages, surpassing the performance of normal concrete. This suggests a reduction in the required cement quantity for construction purposes. Promoting the use of Silica Fume not only enhances concrete performance but also contributes to environmental sustainability.

KEY WORDS:- Highperformance concrete, silica fume, superplastisicer, concrete, compressive strength,

INTRODUCTION :-

Concrete, second only to wood in terms of usage, is predominantly produced using ordinary Portland cement (OPC), which has well-known environmental issues due to high carbon dioxide emissions and energy consumption. High performance concrete (HPC) surpasses the properties of normal concrete and is achieved through carefully selected high-quality ingredients and optimized mixture designs. HPC typically has a low water-cement ratio (w/c) ranging from 0.2 to 0.45, with superplasticizers used to enhance workability. Various methods, such as those proposed by ACI, Aitcin, Islam Lascar, and Talukdar, are employed for HPC mix design, with an increasing emphasis on incorporating silica fume and superplasticizers to achieve higher performance. Research by Vinayagam, Hooton, Yogendron and Langan, Annaduarai and Ravichandran, and Shreedhar and Kumbhar has demonstrated the effectiveness of silica fume in enhancing the properties of HPC. This thesis investigates the process of making silica fume-based concrete and explores its short-term engineering properties in both fresh and hardened states.

HISTORY OF HIGH PERFORMANCE CONCRETE :-

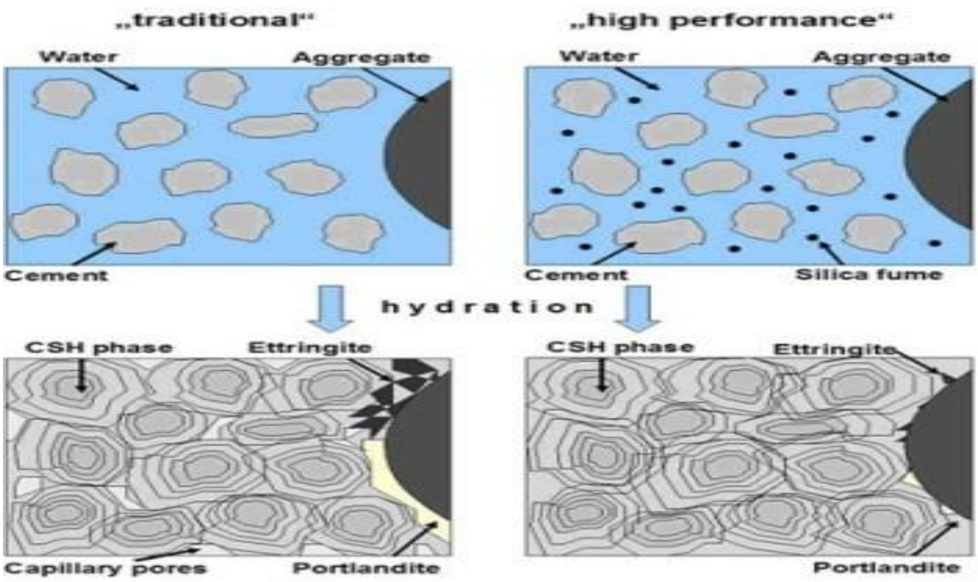


WHAT IS HIGH PERFORMANCE CONCRETE?

High-performance concrete can also be produced with lightweight aggregates. However, the aggregate needs to be very carefully chosen to make sure it is sufficiently strong. As long as the lightweight aggregate is strong enough, its use can indeed be advantageous. By saturating their pores with water before mixing, these aggregates can act as internal reservoirs that supply water to ensure continued cement hydration and prevent autogeneous shrinkage due to self-desiccation. This aspect is of Fig.2: Hydration varaions in concretes

particular relevance to concrete with a very low w/c, in which the early development of high density and low permeability makes it difficult for water to penetrate uniformly for the hydration process to continue.

SCOPE OF WORK



In a high-performance concrete contract utilizing silica fume, the scope of work typically includes material procurement, mix design optimization, concrete production, quality control, placement and finishing, curing and protection, quality assurance, and documentation. This involves procuring high-quality silica fume, conducting mix design trials, accurately batching and mixing materials, implementing rigorous quality control measures, ensuring proper placement and finishing, implementing effective curing methods, and maintaining detailed documentation and reporting. Quality assurance involves regular inspections and performance evaluations to ensure compliance with project requirements and standards.

OBJECTIVES

- To develop a mixture proportioning process of making silica fume based HPC.

- To study the short-term engineering properties of fresh and hardened silica fume based HPC.
- To compare the properties of conventional concrete with silica fume based HPC.
- To assess better characteristics of silica fume based HPC compared to conventional concrete.

LITERATURE REVIEW:-

- **R.Selvapriya(2019)** explained about Silica fume as Partial Replacement of Cement in Concrete and she concluded Based on the experimental investigation carried out on concrete by using various percentages of silica fumes. Concrete mixtures with different proportions of silica fume ranging from 0%, 5%, 10%, 15% and 20% for each three numbers of cube, cylinder and prism casted. Compressive strength was increased in silica fume 15% at 7 days and 14 days. Split tensile strength was increased in silica fume 15% at 7 days and 14 days. Flexural strength was increased in silica fume 15% at 7 days and 14 days.
- **SudarsanaRao. H, Sashidhar. Chandupalle, Vaishali. G. Ghorpode, VenkataReddy.T.C(2014)** explained about Mix Design of High Performance Concrete Using Silica Fume and Superplasticizer and they concluded that The following conclusions can be made on the basis of the current experimental results. A mix design procedure for HPC using silica fume and super plasticizer is formulated by ACI method of mix design and available literature on HPC. As the silica fume content increases the compressive strength increases up to 15% [HPC4] and then decreases. Hence the optimum replacement is 15%. The 7 days and 28 days cube compressive strength ratio of HPC is 0.84 to 0.9 The percentage replacement of cement by silica fume increases, the workability decreases.
- **Dr. T.V.S. Vara Lakshmi, Prof. S. Adiseshu(2016)** explained about Study on Preparing Of High Performance Concrete Using Silica Fume and Fly Ash and they concluded that 4.1 General In this paper the effect of silica fume on compressive strength on high strength concrete was studied by carrying out. The silica fume was replaced by 0%, 5%, 10% and 12.5% for water-binder ratio of 0.26. And also for the constant replacement of fly ash by 10% along with the above mentioned replacement.
- **Dr. T.Shanmugapriya, S. Yamini Roja, R. Resmi, Dr. R.N. Uma (2016)** explained on Studies on flexural behaviour of high performance RC beams with manufactured sand and silica fume(2016) and they concluded that High Performance Concrete with M-Sand can be used as an alternative material to natural sand in the presence of silica fume. The optimum percentage of natural sand is replaced by 100% M-Sand and cement by 10% of silica fume for achieving maximum compressive and flexural strength. The load carrying capacity is found to be 20% higher for the concrete made with 100% replacement of fine aggregate by M-Sand and 10% replacement of cement by silica fume compared to control beam. Based on the test results, it can be concluded that M-Sand can be adopted with presence of silica fume in High Performance Concrete.
- **Saber Fallah, Mahdi Nematzadeh (2017)** has explained about Mechanical properties and durability of high-strength concrete containing macro-polymeric and polypropylene fibers with nano-silica and silica fume and they concluded that by Adding polypropylene (PP) fibers to the concrete mixture leads to a reduced workability of the fresh concrete while adding macro-polymeric (MP) fibers has a minimal influence on the slump. Moreover, the introduction of nano-silica and silica fume in different percentages of the cement weight decreases the concrete slump and workability. Increasing the level of PP and MP fibers in the high-strength.

METHODOLOGY:-

Collection of Materials

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Design Mix Ratio for M25 Grade Cubes

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Casting M25 Grade Concrete Cubes

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Purchasing of silica fume and super plasticizers

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Design Mix Ratio for HPC Cubes

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Casting HPC Cubes

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Curing Period

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Comparative Strength Analysis

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Analysing Results

Conclusions

Materials used:

Cement:

Cement is a binding material used in construction to bond or hold together other materials, such as aggregates (like sand and gravel) and water, to form concrete. It's typically a fine powder made from a combination of limestone, clay, and other materials that are heated in a kiln to form a hard substance. When mixed with water, cement undergoes a chemical reaction known as hydration, which causes it to harden and set, providing strength and stability to structures like buildings, roads, bridges, and dams.

TYPE OF CEMENT USED: Portland pozzolona cement (53 grades) with 28% normal consistency conforming to IS: 8112-1989 (3) was used.

ADMIXTURES USED

The admixtures such as silica fume and super plasticizer obtained from Bangalore was used in concrete test cubes.

Fine Aggregate:

Natural sand having density of 1460kg/m^3 was used. The specific gravity was found to be 2.65.

Coarse aggregates:

Natural granite aggregate having density of 2700kg/m^3 was used. The specific gravity was found to be 2.7.

Tests on materials and its results :-

Fineness of cement

S.no	Weight of sample taken (g)	Weight of residue(g)	Fineness (%)
1	100	7	7
2	100	6.5	6.5

Average fineness of cement= 6.75%.

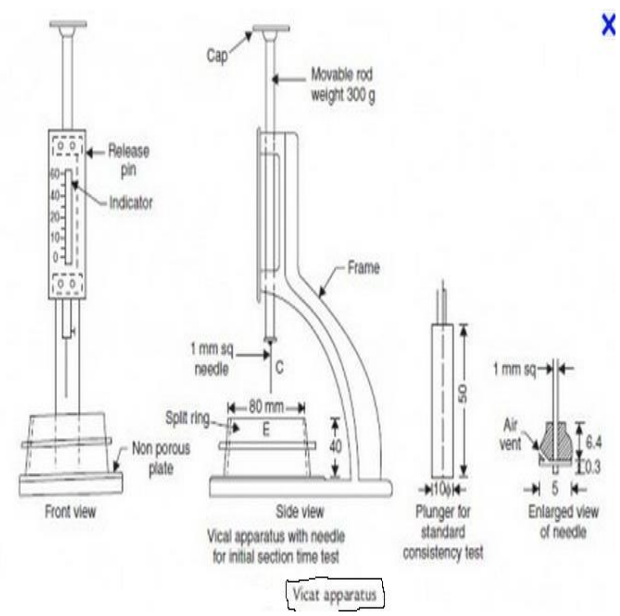
Initial and Final setting time

Trail no	Initial reading (mm)	Final reading (mm)	Penetration (mm)	Time taken (min)
1	50	31	19	5
2	50	34	16	10
3	50	36	14	15
4	50	40	10	20
5	50	42	8	25
6	50	45	5	30

Water taken (ml) = 74 ml.

Initial setting time= 30 min.

Final setting time= 600 min.



Specific gravity of cement

Description of item	Values
Weight of empty bottle (W1) gm	28
Weight of bottle + cement (W1) gm	37
Weight of bottle + cement + water (W3) gm	72
Weight of the bottle + water (W4) gm	60
Specific gravity of cement G=(W2-W1)/((W4-W1) - (W3-W2))	3

Specific gravity of given sample of cement= 3

Specific gravity of sand

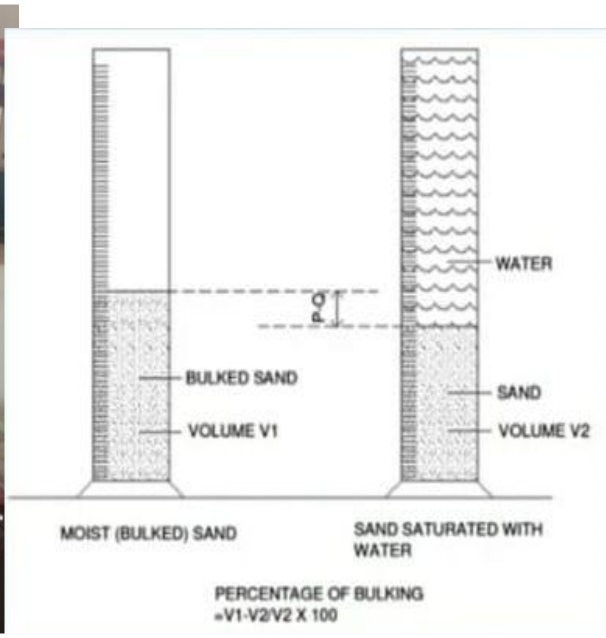
Description of item	**Values**
Weight of pycnometer (W1) gm	627
Weight of pycnometer + dry sand (W2) gm	1040
Weight of pycnometer + dry sand + water (W3) gm	1780
Weight of pycnometer + water (W4) gm	1530
Specific gravity of sand G=(W2-W1)/((W4-W1) - (W3-W2))	2.533

Specific gravity of sand = 2.533.

Bulking of sand

S.no	**Height of dry sand (V1) cm**	**% of water added**	**Height of wet sand (V2) cm**	**% of bulking ((V2-V1)/V1) *100**
1	22.9	1	25.9	13.1
2	22.9	2	27.8	21.39
3	22.9	3	31.4	37.11
4	22.9	4	28	22.27

Maximum % of bulking of sand= 33.11%.



Grain Size distribution of sand

S.no	**IS sieve Number (mm)**	**Aperture size(mm)**	**Weight of soil retained**	**% weight retained**	**Cumulative % weight retained**	**% passing through**
1	4.75	4.75	161	16.1	16.1	83.9

2	2.36	2.36	161	16.1	32.2	67.8
3	1.18	1.18	282	28.2	60.4	39.6
4	60	0.6	184	18.4	78.8	21.2
5	300	0.3	111.5	11.15	89.95	10
6	150	0.15	58.5	5.85	95.8	4.2
7	75	0.075	36	3.6	99.55	0.45
8	Pan	0	4.5	0.45	100	0

Uniformity coefficient Cu= 6.25.
Coefficient of curvature Cc= 1.23.
% of gravel= 32.2%.
% of coarse sand= 47%.
% of medium sand= 11.2%.
% of fine sand= 9.4%.
% of silt and clay= 0.2%

Specific gravity of aggregate

Description of item	Values
Weight of pycnometer (W1) gm	0.63
Weight of pycnometer + dry sand (W2) gm	1.75
Weight of pycnometer + dry sand + water (W3) gm	2.190
Weight of pycnometer + water (W4) gm	1.484
Specific gravity of sand G = (W2-W1) / ((W4-W1) - (W3-W2))	2.70

Specific gravity of aggregate= 2.70

Mix design :-

The mix design process for M25 grade concrete entails identifying the required strength, workability, durability, and exposure conditions. This is followed by selecting a suitable water-cement ratio, estimating water content, and determining cement, coarse aggregate, and fine aggregate proportions. Adjustments are made for factors like aggregate moisture and workability, with trial mixes conducted to validate proportions. Testing for compressive strength and slump ensures specifications are met, leading to final mix proportions. Quality control measures are then implemented throughout production, and documentation of the entire procedure is maintained for reference and quality assurance purposes.

Final Mix Proportion (M25 Grade of Concrete)

Mixes	Control mix	5% of silica fume	10% of silica fume	15% of silica fume	20% of silica fume
W/C ratio	0.45	0.45	0.45	0.45	0.45
Cement (kg/m^3)	444	421.80	399.60	377.40	355.20
Water (kg/m^3)	196	196	196	196	196
Coarse Agg (kg/m^3)	982	982	982	982	982

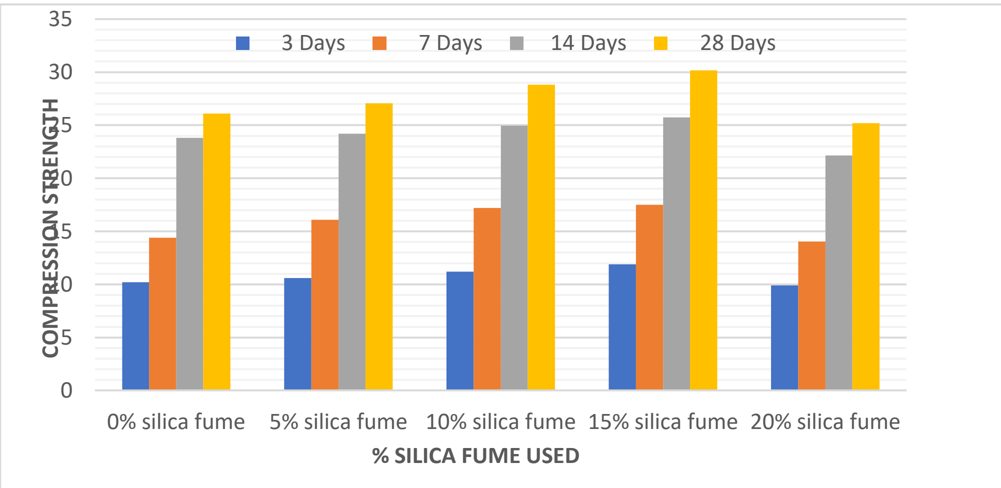
Sand (kg/m^3)	735	735	735	735	735
Silica Fume (kg/m^3)	0	22.20	44.40	66.60	88.80

Test Result on Fresh Concrete

S.no	Concrete mix	Slump flow (mm)	Compaction factor
1	M25 Control mix	120	0.94
2	M25 (5% of silica fume)	114	0.92
3	M25 (10% of silica fume)	106	0.90
4	M25 (15% of silica fume)	98	0.87
5	M25 (20% of silica fume)	94	0.85

TOTAL STRENGTH COMPARISION OF THE COMPRESSIVE STRENGTH TEST OF CONCRETE WITH 0%,5%,10%,15%,20% OF SILICA FUME

S. No	% of silica fume	3 Days	7 Days	14 Days	28 Days
1.	0% silica fume	10.2	14.4	23.8	26.1
2.	5% silica fume	10.6	16.1	24.2	27.06
3.	10% silica fume	11.2	17.2	24.96	28.8
4.	15% silica fume	11.9	17.5	25.73	30.16
5.	20% silica fume	9.92	14.03	22.16	25.2



This graph presents the compressive strength test results of concrete with varying percentages of silica fume at different ages (3 days, 7 days, 14 days, and 28 days). As the percentage of silica fume increases from 0% to 20%, there is generally an increase in compressive strength up to 15% silica fume inclusion. However, at 20% silica fume, there is a notable decrease in strength compared to the previous percentages, especially evident at 3 days and 7 days. Overall, the graph provides a comparison of the compressive strength of concrete mixes with different silica fume percentages.

Conclusion:

Based on the results obtained from the current experiment, several key conclusions can be drawn.

1. Formulation of Mix Design Procedure: A mix design procedure for High Performance Concrete (HPC) utilizing silica fume and superplasticizer has been developed. This procedure is based on the ACI method of mix design and incorporates findings from available literature on HPC.
2. Optimum Silica Fume Content: The compressive strength of HPC exhibits a trend where it increases with the inclusion of silica fume up to 15%, labeled as [HPC4], after which it begins to decline. Therefore, the optimal replacement ratio of silica fume is determined to be 15%.
3. Strength Development: The ratio of 7 days to 28 days cube compressive strength of HPC ranges from 0.84 to 0.9, indicating a consistent strength development over time.
4. Effect on Workability: As the percentage replacement of cement by silica fume increases, the workability of the concrete decreases. This is evidenced by the results of the compacting factor test, which show a decrease in workability with increasing quantities of silica fume. For M25 grade concrete mixes, the compacting factor decreases from 0.97 to 0.94 as the silica fume replacement level increases from 5% to 20%. However, it is noted that the use of plasticizers can mitigate this decrease in workability.
5. Density and Compressive Strength: Concrete mixes containing 15% silica fume as a partial replacement of cement exhibit the maximum fresh and dry densities. This increase in density may contribute to the enhanced compressive strength due to improved particle packing.

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