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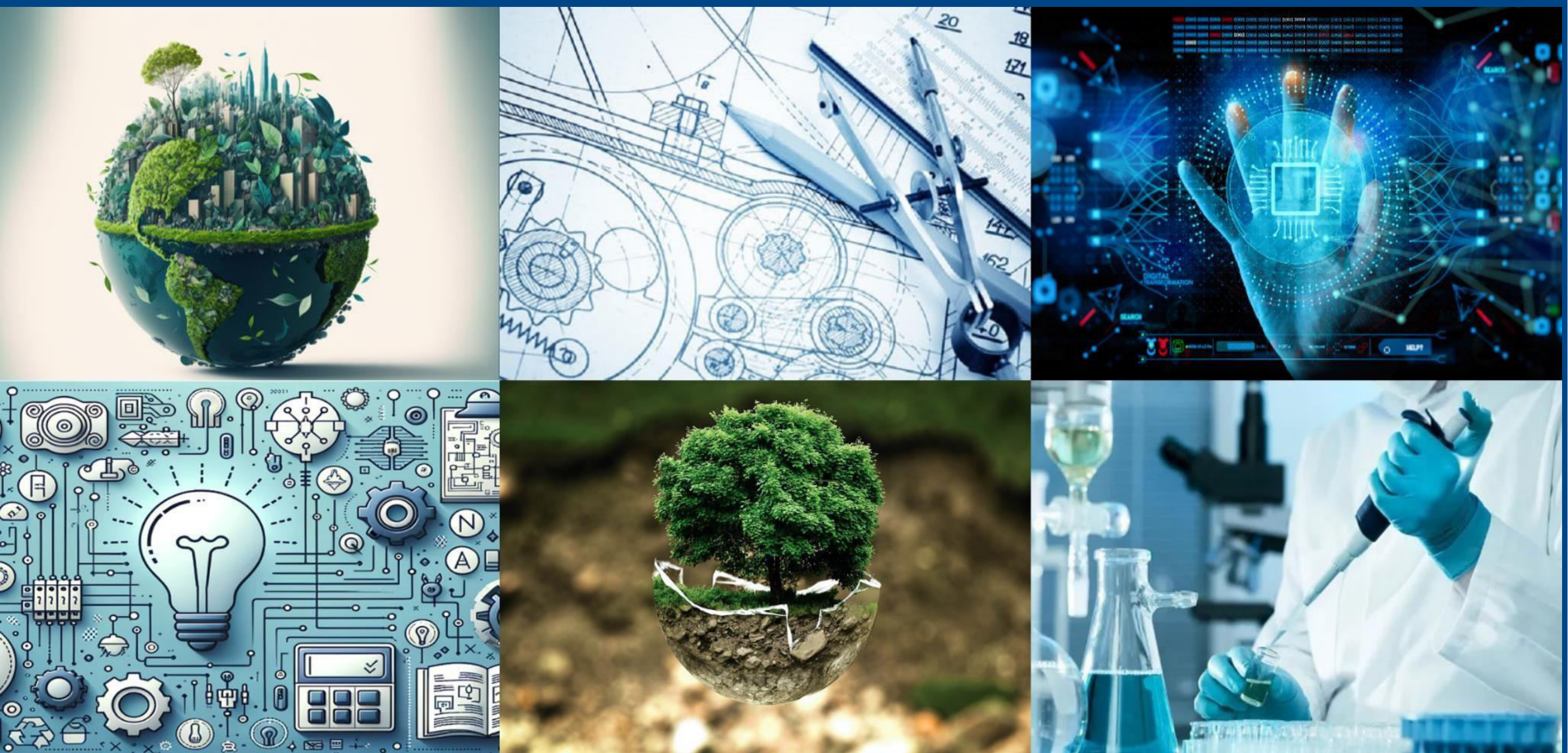

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Performance Evaluation of Concrete with Silica Fume and Palm Oil Fuel Ash as Partial Cement Replacements

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ABSTRACT: This research investigates the performance evaluation of concrete incorporating Silica fume and Palm Oil Fuel Ash (POFA) as supplementary cementitious materials. In this study, 15% silica fume was used consistently, while POFA was introduced as a partial cement replacement at 5%, 10%, 15%, and 20% by weight. The experimental program assessed workability, compressive strength, split tensile strength, and durability characteristics of the concrete mixes at different curing ages. The inclusion of silica fume improved the microstructure and contributed to higher early-age strength, while POFA enhanced long-term strength and durability due to its pozzolanic reactivity. Results indicated that an optimum replacement level was achieved at 10–15% POFA with silica fume, providing a balanced improvement in mechanical properties without significant reduction in workability. The study highlights the potential of using agricultural and industrial by-products in sustainable concrete production, contributing to reduced cement consumption and environmental impact.

KEYWORDS: Compressive strength, Split tensile strength, Flexural strength, silica fume and palm oil ash.

I. INTRODUCTION

Concrete is the most widely used construction material across the world due to its versatility, strength, and durability. However, its major ingredient Portland cement contributes significantly to environmental pollution, particularly through the emission of carbon dioxide during manufacturing. This challenge has encouraged researchers to explore Supplementary Cementitious Materials (SCMs) that can partially replace cement, thereby reducing environmental impact while enhancing concrete performance. Among these SCMs, Silica fume and Palm Oil Fuel Ash (POFA) have gained attention because of their pozzolanic properties and sustainable nature. Silica fume, a by-product of the silicon and ferrosilicon alloy industry, is extremely fine with a high surface area and rich in amorphous silica. When incorporated into concrete, it improves particle packing, refines the pore structure, and enhances both mechanical strength and durability. Typically, silica fume is used in small proportions (5–15%) to improve high- performance concrete.

On the other hand, POFA is an agro-industrial waste obtained from burning palm oil residues in mill boilers. It contains reactive silica and other oxides that contribute to long-term pozzolanic activity. Utilization of POFA in concrete not only reduces the need for cement but also provides an environmentally friendly disposal method for palm oil industry waste. However, excessive replacement levels may affect workability and early-age strength due to its relatively lower reactivity compared to cement. This study focuses on evaluating the combined use of 15% silica fume with varying proportions of POFA (5%, 10%, 15%, and 20%) as partial cement replacements. The performance of these mixes is assessed in terms of workability, compressive strength, split tensile strength, and durability. By combining industrial and agricultural by-products, this investigation seeks to promote sustainable concrete technology while maintaining or enhancing engineering properties required for structural applications.

II. OBJECTIVES

The objectives of the study are;

➢ To investigate the fresh properties of concrete incorporating 15% silica fume and different proportions of palm oil fuel ash (5%, 10%, 15%, and 20%) as partial cement replacements.

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- To evaluate the mechanical properties of the modified concrete mixes, including compressive strength and split tensile strength, at different curing ages.
- To identify the optimum replacement level of POFA that, when blended with silica fume, provides maximum strength and durability without adversely affecting workability.

III. MATERIALS AND PROPERTIES

- **Cement:**

Cement acts as binding material in concrete, holding the aggregates together when mixed with water. The quality and proportion of cement influence the strength, workability and long-term performance of concrete. It plays a key role in achieving the desired structural properties. OPC 53 grade Nagarjuna cement is used. Cement is replaced to lower CO_2 emissions.

Table 1:- Properties of cement

S.No.	Properties	Typical values
1.	Specific gravity	3.15
2.	Normal consistency	27.5%
3.	Initial setting time	80 min
4.	Final setting time	180 min
5.	Fineness	8%
6.	Density	1440 kg/m³

- **Silica Fume (SF):**

Silica fume is a highly reactive ultrafine pozzolanic by-product, leading to higher strength and durability but lower workability. It is widely used in high-performance and durable concrete applications. It is used as constant replacement material in this mix. It is available from GRR Associates, Vishakhapatnam.

Table 2: Properties of silica fume

S.No.	Characteristics	Requirement as per IS 15388:2003	Test results
1	Specific gravity	2.2 to 2.3	2.21
2	SSA (m^2/kg)	>15000 m^2/kg	17500
3	Colour	-	Light black
4	Mean particle size (µ)	0.1 to 0.3	0.2
5	Bulk density(kg/m^3)	500 to 700 (kg/m^3)	565
6	SiO_2		93.57
7	Al_2O_3		0.87
8	Fe_2O_3		0.74
9	Cao		0.35
10	MgO	3.4	0.81
11	Na_2O	0.7	0.18
12	K_2O	0.3	1.05

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- **Palm Oil Fuel Ash (POFA):**

It is an industrial by-product obtained from burning palm Oil husks and shells in biomass power plants. It is a fine, pozzolanic particles enhance strength and improve durability by refining the concretes microstructure. Using POFA reduces cement consumption, making the mix more sustainable and eco-friendly. It also lower CO_2 emissions. It is replaced as varying percentages in this mix. It is available from Patanjali private limited, Pedhapuram.

Table 3: Physical properties of POFA

Physical Property	Value
Specific gravity	1.19
Colour	Grey
Bulk density	580 Kg/m^3

- **Fine aggregate:**

It is naturally occurring or manufactured materials such as sand, crushed stone dust, or industrial by-products used in concrete. It fills the voids between coarse aggregates and contribution to all the overall workability and strength of the mix. The particle size typically passes through a 4.75mm sieve. Good-quality fine aggregate ensures better compaction, reduced segregation. Locally available Zone II river sand was used in this project.

Table 4:- Physical properties of fine aggregate

Physical properties	Test values
Specific gravity	2.51
Fineness modulus	2.9
Water absorption	1%
Bulk density	1563 kg/m^3

- **Coarse Aggregate (CA):**

Coarse aggregate refers to the larger-sized particles used in concrete, typically gravel or crushed stone. It provides bulk to the mix and helps improve the concrete's overall strength and stability. The interlocking action of coarse aggregate particles enhances load-carrying capacity. Their size, shape, and grading influence workability, durability, and the performance of hardened concrete. Proper selection of coarse aggregate ensures strong and economical concrete.

Table 5:- Physical properties of CA

S.No.	Properties	Test values
1.	Specific gravity	2.54
2.	Fineness modulus	1.89
3.	Density	1500 kg/m^3
4.	Water absorption	1.1 %
5.	Aggregate size	25 to 10 mm

- **WATER:**

Water plays a vital. Role in the production of concrete. It should be clean and free from impurities. It also used for curing specimens. Water available in the laboratory is used.

- **ADMIXTURE:**

Conplast SP 430 is a high-range water-reducing superplasticizer used to improve the workability and strength of concrete. It allows significant water reduction while maintaining good flow, making it ideal for high-strength and pumped concrete. Being chloride-free, it enhances durability, reduces permeability, and provides a smooth, cohesive mix.

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- **Mix Ratio for M25 Grade Concrete**

Table 6:- mix proportion

Cement (Kg/m³)	Fine aggregate (Kg/m³)	Coarse aggregate (Kg/m³)	Water (L/m³)
385	644.92	1101	177.44
1	1.67	2.74	0.46

Table 7:- Details of test specimens

Specimen type	Size of specimen (mm)	Test conducted
Cubes	150 x 150 x 150	Compressive strength test
Cylinders	300 x 150	Split tensile strength
Plane concrete beam	700 x 150 x 150	Flexural strength test

IV. TESTS ON CONCRETE

1. Tests on Fresh Concrete

- **Workability:**

Workability refers to how easily fresh concrete can be mixed, placed, compacted, and finished without segregation or loss of homogeneity. It depends on factors like water content, aggregate shape, grading, and the use of admixtures. Higher workability makes concrete easier to handle, especially in congested reinforcement areas. Proper workability ensures good compaction and ultimately improves the strength and durability of concrete.

2. Tests on Hardened Concrete

- **Compressive Strength Test:**

Compressive strength is the ability of concrete to resist crushing loads when subjected to pressure. It is one of the most important indicators of concrete quality and durability. The strength is determined by testing concrete cubes or cylinders after specific curing periods. Higher compressive strength generally means better performance, stability, and load-carrying capacity in structures.

$$\text{Compressive strength fc} = \frac{P}{A}$$

Where, P = Load, A = Area of cube

- **Split Tensile Strength Test:**

Split tensile strength measures the ability of concrete to resist tension when a compressive load is applied along its diameter. It helps evaluate the cracking resistance and overall tensile behavior of concrete, which is naturally weak in tension. This test gives a better understanding of concrete's performance in real structural conditions. Higher split tensile strength indicates improved ductility and reduced crack formation.

$$\text{Split tensile strength} = \frac{2P}{\pi LD}$$

Where, P = Load, L = Length of the cylinder and D = Diameter of the cylinder.

- **Flexural Strength Test:**

Flexural strength test determines the ability of concrete to resist bending or flexural stresses. It is performed by applying a load at the midpoint or third points of a beam specimen until failure occurs. This test helps assess the concrete's performance in elements like slabs, pavements, and beams, where bending stresses are significant. Higher flexural strength indicates better resistance to cracking and deformation under load.

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$$\text{Flexural strength} = \frac{PL}{bd^2}$$

Where, P = Load, L = Length of the beam, b = Width of the beam and d = Depth of the beam.

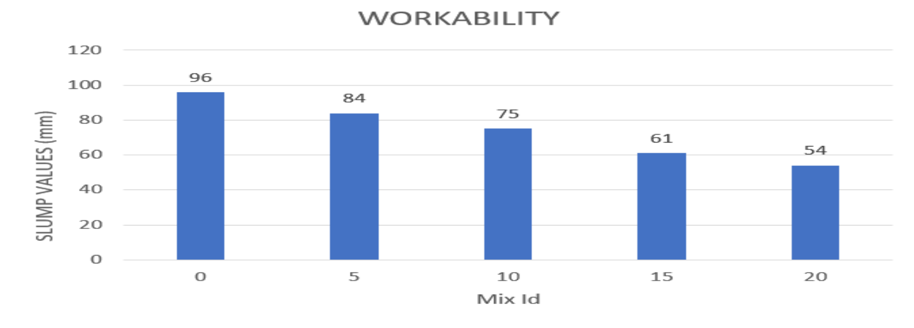
V. RESULTS AND DISCUSSIONS

A. SLUMP CONE TEST

M1 = Conventional concrete., M2 = 15% Silica fume 5% palm oil ash., M3 = 15% Silica fume 10% palm oil ash., M4 = 15% Silica fume 15% palm oil ash. and M5 = 15% Silica fume 20% palm oil ash.

Table 8:- Slump Values

Mix ID	Slump (mm)
M1	96
M2	84
M3	75
M4	61
M5	54



Graph 1: Workability of Concrete

The slump values gradually decreased from M1 to M5 as the POFA content increased, even with a constant 15% silica fume. This shows that higher replacement levels make the mix less workable because both silica fume and POFA increase fineness and water demand. Overall, the concrete became stiffer with each addition of POFA.

B. COMPRESSIVE STRENGTH TEST

➢ **Test results for Silica Fume (SF) and Palm Oil Fuel Ash (POFA) concrete.**

Table 9:- Compressive strength results for SF+POFA concrete (N/mm²)

Mix ID	Percentage replacement		Compressive strength (N/mm²)	
	Silica fume (%)	POFA (%)	7 days	28 days
M1	0	0	29.41	34.88
M2	15	5	28.94	33.605
M3		10	31.56	37.62
M4		15	29.73	36.38
M5		20	25.942	32.008

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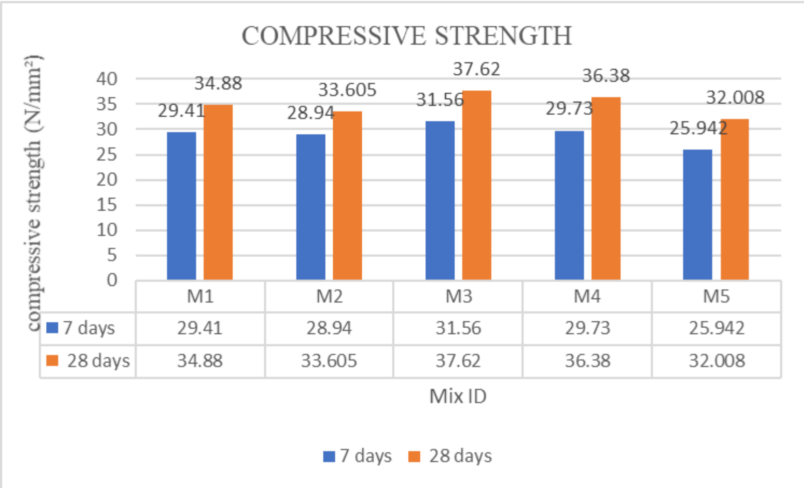

Graph 2: Compressive Strength for SF+POFA

Fig 1: Cube specimens

Fig 2: Compression test for cube specimens

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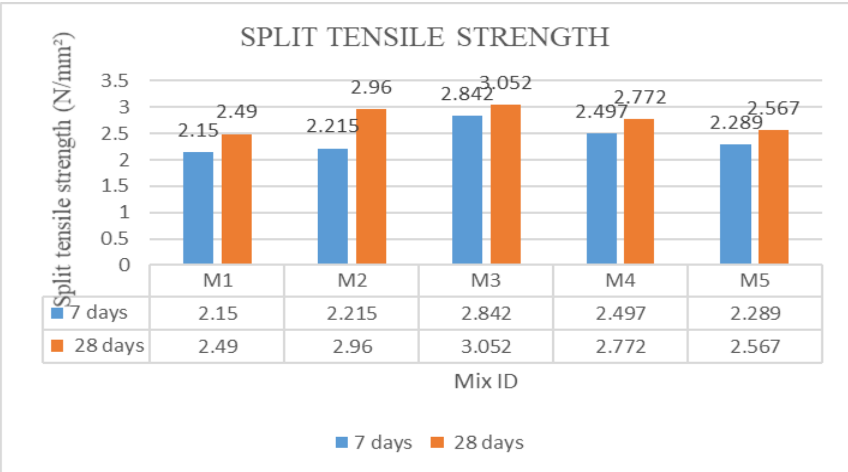
The compressive strength results show that M3 achieved the highest strength at both 7 and 28 days, outperforming all other mixes. M4 also performed better than the control mix (M1) at 28 days. M2 and M5 showed lower strengths, with M5 having the lowest values. Overall, M3 delivered the best compressive strength development.

C. SPLIT TENSILE STRENGTH

Split tensile strength shows noticeable variation across mixes. M3 achieved the highest values at both 7 and 28 days, indicating the best performance. M2 also showed good improvement over the control mix (M1), while M4 and M5 recorded moderate strength. Overall, M3 demonstrates the most enhanced tensile behavior among all mixes.

Table 10:- Split tensile strength results for SF+POFA concrete (N/mm²)

Mix ID	Percentage replacement		Split tensile strength (N/mm²)	
	Silica fume (%)	POFA (%)	7 days	28 days
M1	0	0	2.15	2.49
M2	15	5	2.215	2.96
M3		10	2.842	3.052
M4		15	2.497	2.772
M5		20	2.289	2.567



Graph 3:- Split Tensile Strength for SF+POFA

Fig 3: Cylinder specimens

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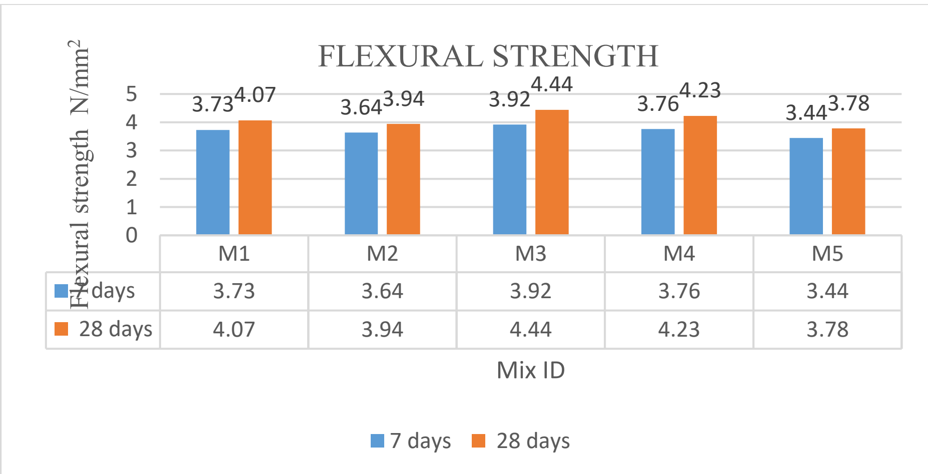
Fig 4: Compression test for cylinder specimens

D. FLEXURAL STRENGTH

The flexural strength results show that most mixes performed close to the control (M1), except M3 which showed a noticeably higher 7-day strength. At 28 days, M4 slightly improved over M1, while M2 and M5 showed lower values. Overall, M3 displayed the highest early strength, whereas long-term flexural performance remained similar across most mixes.

Table 11:- Flexural strength results for SF+POFA concrete

Mix ID	Percentage replacement		Flexural strength (N/mm²)	
	Silica fume (%)	POFA (%)	7 days	28 days
M1	0	0	3.73	4.07
M2	15	5	3.64	3.94
M3		10	3.92	4.44
M4		15	3.76	4.23
M5		20	3.44	3.78



Graph 4: Flexural test for 7 and 28 days

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Fig 5: Testing of beams

VI. CONCLUSION

This study examined how concrete behaves when a constant 15 percent silica fume is combined with varying proportions of palm oil fuel ash (POFA) as a partial replacement for cement. The results provide a clear picture of how these two supplementary materials interact and how their combined use can contribute to both performance improvement and sustainability.

- The workability results showed a steady reduction as POFA content increased. Although each mix remained workable, the decline in slump demonstrated the increased fineness and water demand created by the dual addition of silica fume and POFA. This behavior is expected, yet it highlights the need for careful water or admixture adjustments when higher POFA levels are used.
- The mechanical performance offered a more positive outcome. A balanced combination of 15 percent silica fume with 10 percent POFA (Mix M3) consistently delivered the highest compressive, split tensile, and flexural strengths at both 7 and 28 days. The improvement is tied to the synergistic pozzolanic reaction of silica fume and POFA, which refined the pore structure, enhanced particle packing, and strengthened the concrete matrix. Beyond the 10–15 percent POFA range, strength gradually declined, indicating that excessive replacement reduces the binder's reactivity and limits early-age strength development.
- Flexural and tensile strength trends closely mirrored the compressive results, confirming that moderate POFA replacement can improve cracking resistance and overall structural integrity. These findings suggest that the microstructural benefits gained from controlled POFA incorporation extend to multiple modes of loading, not just compression.
- Overall, the study identifies 10 percent POFA with 15 percent silica fume as the most effective combination in terms of both performance and practicality. This proportion achieved the best balance between strength enhancement, workability, and sustainable material utilization. By replacing a portion of cement with industrial by-products, the optimized mix not only improves engineering properties but also contributes to reduced environmental impact.

The results reaffirm that integrating agricultural and industrial waste materials into concrete is a viable pathway for developing more sustainable and high-performing construction materials. Future investigations involving durability, microstructural characterization, and long-term performance would further strengthen the understanding of this composite system and support its broader implementation in structural applications.

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REFERENCES

1. Oyejobi, D. O., Abdulkadir, T. S. and Ahmed, A. T "A Study of Partial Replacement of Cement with Palm Oil Fuel Ash in Concrete Production."
2. Jonida Pone, Ahmed Ash, John Kamau and Fraser Hyndman "Palm Oil Fuel Ash as A Cement Replacement in Concrete"
3. Hussein M Hamada, Gul Ahmed Jokhio, Fadzil Mat Yahaya and Ali M Humada, studied on "Properties of fresh and hardened sustainable concrete due to the use of palm oil fuel ash as cement replacement."
4. M.N. M. Sidek, N.H. Hashim, S.R. Rosseli, M. R. M. Nor, S. Ismail, H. M. Saman, M. F. Arshad, A. Alisibramulisi and F. Zainudin, Utilization of Palm Oil Fuel Ash (POFA) as Cement Replacement by Using Powder and Liquidation Technique, AIP Conference Proceedings.
5. S.N. Chinnu, S.N. Minnu, A. Bahurudeen, R. Senthilkumar "Influence of palm oil fuel ash in concrete and a systematic comparison with widely accepted fly ash and slag: A step towards sustainable reuse of agro-waste ashes."
6. M. Mazloom a, A.A. Ramezanianpour, J.J. Brooks studied on "Effect of silica fume on mechanical properties of high-strength concrete "(2004)
7. Thanongsak Nochaiya, Watcharapong Wongkeo, Arnon Chaipanich "Utilization of fly ash with silica fume and properties of Portland cement–fly ash–silica fume concrete"
8. R. Selvanpriya "Silica fume as Partial Replacement of Cement in Concrete."
9. Raghavender Chinthakuntaa, Ravella Durga Prasad, Sri Rama Chand M, Janardhan Yadav M "Performance evaluation of self-compacting concrete containing fly ash, silica fume and nano titanium oxide"
10. Mohammad Iqbal Khana, Rafat Siddique "Utilization of silica fume in concrete: Review of durability properties."