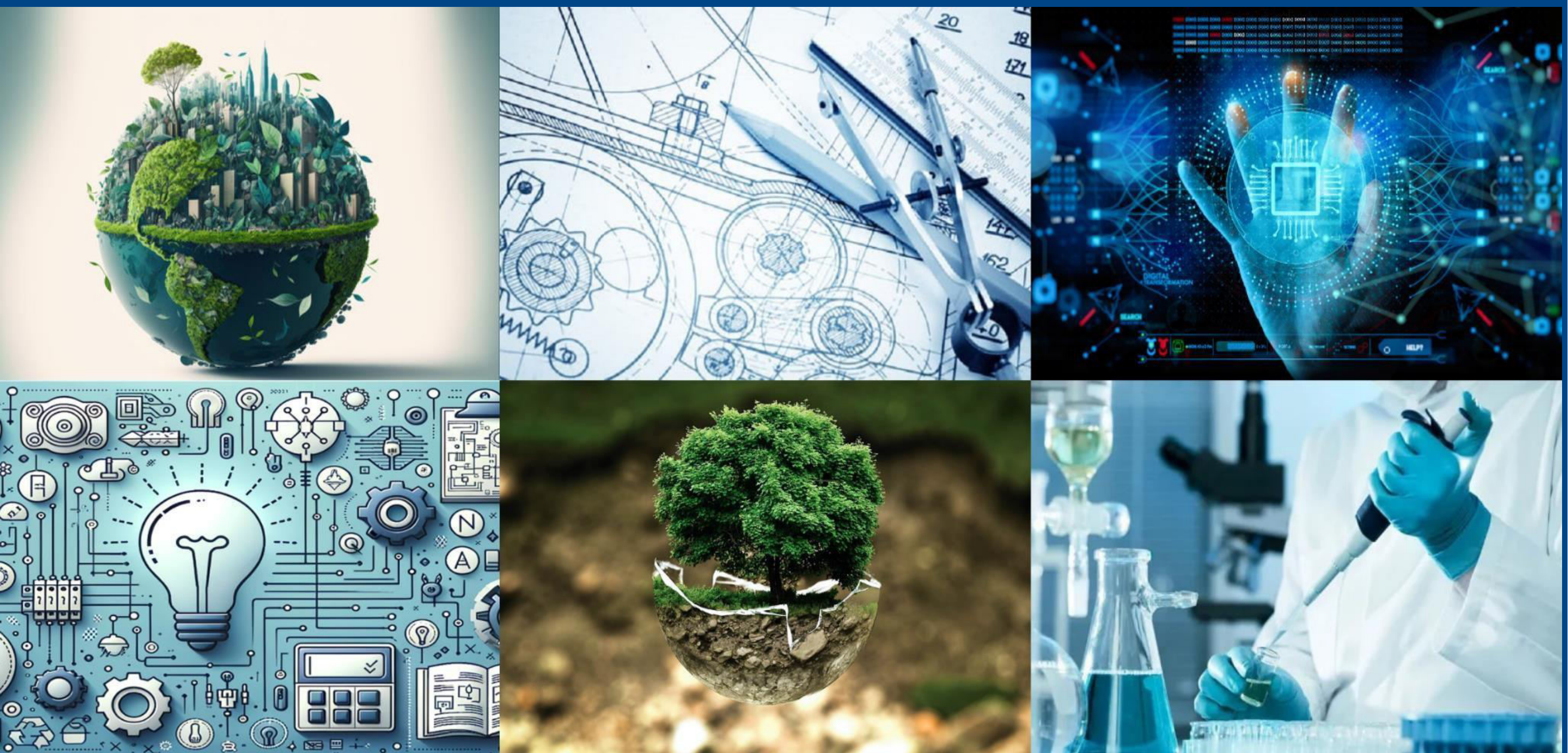
ISSN: 2582-7219

International Journal of Multidisciplinary Research in Science, Engineering and Technology

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.206

Volume 8, Issue 11, November 2025

www.ijmrset.com ijmrset@gmail.com +91 6381 907 438 +91 63819 07438

© 2025 IJMRSET | Volume 8, Issue 11, November 2025| DOI:10.15680/IJMRSET.2025.0811050

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Experimental Study on Partial Replacement of PVC Waste and Silica Fume in Cement Concrete

Suravarapu Harshavardhan[1], Boddepalli Krishnarao[2]

PG Scholar, Department of Civil Engineering, University College of Engineering Kakinada, JNTUK, A.P, India[1]

Professor, Department of Civil Engineering, University College of Engineering Kakinada, JNTUK, A.P, India[2]

*Corresponding author

ABSTRACT: This study examines the feasibility of using PVC waste as a partial fine aggregate replacement and silica fume as a supplementary cementitious material in cement concrete. The aim is to enhance sustainability while maintaining or improving mechanical performance. Concrete mixes with varying PVC and silica fume proportions were tested for compressive, split tensile, and flexural strength at 7 and 28 days. Silica fume improved matrix densification and strength, compensating for the non-reactive nature of PVC particles. Optimized combinations showed notable gains in strength, reduced voids, and improved microstructural integrity. The results confirm that integrating PVC waste with silica fume supports resource efficiency, reduces environmental burden, and produces concrete with reliable engineering properties. This approach demonstrates a practical pathway for sustainable, high-performance concrete.

KEYWORDS- Compressive strength, Split tensile strength, Flexural strength, Silica fume and PVC waste powder.

I. INTRODUCTION

The increasing accumulation of PVC waste in the environment and the demand for high-performance, low-carbon concrete have prompted researchers to explore alternative materials that enhance sustainability without compromising structural integrity. PVC waste, when processed as a partial fine aggregate replacement, offers significant potential for diverting non-biodegradable plastics from landfills. However, its hydrophobic and non-reactive characteristics can influence the mechanical response of concrete. Silica fume, a highly reactive pozzolanic by-product, has proven capability in densifying the cement matrix, improving bond characteristics, and compensating for strength losses associated with lightweight or inert additives.

In this study, Silica fume was incorporated at a constant 15 percent replacement of cement to enrich the microstructure, while PVC waste was introduced at varying levels ranging from 5 to 20 percent as a fine aggregate substitute. The focus was to assess how this combined approach influences the mechanical and microstructural performance of concrete. By integrating an industrial by-product with a plastic waste stream, the study aims to contribute to sustainable material development, reduce environmental footprints, and evaluate the compatibility of PVC–Silica fume blended concrete for structural and non-structural applications.

OBJECTIVES

The objectives of the study are

- To evaluate the mechanical performance of concrete containing 15 percent Silica fume and PVC waste powder ranging from 5 to 20 percent as a partial fine aggregate replacement.
- To analyze the influence of PVC waste powder on compressive, split tensile, and flexural strength at 7 and 28 days.
- To determine whether silica fume incorporation compensates for strength reductions typically associated with PVC waste powder.
- To examine the improvement in matrix densification, particle packing, and microstructural characteristics due to silica fume. To identify the optimum PVC waste powder replacement level that achieves a balance between sustainability, mechanical performance, and material efficiency.
- To assess the overall suitability of PVC waste powder -silica fume concrete for practical engineering applications and sustainable construction practices.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

II. MATERIAL PROPERTIES

➢ **Cement:**

Cement is a binding material used in concrete to hold aggregates together. When mixed with water, it hardens and gains strength over time. It plays a key role in giving concrete its durability and load-carrying capacity. 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	17500
3	Color	-	Light black
4	Mean particle size (μ)	0.1 to 0.3 0.2 microns	0.2
5	Bulk density (kg/m^3)	500 to 700	565
6	SiO_2	93.57	98.9
7	$Al2O_3$	0.87	0.53
8	Fe_2O_3	0.74	-
9	CaO	0.35	0.12
10	MgO	0.081	0.08
12	K_2O	-	0.7
13	Na_2O	0.15	0.15

➢ **Fine aggregate:**

Fine aggregate consists of natural or manufactured sand used to fill voids and provide workability in concrete. It helps create a dense matrix by occupying spaces between coarse aggregates. Its quality directly influences strength, durability, and overall performance of concrete. Locally available Zone -II river sand was used in this project.

© 2025 IJMRSET | Volume 8, Issue 11, November 2025| DOI:10.15680/IJMRSET.2025.0811050

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Table 3: Sieve analysis of fine aggregate

S.No	Sieve size (mm)	Weight of the FA retained (kg)	% of FA retained of total weight	Cumulative % of FA retained of total weight	% of passing of each sieve
1	4.75	0.004	0.4	0.4	99.6
2	2.36	0.019	1.95	2.35	97.6
3	1.18	0.095	9.55	11.9	88.1
4	600µ	0.305	30.5	42.4	57.6
5	300µ	0.042	4.2	46.6	53.4
6	150µ	0.489	48.9	95.5	4.5
7	pan	0.045	4.5	100	0
				299.15	
Physical properties					
8	Specific gravity		2.51		
9	Fineness modulus		2.9		
10	Bulk density		1563 m^3		

- **PVC waste powder**

PVC waste powder is obtained by grinding discarded PVC materials into fine particles. It is lightweight, non-biodegradable, and chemically inert. When used in concrete, it helps recycle plastic waste while partially replacing natural fine aggregates. It is replaced in fine aggregates by varying different percentages.

S.No	Sieve size (mm)	Weight of the FA retained (kg)	% of FA retained of total weight	Cumulative % of FA retained of total weight	% of passing of each sieve
1	4.75	0	0	0	100
2	2.36	6.00	0.60	0.60	99.4
3	1.18	30.0	3.00	3.60	96.40
4	600µ	120	12.0	15.60	84.40
5	300µ	280	28.00	43.60	56.40
6	150µ	360	36.00	79.60	20.40
7	90 µ	150	15.00	94.60	5.40
7	pan	54	5.40	100.0	0.00
				337.6	

© 2025 IJMRSET | Volume 8, Issue 11, November 2025| DOI:10.15680/IJMRSET.2025.0811050

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Properties of PVC waste powder:

S.No	Characteristics	Test results
1	Specific gravity	1.62
2	Fineness (By Sieving)	0.5%
3	Particle size	<90 µm

- **Coarse Aggregate (CA):**

Coarse aggregate, like gravel or crushed stone, makes up most of the concrete and plays a key role in giving it strength and stability. The size and shape of the stones affect how easy the mix is to work with and how well it bonds. Using clean and properly graded aggregate helps the concrete become stronger, more durable, and perform better in structures. It occupies about 60–70% of the total volume.

Table 5: Physical properties of CA

S.No	Properties	Values
1	Specific gravity	2.54
2	Fineness modulus	1.89
3	Density	1500 kg/m³
4	Water absorption	
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 used as admixture. It reduces water content. It increases workability and also improves cohesion especially when we use silica fume. It also increases compressive strength.

- **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

TESTS ON CONCRETE

1.Tests on Fresh Concrete

- **Workability:**

Slump is a measure of the workability or flow of fresh concrete. It is determined by filling a slump cone with concrete, lifting the cone, and measuring how much the concrete subsides. A higher slump indicates more workable concrete, while a lower slump reflects a stiffer mix.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

2.Tests on Hardened Concrete

- **Compressive Strength Test:**

Compressive strength of concrete is commonly determined using a cube specimen of size 150×150×150 mm. The cube is cast, cured, and then tested by applying a gradual compressive load until failure. The maximum load carried by the cube, divided by its cross-sectional area, gives the compressive strength value used to assess the concrete's structural performance.

$$\textbf{Compressive strength fc} = \frac{\mathbf{P}}{\mathbf{A}}$$

Where,
P = Load and A = Area of cube

- **Split Tensile Strength Test:**

Split tensile strength is determined using a cylindrical concrete specimen, typically sized 300 mm in length and 150 mm in diameter. The specimen is placed horizontally in the testing machine, and a compressive load is applied along its diameter to create indirect tensile stress. The load at failure is used to calculate the split tensile strength, which reflects the concrete's resistance to cracking and tensile forces.

$$\textbf{Split tensile strength} = \frac{\mathbf{2P}}{\boldsymbol{\pi}\mathbf{LD}}$$

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

- **Flexural Strength Test:**

Flexural strength is measured using a beam specimen typically sized 700×150×150 mm. The beam is placed on supporting rollers and loaded either at the midpoint or at two third points to induce bending. The load at which the beam fails is used to calculate flexural strength, indicating the concrete's ability to resist bending and crack formation under service loads.

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

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

III. RESULTS AND DISCUSSIONS

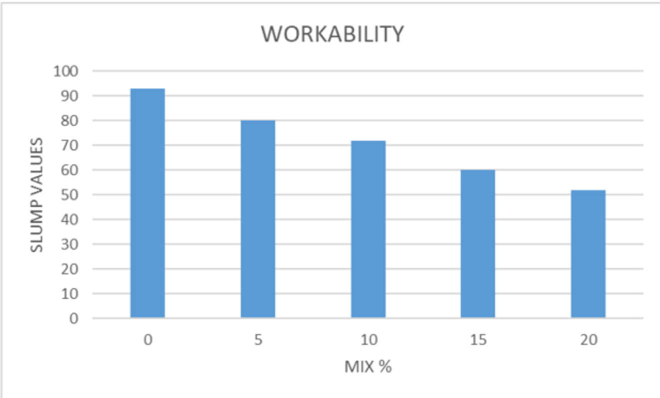
A. SLUMP CONE TEST

M1 = Conventional concrete, M2 = 15% Silica fume 5% PVC , M3 = 15% Silica fume 10% PVC, M4 = 15% Silica fume 15% PVC, M5 = 15% Silica fume 20% PVC.

Fig.1: Slump cone test

Table 7: Slump Values

Mix ID	Slump (mm)
M1	93
M2	80
M3	72
M4	60
M5	52



Graph1: - Workability of Concrete

The slump value decreased progressively with the increase in PVC waste replacement from 0% to 20%. This reduction in workability indicates that higher PVC content makes the concrete mix stiffer. However, the constant 15% silica fume addition remained workable but required proper mixing and compaction. Therefore, increasing PVC replacement negatively affects workability, and mixes with higher PVC content may need additional water or superplasticizer to maintain desirable slump.

- **Test results for Silica Fume (SF) and PVC Waste Powder (PVC) concrete.**

Table 8: Compressive strength results for 7 and 28 days

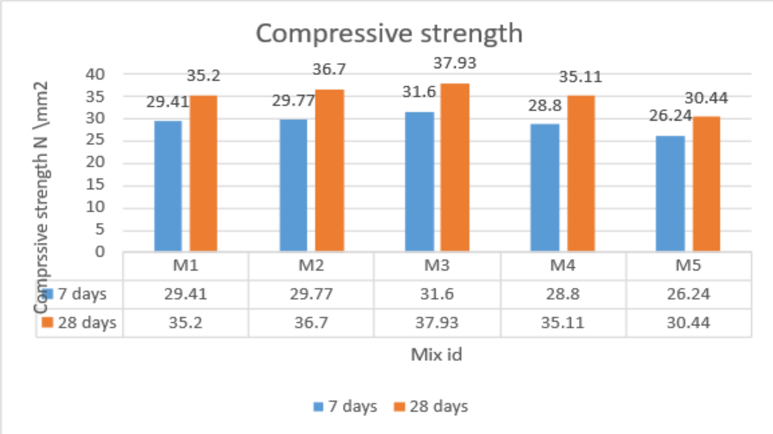
Mix ID	Compressive strength (N/mm²)	
	7 days	28 days
M1	29.41	35.2
M2	29.77	36.7
M3	31.6	37.93
M4	28.8	35.11
M5	26.24	30.44

© 2025 IJMRSET | Volume 8, Issue 11, November 2025| DOI:10.15680/IJMRSET.2025.0811050

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Graph 2:- Compressive Strength for SF+PVC

The compressive strength increased up to 10% PVC replacement with 15% silica fume (M3), showing the highest strength at both 7 and 28 days. Beyond this level, strength gradually decreased, indicating that excessive PVC reduces performance. Therefore, 10% PVC with 15% silica fume is the optimum mix for strength.

Fig. 2: Compressive strength test

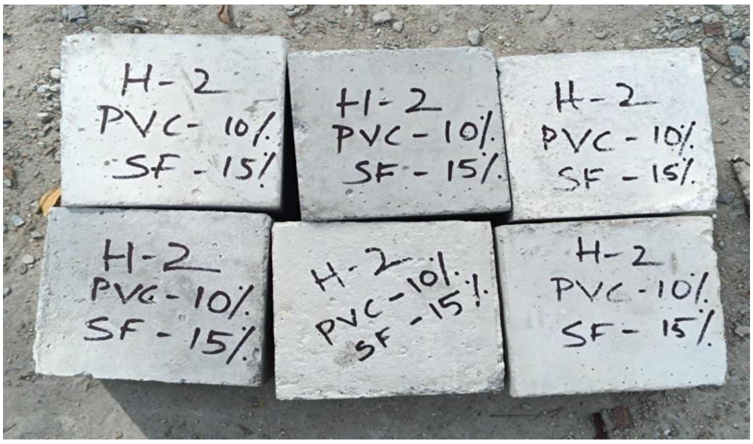


Fig. 3: Cube specimens

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

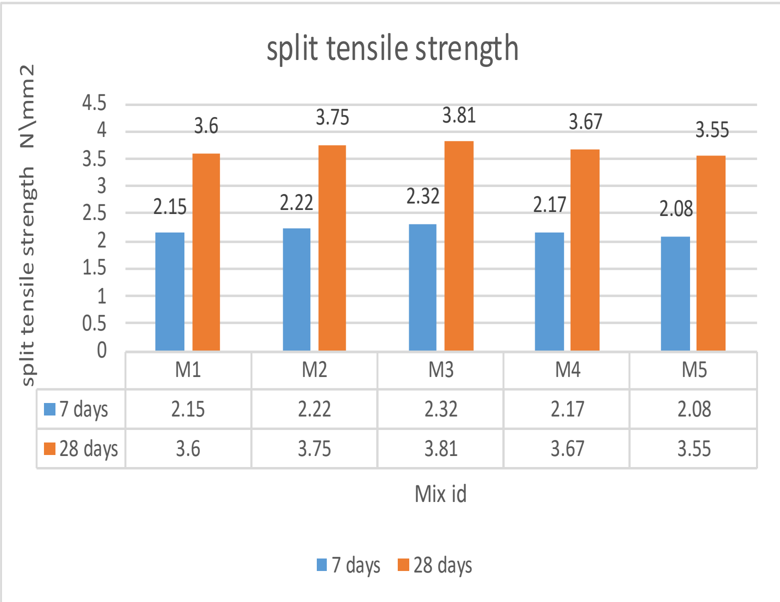
A. SPLIT TENSILE STRENGTH

Table 11: - Split tensile strength results for SF+POFA concrete (N/mm²)

Mix ID	Split tensile strength (N/mm²)	
	7 days	28 days
M1	2.15	3.6
M2	2.22	3.75
M3	2.32	3.81
M4	2.17	3.67
M5	2.08	3.55

Fig 4: Split tensile strength test

Fig 5: Flexural strength test



Graph 3: - Split Tensile Strength for SF+PVC

The split tensile strength also exhibited a similar trend. The value increased gradually from 2.15 N/mm² (control) to 2.32 N/mm² at 7 days and from 3.60 N/mm² to 3.81 N/mm² at 28 days.

ISSN: 2582-7219 | www.ijmrset.com | Impact Factor: 8.206| ESTD Year: 2018|

International Journal of Multidisciplinary Research in Science, Engineering and Technology (IJMRSET)

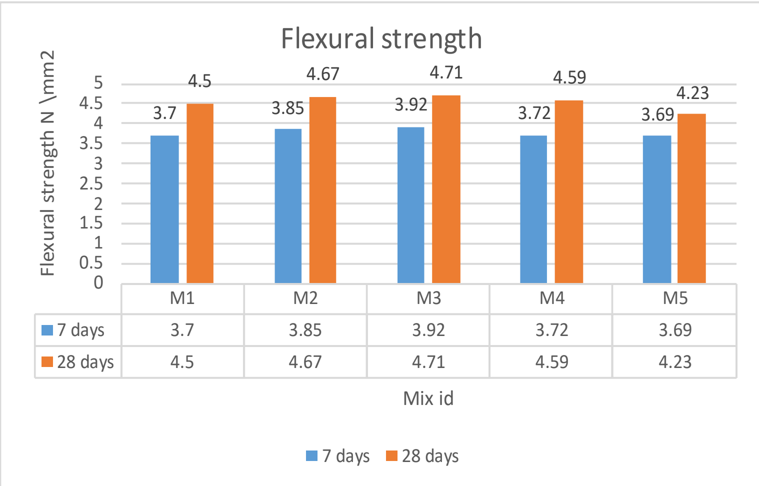
(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

This increase indicates that the inclusion of silica fume enhances the matrix density and tensile bonding within the concrete, while the fine PVC particles help in improving internal stress distribution. However, at higher replacement levels (above 10%), the tensile strength decreased due to reduced cohesion and less effective bonding between cement paste and aggregates.

➢ FLEXURAL STRENGTH

Table 12: - Flexural strength results for SF+PVC concrete

Mix ID	Flexural strength (N/mm²)	
	7 days	28 days
M1	3.7	4.5
M2	3.85	4.67
M3	3.92	4.71
M4	3.72	4.59
M5	3.69	4.23



Graph 4: Flexural Strength for SF+PVC

The flexural strength increased with the addition of PVC waste up to 10% along with 15% silica fume (M3), achieving the highest strength values at both 7 and 28 days (3.92 N/mm² and 4.71 N/mm²). This indicates improved flexural performance due to the combined effect of silica fume enhancing bonding and optimal PVC replacement. However, beyond 10% PVC content (M4 and M5), a decline in strength was observed, suggesting that excessive PVC adversely affects the flexural capacity of concrete. Therefore, 10% PVC replacement with 15% silica fume is identified as the optimum mix for achieving maximum flexural strength.

IV. CONCLUSION

- The experimental study demonstrated that the combined use of silica fume and PVC waste powder as partial replacements for cement and fine aggregate, respectively, can significantly influence the mechanical properties of M20 grade concrete.
- The compressive, split tensile, and flexural strengths showed a consistent increase up to 10% hybrid replacement level, after which a gradual reduction in strength was observed. This indicates that 10% replacement provides an optimum balance between strength, durability, and material economy.
- The improvement at 10% can be attributed to the pozzolanic activity of silica fume, which enhances the cementitious matrix and reduces porosity, along with the filler effect of finely ground PVC waste, which improves packing density and internal bonding.

- 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.
- Beyond 10% replacement, the reduction in strength parameters is primarily due to the excessive presence of PVC, which is non-reactive and leads to weaker bonding and reduced cement paste content.
- The study confirms that silica fume and PVC waste powder can be effectively utilized in concrete production up to a 10% hybrid replacement without compromising performance, contributing to the development of a more sustainable and eco-friendly construction material.
- By incorporating industrial by-products and plastic waste into concrete, this approach promotes waste recycling, reduces environmental pollution, and supports sustainable construction practices aligned with modern green building standard

REFERENCES

1. Akshay Suryavanshi, Siddhartha Nigam et.al “An Experimental Study on Partial Replacement of Cement in Concrete by Using Silica Fume.”
2. R. Selvanpriya “Silica fume as Partial Replacement of Cement in Concrete.”
3. Dilip Kumar Singh Roy and Amitava “Effect of Partial Replacement of Cement by Silica Fume on Hardened Concrete.”
4. Pushpa Lumina, Pallavi G A, Bhavya C H, Vanishree S, Supriya C B “Use of Waste Plastic as Fine Aggregate Substitute in Concrete”
5. Manjunatha M, Dinesh Seth, Balaji KVGD, Chilukoti Srilakshmie studied on “Influence of PVC waste powder and silica fume on strength and microstructure properties of concrete.”
6. “Partial Replacement of Cement by Using Silica Fume in Concrete” Prof. Vishal S. Ghutke, Prof. Pranita S.Bhandari “Influence of silica fume on concrete.”
7. Abinav Shyam, Abdullah Anwar, et al “literature review on study of silica fume as partial replacement of cement in concrete”.
8. Uma Reddy, Swaminathan P., Ch. Vijendar Reddy, Sorabh Lakhanpal, Lalit Kumar Tyagi, Muntadar Muhsen & Irfan Khan (2024). Use of Silica Fume as a Replacement of Cement in Concrete. E3S Web of Conferences, 529, 01036 Rafat Siddique “Utilization of silica fume in concrete: Review of hardened properties.”
9. S.Pream Kumar ,K.Vijay Sankar, U.Nandhini, M.Priyanka, J.Rabiun Rahul ,S.Mohanraj “Experimental Investigation on Plastic Aggregate and Silica Fume In Concrete”.
10. Dr. Vidya B, Janaradhan CH, Sri Harsha P, Venkat naidu B and Sai Sasidhar Reddy CH “Utilization of PVC Waste as a Partial Replacement in Concrete”.
11. Rohit sharma “Partial replacement of cement by silica fume.”
12. Nasratullah Amarkhail “Effect of silica fume on properties of high strength concrete.”
13. Bhanja, S., b, Sengupta, b., “Modified water cement ratio law for silica fume concretes.”

INNO SPACE
SJIF Scientific Journal Impact Factor

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

निस्केयर
NISCAIR

INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH

IN SCIENCE, ENGINEERING AND TECHNOLOGY

| Mobile No: +91-6381907438 | Whatsapp: +91-6381907438 | ijmrset@gmail.com |

www.ijmrset.com