International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 11 Issue: 11 | Nov 2024 www.irjet.net p-ISSN: 2395-0072

EFFECT OF MICRO SILICA ON THE PROPERTIES OF HARDENED CONCRETE

Samir Sarkar[1],

[1]M-Tech Student, Department of Civil Engineering, Maharishi University of Information Technology (MUIT), Lucknow, Uttar Pradesh, India

---

Abstract - *In the dynamic field of construction materials, the integration of supplementary cementitious materials (SCMs) aimed at improving the mechanical and durability properties of concrete has attracted increasing interest. Among these SCMs, micro silica, also known as silica fume (SF), stands out as a promising candidate. This work presents the function of micro-silica in enhancing concrete performance through a thorough review of the literature and experimental analysis.In-depth research is done on important characteristics like water permeability, chloride permeability, tensile strength, and compressive strength to determine how microsilica affects the mechanical and durability qualities of concrete.*

Key Words: Supplementary Cementitious Materials, Silica Fume, Compressive strength, Tensile strength, Water permeability, Chloride permeability.

1. INTRODUCTION:

As the demand for high-performance concrete escalates in tandem with the burgeoning infrastructural needs of contemporary society, understanding the nuanced effects of microsilica (MS) becomes imperative for advancing the frontiers of construction technology. Chemical composition of MS while infuse with concrete noticed significant changes, more porous of SF has a better ability to broaden the pozzolanic reaction's range [1]. Cheng Ding [2] demonstrated that adding of SF, improved the microstructure of concrete by bridging gaps and promoting a subsequent hydration reaction. Osma [3] established that adding 45% coconut shell, 1.5% glass fiber and 15% SF increases the compressive strength by 20%, tensile strength by 22%. Inclusion of 20% SF into SCC as a cement substitute did not impact on concrete properties, rather, combine this with steel fiber led to produce a more economical and durable SCC [4]. Adding 5% SF to the OPC-NP (Ordinary Portland cement - Normal Pozzolona) mix did not improve its compressive strength compared to normal OPC concrete for 28 days. OPC-NP-SF concrete has greater compressive strength than OPC concrete after 28 days. Moreover, both OPC-NP and OPC-NP-SF blends decreased drying shrinkage contrasted with OPC concrete, showing the gainful impacts of NP and SF in the progress of shrinkage [5]. Promise D [6] demonstrated that inclusion of SF into Lytag Silica Fume Concrete (LSFC) led to achieve ultimate compressive strain of 2.18% while normal concrete exhibited 3.5%. Furthermore, 94.15% of compressive strength was attained within 7 days. Tao Lou [7] investigated the workability of concrete and found that inclusion of SF by 0%-10%, slump of concrete decreased by 27% and air content reduced by 13.7%. The research also concluded that infusing of 10% SF, resulted in anincrement of compressive and splitting tensile strength by 26.7% & 40.7% respectively. Reni Suryanita [8] recommended to use SF dose at 0.15%-0.5% in the production of cellular light weight concrete (CLWC) to get better result. Vikash Kumar [9], demonstrated that replacement of SF as a substitute of cement is enhanced the concrete properties and found optimum dose of SF as 8% to get maximum result for compressive strength 7% for Split tensile strength and 8% for Flexural strength respectively. Akshay Suryabanshi [10], Conducted trials on concrete with silica fumes of variable doses and reported that the workability of concrete decreases as the proportion of silica fumes increases, besides, increments of compressive strength, tensile strength, and flexural strength are observed when silica fume replacement is about 10%.

It was evident that, even though the strength properties are improved, further study on higher grade concrete has been conductedand oversaw not only the strength propertiesbut also various durability characteristics, likechloride permeabilityas well aswater permeability for further advancements in their reliability. In this paper, SF is replaced with cementitious materials by a range from 2.5%-10% and compare the mechanical and durable properties of concrete with control mix.

2. MATERIALS

2.1 CEMENT

In the present study, Ordinary Portland Cement (OPC) of Ultratech brand of 53 grade confirming to IS: 269-2015 was used. The properties of cement found are shown in Table I:

Table 1: Properties of Cement:

Properties	Unit	Value observed
Fineness Index	(M^2 / Kg)	263
Normal Consistency	(%)	26.5
Specific Gravity	-	3.15

Initial Setting Time	Mins	100
Final Setting Time	Mins	255
Compressive Strength	(N /mm^2)	
(i) 72 ± 1 Hour		30.0
(ii) 168 ± 2 Hours		39.5
(iii) 672 ± 4 Hours		58.5

2.2 AGGREGATE

Natural River sand from Sone River as Fine Aggregate (FA) and Crushed stone obtained from Chatterpur, Jharkhand. of different sizes i.e. 20 mm and 10 mm were used as Coarse Aggregate (CA) for carrying out the experimental study. Testing of aggregate as per the specification given by IS: 383 – 1970. The properties details for Fine Aggregate and Coarse Aggregate are mentioned in Table2 & Table3 respectively:

Table 2: Properties of Fine Aggregate:

Properties	Unit	Observed value
Zone		II
Specific Gravity		2.611
Water Absorption	(%)	1.23
Silt Content	(%)	2.04
Bulking	Kg / Lt.	4.17

Table 3: Properties of Coarse Aggregate:

Properties	Unit	Observed value	
		20MM	10MM
Specific Gravity	-	2.89	2.85
Water Absorption	(%)	0.3	0.55
Impact Value	(%)	19	20
Crushing Value	(%)	21	22
Bulk Density	Kg / Lt.		
(i) Loose State		1.554	1.562
(ii) Compacted		1.644	1.621

2.3 MICRO-SILICA:

Micro Silica (MS) purchased from Elkem. The details of the physical and chemical properties ofmicro-silica have been provided by the manufacturer itself and are depicted in Tables 4&5:

Table 4: Physical Properties of Micro Silica:

Properties	Unit	Observed value
Available form		Powder
Color		Off-white/ Grey
Bulk Density	g/cc	0.84
Specific Gravity	-	2.18
Oversize retained on 45µ IS sieve	(%)	2.71
Pozzolana Activity Index (7-Days)	(%)	113.6

Table 5: Chemical Properties of Micro Silica:

Properties	Unit	Observed value
Silica (SiO2)	(%)	87.20
Moisture Content	(%)	1.21
Loss on Ignition	(%)	2.85
Alkalies as Na2O	(%)	0.75

2.4 SUPER PLASTICIZER:

A superplasticizer (SP) with specification Cryso Delta G-8236 was used to maintain the slump value in the acceptable range of 75 - 100 mm. The SP grade compiles with the recommendations of IS: 9103-1999(2007) and ASTM C 494 was adopted at a constant dose of 0.7% (by weight of cement). The details of the physical and chemical properties ofSP have been provided by the manufacturer itself and are depicted in Tables- 6 & 7:

Table 6: Physical Properties of SP:

Properties	Unit	Observed value
Initial Setting Timeof controlled sample	Minutes	120
Final Setting Time of controlled sample	Minutes	115
Compressive Strength of controlled sample		
(i) Three Days	(%)	149.2
(ii) Seven Days	(%)	158.1
(iii) Twenty-eight Days	(%)	117.8
Water Content over controlled sample	(%)	67.67
Air Content over controlled sample	(%)	0.70
Bleeding increase over controlled sample	(%)	3.91

Table 7: Chemical Properties of SP:

Properties	Unit	Observed value
PH Value	-	7.32
Ash Content	(%)	2.48
Relative Density	-	1.12
Dry Materials Content	(%)	39.66
Chloride Content	(%)	0.029

2.5 CONCRETE DESIGN MIX

In the present study, Concrete mix proportioning was calculated for the unit volume of concrete as per the recommendations given by IS 10262: 2009 for M 50 grade of concrete. The quantities for unit volume were taken as given in Table 8:

Table 8: Quantities per unit volume of concrete:

Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)		Water (Kg/m^3)	Superplasticizer (Kg/m^3)
		10mm	20mm		
469	699	474	711	150	2.81

The water-cement ratio remained at 0.32 throughout the test.After curing, the cast samples were examined for mechanical capabilities (compressive and split tensile strength) and durability properties (permeability and chloride penetration). A number of samples were cast for different types of testing and each trial mixis as under:

- For testing of Compressive strength- 12 cubes (150mm×150 mm×150 mm),
- For testing of Split tensile strength-3 cylinders (150mm × 300 mm),
- For testing of Water Permeability-3 cylinders (150mm x 160mm),
- For testing of Chloride Permeability- 3 cylinders (50mmx100 mm)

Considering the 18% wastage of material, the final volume of each trial mix batch was calculated as 0.037 m3. Qualitative details of each trial mix are illustrated in Table9 and designated as TM-1(control mix, SF-0%), TM-2(SF-2.5%), TM-3(SF- 5%), TM-4(SF-7.5%), and TM-5(SF-10%)respectively in order to avoid any experimental mishap.

Table 9: Trial Mix with variable dosage of Silica Fumes:

Trial Mix No.	Cem (Kg)	SF (Kg)	FA (Kg)	CA (Kg)		Water (Kg)	SP (Kg)
				10 mm	20 mm		
TM-1 (0% SF)	17.353	0	25.532	17.442	26.228	6.056	0.104
TM-2 (2.5% SF)	16.923	0.43	25.532	17.442	26.228	6.056	0.104
TM-3 (5% SF)	16.483	0.87	25.532	17.442	26.228	6.056	0.104
TM-4 (7.5% SF)	16.053	1.30	25.532	17.442	26.228	6.056	0.104
TM-5 (10% SF)	15.613	1.74	25.532	17.442	26.228	6.056	0.104

3. METHODOLOGY

The methods used to determine the purpose of the experimental study and carry out the work step by step are as follows:

3.1 **Weighing:** Using a laboratory scale, the amounts of all the ingredients, i.e. cement, silica fume, fine and coarse aggregate, and water, etc. in each batch of concrete were measured in accordance with the intended mix ratio.

3.2 **Mixing-**All the materials mentioned above, were combined in accordance with IS: 456-2000, and mixing was done by using a mechanical mixer till they were mixed uniformly.

3.3 **Mold preparation:** All cylindrical and cubical molds were thoroughly cleaned, snugly screwed, and coated with oil on all surfaces before casting so that de-molding of the same can be done easily.

Fig.- 1

Fig.- 2

3.4 **Compaction:** Three layers of concrete were poured into oiled molds, by using a tamping rod of 16 mm diameter & 600 mm length to tamp each layer 25 times. Following the tamping process, the top surface of the mold is finished, and identification details like the batch number and casting date are marked.

3.5 **Curing:** All of the cast specimens were removed from the molds after 24hrs., labeled to identify the casting batch, and then promptly placed in the curing tank to cure for seven, fourteen, and twenty-eight days, respectively. Moldswere kept in submerged condition throughout the curing period.

3.6 Testing-After 7, 14 & 28 days, The tank samples were used for the following experiments, following the specified technique.

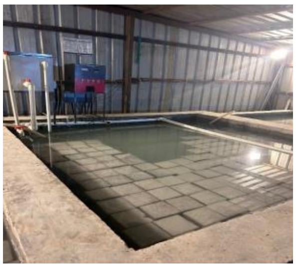


Fig.- 3

Fig.- 4

4. RESULTS AND DISCUSSIONS

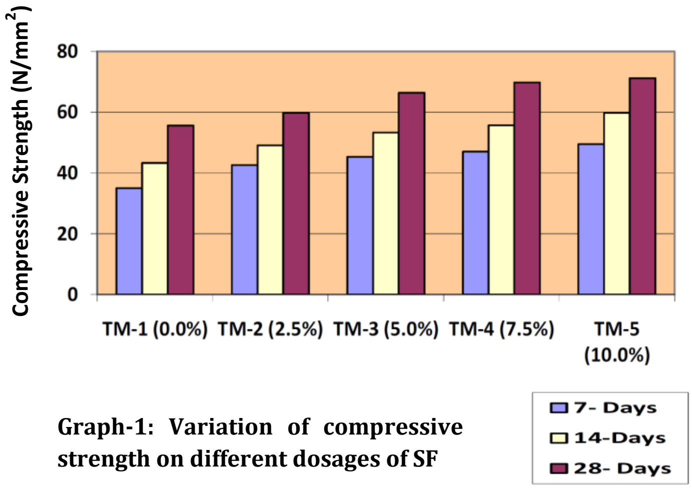
105 specimens comprising 60 cubes and45 cylinders were cast and tastingswere performed as per the specifications. Results attained by testing specimens are elaborated in this section.

4.1 TESTING OF CONCRETE FOR COMPRESSIVE STRENGTH:

- Compressive strength tests were donein terms ofIS 456-2000 and IS 516-2021, respectively. A 2000kN capacity Compression Testing Machine (CTM) is employed to test the cubes (Fig. 4).
- After wet curing for 7, 14, and 28 days, respectively, concrete cubes (150 mm150 mm x 150mm) were subjected to a compressive strength test.
- Table 10 represents the variations in compressive strength of five concrete mixes displayed in Graph1 over seven, fourteen, and twenty-eight days, respectively.
- From Graph-1, it was noted thatthe compressive strength of concrete increases with an increase in silica fume dosage by 2.5% and continues to increase as the replacement level increases upto 10%.
- Approximately 28% of the increase in strength (71.20 N/mm2) has been noted in the replacement of cement with 10% Micro Silica in comparison to the control mix (55.63 N/mm2).
- The usage of micro silica has been found to significantly enhance concrete's compressive strength due to its high pozzolanic activity as well as its capacity to fill voids.

Table 10: Result of compressive Strength of concrete:

Sl. No.	Trial Mix no.	Compressive Strength (N/mm^2)		
		At 7-Days	At 14-Days	At 28-Days
1	TM-1 (0% SF)	35.0	43.3	55.6
2	TM-2 (2.5% SF)	42.6	49.1	59.8
3	TM-3 (5.0% SF)	45.3	53.3	66.4
4	TM-4 (7.5% SF)	47.0	55.7	69.8
5	TM-5 (10.0% SF)	49.5	59.8	71.2



Graph-1: Variation of compressive strength on different dosages of SF

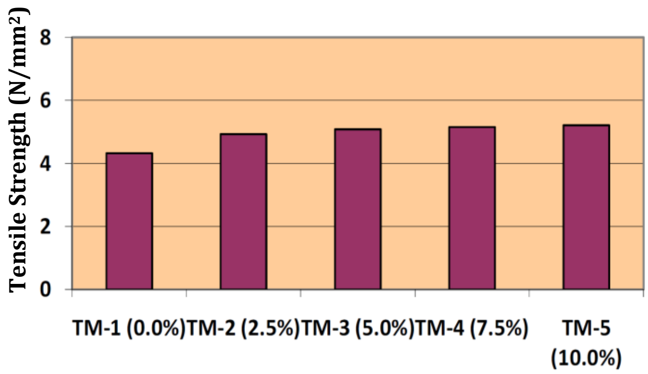
TESTING OF CONCRETE FOR TENSILE STRENGTH:

- Split tensile strength was tested for concrete according to IS 456-2000 and IS 5816-1999 (Fig.7).
- After twenty-eight days of wet curing, split tensile strength wasperformed on concrete cylinder size (150mm x 300mm) by employingCTM of capacity 1000KN, and the rate of loading was sustainedbetween 1.2 N/(mm2/min) - 2.4N/(mm2/min).
- From Graph 2,it was shown that when the dose of silica fume is increased to 2.5%, the tensile strength of concrete increases and continues to rise until the replacement level is increased to 10.0%.
- Almost a 20% increase in tensile strength (i.e. 5.21 N/mm2) is observed when replacing cement with ten percent micro silica in comparison to the tensile strength of the control mix (i.e. 4.32 N/mm2).

Fig. 5

Table 11: Result of Split tensile strength of concrete:

Sl. No.	Trial Mix no.	28-Days Split Tensile Strength (N/mm²)
1	TM-1 (0% SF)	4.32
2	TM-2 (2.5% SF)	4.93
3	TM-3 (5.0% SF)	5.08
4	TM-4 (7.5% SF)	5.15
5	TM-5 (10.0% SF)	5.21



Graph-2: Variation of 28 days tensile strength on different dosages of SF

4.2 TESTING OF CONCRETE FOR PERMEABILITY:

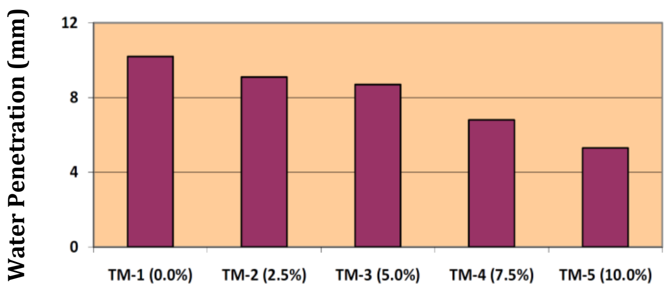
- The permeability of concrete was determined by a water penetration test.
- Water Penetration Test (WPT) of concrete is done as per the procedure laid down in clause 1717.7.5 of MoRTH specifications and DIN: 1048- 1991 (Part-V).
- Cast 150mm x 160mm cylindrical samples cured for 28 days. Subsequently, the test was performedby fixing the samplesin such a manner that they were subjected toa water pressure of 7 bars (Fig.6 & 7).
- At first, for three days, the concrete specimens were subjected to a continuous water pressure of 0.5N/mm2 (5 bar) from the top. The test may be stopped and the specimen dismissed as "failed" if the water seeps through to the underside of the object.
- After 3 days, the pressure was released and the sampleswere taken out. Thencompression was applied by means of two round bars above and below of sample, causing it to split in the middle.
- The maximum depth of penetration in the direction of height should be measured using the measuring scale when the split faces begin to show symptoms of drying (varied from 5 to 10 minutes).
- The average maximum penetration depth measured across three specimens will be used to determine the concrete's water penetration test result; this depth should not exceed25 mm.

Fig.-6

Fig.-7

Table 12: Result of water penetration of concrete:

Sl. No.	Trial Mix no.	28-Days WPT (mm)
1	TM-1 (0% SF)	10.2
2	TM-2 (2.5% SF)	9.1
3	TM-3 (5.0% SF)	8.7
4	TM-4 (7.5% SF)	6.8
5	TM-5 (10.0% SF)	5.3



Graph-3: Variation of 28 days water permeability on different dosages of SF

4.3 TESTING OF CONCRETE FOR THE PRESENCE OF CHLORIDE CONTENT:

- Chloride ingress-induced corrosion of reinforcing steel is a prevalent environmental attack that results in the degradation of concrete structures.
- ASTM C 1202 guidelines are used to perform the Rapid Chloride Permeability Test (RCPT) to assess chloride ion resistance. Because RCPT is a quick and easy method, it is frequently used to assess how resistant concrete is to the intrusion of chloride ions.
- Following twenty-eight days of wet curing, RCPT was carried out on a cylindrical specimen measuring 50mm in thickness & 100mm in dia. Before starting the testing, specimens were removed from the water and kept inside the desiccator to the main humidity level above 95%.
- Two nos. of gasket-fitted cells were used to mount eachspecimen (Fig.10). Then one cell was filled with 3.0% NaCl and the other with 0.3N NaOH. The power supply is then turned on and the voltage is 60.0±0.1V and record initial reading of passing current (amperes).
- Apart from maintaining the proper solution fill level in half of the test cell until the end of the test, the specimen's surrounding air temperature was maintained between 20° and 25° C throughout the test.
- Reading of passing current at every 30-minuteinterval was recorded for a period of six hours. After completion, all specimenswere removed from the cell and the residual sealant.
- The formula below is employedin order to determine the total charge passed:
- $Q = 900(I_o + 2I_{30} + 2I_{60} + \ldots + 2I_{300} + 2I_{330} + I_{360})$, Where:
- Q = charge passed (coulombs)
- Io = current (amperes) immediately after voltage is applied
- It = current (amperes) at t min after the voltage is applied
- The schematic diagram and testing of RCPT is referredto as Fig.8 & 9.

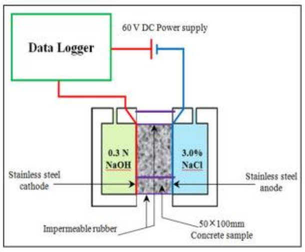


Fig. 8- SCHEMATIC DIAGRAM

Fig. 9- RCPT Testing

- Qualitative indications of the chloride ion permeability with respect to the measured value of total charge passing through the sample are illustrated in ASTM C 1202 and mentioned in Table 13:

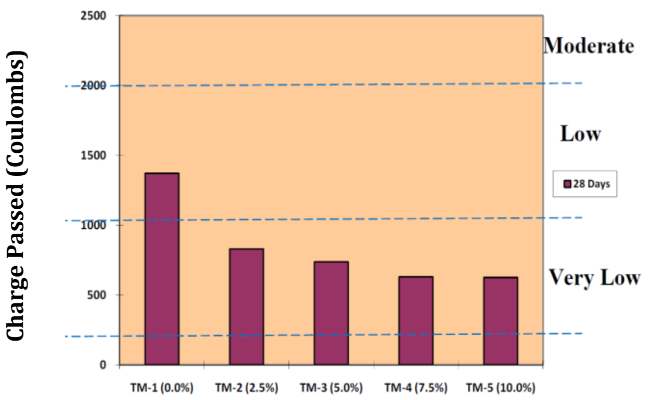
Table 13: Qualitative indications of the chloride ion permeabilityw.r.t Total Charge Passing:

Chloride Permeability	Charge passed in Coulombs
High	>4000
Moderate	2000 to 4000
Low	1000 to 2000
Very Low	100 to 1000
Negligible	<100

- The total charge passing through each sampleis computed and tabulated below in Table 14 to conclude the quality of concrete regarding chloride ion permeability is plotted in Graph-4.

Table 14: Result of chloride penetration of concrete:

Sl. No.	Trial Mix no.	28-Days RCPT (Coulomb)
1	TM-1 (0% SF)	1370.4
2	TM-2 (2.5% SF)	828.7
3	TM-3 (5.0% SF)	737.3
4	TM-4 (7.5% SF)	630.2
5	TM-5 (10.0% SF)	635.8



Graph-4: Variation of chloride permeability on different dosages of SF

5. CONCLUSION

In conclusion, the research conducted on the impact of microsilica on the characteristics of hardened concrete has shed significant light on the transformative potential of this admixture in enhancing concrete performance. Through an extensive review of literature and empirical investigations, it is evident that micro silica, with its pozzolanic properties, contributes to the improvement of various key attributes of hardened concrete, comprisingtensile strength, resistance to corrosion attacks,permeability, along compressive strength.

The current study's findings underscore the importance of considering microsilica as a viable option for optimizing concrete mix designs, especially in applications where high-performance concrete is required. By leveraging the benefits of micro silica, engineers and construction professionals can achieve structures that not only meet but exceed performance expectations, leading to enhanced longevity and sustainability of concrete infrastructure.

In accordance with the limitations imposed by test results, experimental findings lead to these conclusions:

- SF is considered a highly reactive pozzolan that increases the cohesion of concrete due to its high fineness factor resulting in high water content to sustain the desired workability. However, the use of a superplasticizer in our research reduced the amount of water needed.
- When silica fume replacement levels were raised to 2.5%–10%, the compressive strength of concrete increased by 7.5%–28%. Compact strength is at its peak when 10% of the silica fume is replaced.
- Concrete has a tendency to progressively increase its split tensile strength, with a maximum increase of 14–21%. Concrete's tensile strength rose as silica fume replacement increased. The optimum result was found at 10% replacement of microsilica.
- Water permeability of concrete demonstrates a decreasing trend up to a limit of 11-48%. Permeability of concrete mix decreases with elevation of SF replacement. 10% replacement of micro silica is required to achieve the maximum reduction in permeability.
- Chloride penetration of concrete demonstrates a decreasing trend up to a limit of 40-54%. Chloride penetration of concrete mix decreases with the increase of silica fumes replacement and varies from very low to low. The optimum reduction in chloride penetration is obtained when microsilica is replaced witha 10% value.
- When compared to regular OPC concrete, the durability criteria of blended SF concrete include better water absorption, permeability, resistance to sulfate attack, and resistance to chloride penetration.

ACKNOWLEDGEMENT

The Author would extend his gratitude to the Administrative, Technical, and Academic staff of the Department of Civil Engineering, School of Engineering, Maharishi University of Information Technology (MUIT), Lucknow for their valuable support.

REFERENCES

[1] Ales Frýbort, Jana Stulirova , Miroslava Gregreova , Giri Grosek "Changes in the chemical composition of silica fume in the concrete composite system", 2023.

[2] Cheng Ding, Kaixi Xue, Hongzhi Cui, Ziqing Xu, Haibin Yang, Xiaohua Bao ,Guangsheng Yi "Research on fire resistance of silica fume insulation mortar", Journal of Material Research Technology, 2023.

[3] Osama zaid, jawadahmad "A step towards sustainable glass fiber reinforced concrete utilizing silica fume and waste coconut shell aggregate", 2021.

[4] Abdalla M. Saba, Afzal Husain khan, Mohammad Nadeem Akhtar "Strength and flexural behavior of steel fiber and silica and silica fume incorporated self-compacting concrete", 2021.

[5] Shamsad Ahmad, Omar S. Baghabra Al-Amoudi, Saad M.S. Khan, Mohammed Malehuddin "Effect of silica fume inclusion on the strength, shrinkage and durability characteristics of natural pozzolan-based cement concrete", 2022.

[6] Promise D. Nukah, Samuel J. Abbey, Colin A. Booth, Ghassan Nounu "Development of a lytag-silica fume based lightweight concrete and corresponding design equation for pure bending", 2023.

[7] Tao Lou, Cheng Hua, Fang Liu, Qiang Sun, Yu YI, Xiaofeng Pan "Effect of adding solid waste silica fume as a cement paste replacement on the properties of fresh and hardened concrete", 2022.

[8] Reni Suryanita, HarnediMaizir, RizkiZulapriansyah, Yon Subagiono, Mohd Fadzil Arshad "The effect of silica fume admixture on the compressive strength of the cellular lightweight concrete", 2022.

[9] Vikash Kumar, Ashhad Imam, Vikas Srivastava, Atul, Y Kushwaha " Effect of Micro Silica on the properties of hardened concrete", 2017

[10] Akshay Suryavanshi, Siddhartha Nigam, Dr. S. K. Mittal, and Dr. Ram Bharosh, "An Experimental Study on Partial Replacement of Cement in Concrete by Using Silica Fume", (2018).