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RESEARCH ON THE CHARACTERISTICS AND PERFORMANCE OF SELF-COMPRESSING CONCRETE CONTAINING NANO AND MICRO SILICA

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Abstract: An innovative type of concrete known as self-compacting will be poured and compacted without the need for vibration. Since concrete is so versatile, it is frequently used in building projects all over the world to evaluate the viability of employing industrial waste materials including fly ash, Micro silica, and Nano silica. With a focus on the impact of micro and nano silica, the performance of SCC in its fresh, hardened, and durable states following 7, 28, and 56 days of curing was examined. To this end, part of the cement used in M40 mix concrete, which adheres to the IS 10262:2019 standard of 0.35 water to cement, was substituted. Half of the cement was replaced with twenty-five percent fly ash. Micro silica was used in place of cement at percentages of 5%, 10%, 15%, and 20% in order to calculate the optimal amount of micro silica based on the mechanical property test findings. It was demonstrated that after 7 days of curing, 15% of micro silica—which is thought to be the appropriate proportion of micro silica—reached the desired strength. 15% more micro silica than was previously in the cement was added by nano silica in the range of 1%, 2%, 3%, and 4%. In the current experimental study, the fresh, hardened, and durability properties of SCC with and without micro- and nano-silica were investigated. The L-Box, V-Funnel, and Slump Flow tests were used on newly laid concrete to assess its passing and filling capacities. Experiments on the inherent qualities of hardened concrete, such as split tensile strength, flexural strength, and compressive strength, were conducted to look into the performance characteristics of SCC. Concrete's durability was assessed using tests for sorptivity, water absorption, rapid chloride penetration test (RCPT), acid resistance, and alkaline resistance. In this work, SCC with and without nano and micro silica were compared.

Keywords: mechanical and durability properties, fresh properties, self-compacting concrete, micro and nano silica.

1. INTRODUCTION

Concrete is a material that is frequently used in building all over the world, and technological improvement has modified its characteristics. To improve the varied qualities of concrete, numerous different varieties have been developed. Self-compacting concrete is a high-performance concrete that will be poured and compacted without the use of vibration. It is known for its excellent workability and allows for the efficient and sustainable construction of complex structures. There are various admixtures used for the study of self-compacting concrete, which may be replaced fully or partially based on the availability of admixtures. SCC as a high-performance concrete, after the addition of alccofine and GGBS, produces a high-strength concrete, which leads to many advantages, and we can achieve a high-

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performance and strength concrete. The use of all such admixtures, such as alccofine, GGBS, and silica fume, will produce effective concrete, which leads to a new type of concrete mix with good benefits. The micro silica and nano silica are highly pozzolanic, which enhances the strength and durability of the self-compacting concrete. These admixtures will increase the compressive strength and flexural strength and reduce the permeability of SCC to make it more resistant to the ingress of harmful substances. They reduce the shrinkage and increase the workability of SCC by reducing yield stress and increasing flowability. In this project, micro silica and nano silica was used in order to study the fresh, hardened, and durability properties of self-compacting concrete. It was determined that the use of these admixtures increased the workability, as determined by tests such as slump flow tests, V-funnel tests, and L-Box tests as well as hardened properties such as compressive strength, split tensile strength, and flexural strength. The durability properties such as water absorption, acid resistance, and alkaline resistance, were drastically decreased for the mix with admixtures when compared with normal SCC. The chloride ion permeability was low, and sorptivity was also found to have an increase and decrease in the initial and secondary absorption when compared with SCC. The detailed study was made for all the properties of self-compacting concrete with and without micro silica and nano silica in the present investigation.

K. Nandhini and V. Ponmalar (2021) have studied the use of micro and nano silica to replace, respectively, 5% to 15% and 1% to 3% of cement in this work. The behavior of SCC in its fresh form was examined in the lab using the slump test, V-funnel test, and J-ring test. They looked at the mechanical properties of concrete at various ages when the fraction of micro and NS increased. As the C-S-H gel growth in the concrete was significantly better with no discernible pores compared to control SCC, the combined mix of FA 20%, MS 10%, and 2% NS improved the hardened property [1]. **Jyothsna Seelapureddy, et al. (2021)** mix were generated SCC mixes of standard grade 30 and 40 mix while increasing the fly ash and metakaolin content. Micro silica was replaced with cement in the current project. The mechanical and durability properties are dealt with. It was found that 10% of metakaolin was suitable for M30 and M40 grade concrete in terms of strength and workability. Strength had risen by 24% and 34.0%, respectively, for concrete of M30 grade at 7 days and 28 days following 10% replacement with metakaolin. Metakaolin was replaced by 10% in M40 grade, which enhanced strength by 31.0% after 7 days and by 48.2% after 28 days. As a result of silica fume replacing cement, workability was reduced. However, this can be remedied by adding superplasticizers. Silica fume was used in place of 10% of the cement in M30 grade concrete, which boosted the material's strength by 24.5% in just 7 days and by 38.9%. In M40 grade concrete, 10% cement was replaced with silica, resulting in strength increases of 33.4% and 48.5% [2]. **Zena K and Ali Al-Ahmed (2020)** explored the strength parameters of M40 and M50 concrete grades with the use of micro silica 5, 7.5, 10, and 15% and nano silica 1, 1.5, 2, and 2.5% as partially replaced by cement in the current study. The experimental study showed that better concrete composites may be made using micro silica, nano silica, and mixes of micro silica and nano silica. For both M40 and M50 grades cement substitution increases mechanical properties by up to 7.5% with SF and up to 2% with NS. The replacement of silica fume and nano silica for concrete of grades M40 and M50 is 7.5% and 2%, respectively. The percentage increase in mechanical properties of M40 and M50 grades compared to regular concrete is 25%, 25%, and 17% for M40 grade and 25%, 25%, and 15% for M50 grade [3]. **P. Muthuraja and R. Venkatasubramani (2013)** assessed the inherent properties of SCC with various admixtures. The procedure involves replacing admixtures with cement by 30%, 40%, and 50%, followed by performance testing. The effect of mineral admixtures on the various tests was investigated. At 28 days, the compressive strength of fly ash with 30% and 40% was better than that of silica fume and GGBS with values of 48.88 and 42.33 MPa and split tensile and flexural strengths [4]. **Mohammad Reza Sohrab and Yousef Rahmani (2011)** studied the mechanical properties of SCC with fly ash and silica fume at various curing ages. The mechanical strength of the specimen was assessed at 7, 28, and 120 days after curing, while the strength was assessed at 28 days. In order to achieve self-compatibility, several workability tests are performed. In self-compacting mixtures, fly ash and silica fume are used in place of 20, 30, and 40% of the cement, respectively. The compressive strength for control mixes was 60 MPa for 28 days. Tensile strength decreases when fly ash percentage rises, although the addition of 5% silica fume has less of an effect [5].

2. METHODOLOGY

Procurement of materials

⬇

Conducting basic tests on materials

⬇

Mix design calculations based on IS 10269:2019 for M40 grade of concrete

⬇

Casting of required specimens such as cubes, cylinders, and prisms

⬇

Tests for the performance characteristics of SCC with and without micro silica and nano silica are conducted.

⬇

Comparative studies between the SCC with and without micro and nano silica results were carried out.

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3. MATERIAL PROPERTIES

- ***Cement OPC 53 Grade***

In this project, Penna OPC 53 grade cement was employed, with material parameters like fineness, specific gravity, initial setting time, and ultimate setting time fulfilling the necessary standard ranges listed in Table 1.

B. Aggregates

The coarse aggregate of size 12-16mm was used in this project. The specific gravity of fine aggregate and coarse aggregate is given in Table 1.

Table 1. Material Properties

Properties of Materials	Ranges
Fineness of Cement	8%
Grade of Cement	53
Specific Gravity	3.15
Initial Setting time	32 min
S.G of Coarse Aggregate	2.71
Final Setting Time	380 min
S.G of Fine Aggregate	2.68

C. Admixtures

In this investigation, micro and nano silica with specific gravities of 2.21 and 1.03 and sizes of 0.2 m and 50 nm were utilized. In Table 2, the chemical compositions of micro and nano silica were described.

Table 2. Chemical Compositions of Admixtures

Materials	Chemical composition	%
Micro Silica	SiO_2	90.26
	Fe_2O_3	1.11
	Loss of ignition	2.20
	Al_2O_3	5.84
	Moisture	2.2
Nano Silica	SiO_2- content	99.88
	Al_2O_3	0.005
	PH	4.12
	Fe_2O_3	0.001

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4. MIX PROPORTIONS

Design strength of SCC	= 40MPa
Size of aggregate	= 16mm
S.G of coarse aggregate	=2.71
S.G of fine aggregate	= 2.703
S.G of cement	= 3.15
Air content	= 1%

By using 15% as the ideal percentage of micro silica and varying the amount of nano silica added to the cement, the mix proportions were created in accordance with the codal provisions of IS 10262:2019. Table 3 provides the mix proportions for the combined mixes of micro and nano silica with the necessary amounts of components.

Table 3. Mix Proportioning (kg/m^3)

Material	**SCC**	**SMN1**	**SMN2**	**SMN3**	**SMN4**
Cement	356.25	302.82	296.77	293.736	290.71
Coarse aggregate	850.94	823.97	821.13	815.71	813
Fine aggregate	937.5	937.5	937.5	937.5	937.5
Water	167	167	167	167	167
Fly ash	118.75	118.75	118.75	118.75	118.75
Micro silica	-	53.43	53.43	53.43	53.43
Nano silica	-	3.028	6.05	9.084	12.11
Super plasticizer	4.75	4.75	4.75	4.75	4.75
VMA	2.375	2.375	2.375	2.375	2.375

5. EXPERIMENTAL INVESTIGATION

This experimental investigation deals with the various tests to determine the fresh, hardened, and durability properties of self-compacting concrete.

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A. WORKABILITY TEST

Workability tests, including as slump flow, V-funnel, and L-Box tests, were conducted for all the different mixtures used in this study to ascertain the fresh characteristics of SCC. The mix comprising micro and nano silica has a higher viscosity than the nominal SCC, and the slump flow was first seen to increase for the nominal mix before decreasing. It was discovered that there was less internal friction between the particles used in the L-box and V-funnel tests, which improved passing ability and made achieving workability easier. Details on the recent properties are supplied in Table 4.

Fig 1. Slump flow test

Fig 2. V-Funnel test

Fig 3. L-Box test

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Table 4. Fresh Properties of SCC

S.No	Concrete Mixes	Slump flow	V funnel	L-box test
1	SCC	780 mm	9.0	0.86
2	SMN1	782 mm	9.6	0.85
3	SMN2	699 mm	10.5	0.99
4	SMN3	695 mm	10.1	0.88
5	SMN4	675 mm	11.2	0.82

B. MECHANICAL PROPERTIES

Compressive strength test, split tensile strength test, and flexural strength test for varied curing duration of 7, 28, and 56 days are the various tests to measure the mechanical properties of SCC. The mechanical characteristics of SCC with the optimal proportion when compared to normal SCC there was an increase in compressive strength of 4.64% at 7 days, 3.67% at 28 days, and 5.64% at 56 days when 15% micro silica and 2% nano silica were present. There was also an increase in split tensile strength of 8.99% at 7 days, 4.34% at 28 days, and 6.99% at 56 days, and a rise in flexural strength of 10.59% at 7 days, 11.37% at 28 days, and 3.53% at 56 days. The Table 5 provides the test results for each of SCC's toughened qualities.

Table 5. Hardened Properties of SCC

S.No	Concrete Mixes	Compressive strength (MPa)			Split Tensile strength (MPa)			Flexural strength (MPa)		
		7 days	28 days	56 days	7 days	28 days	56 days	7 days	28 days	56 days
1.	SCC	32.32	50.57	55.46	2.78	3.68	4.13	3.21	5.1	5.65
2.	SMN1	30.99	51.82	56.98	2.86	3.76	4.27	3.52	5.29	5.77
3.	SMN2	33.82	52.43	58.59	3.03	3.84	4.44	3.55	5.68	5.85
4.	SMN3	32.25	51.12	54.79	2.8	3.77	4.17	3.51	5.37	5.8
5.	SMN4	31.25	50.12	51.66	2.24	3.46	4.01	3.49	5.19	5.72

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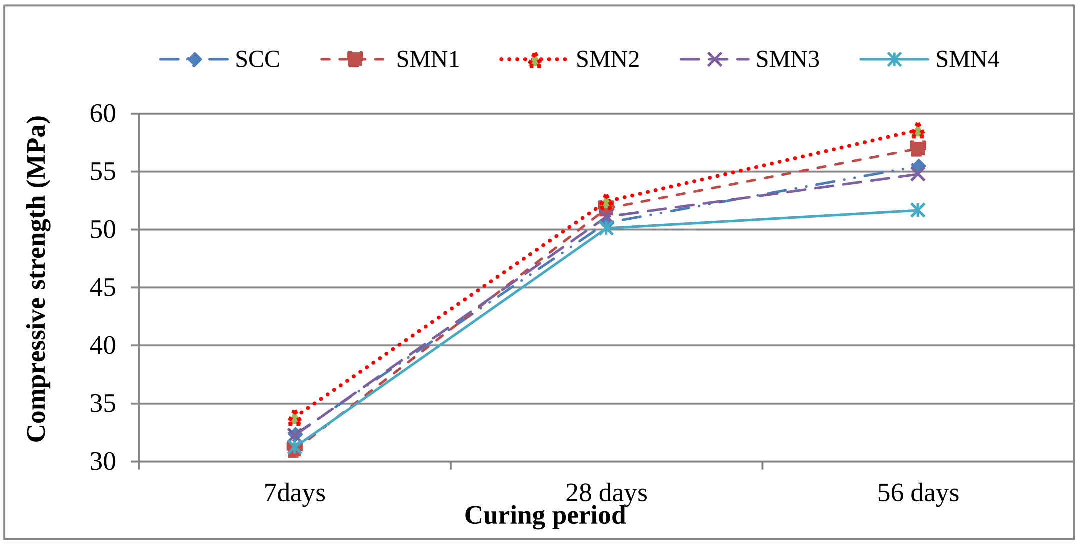

Fig 4. Compressive strength vs Curing period

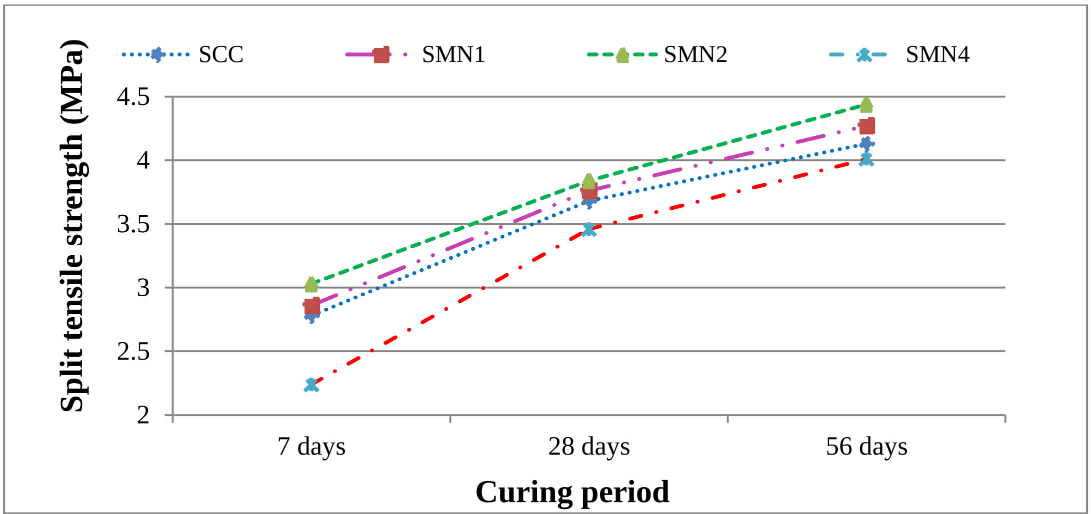

Fig 5. Split tensile strength vs Curing period

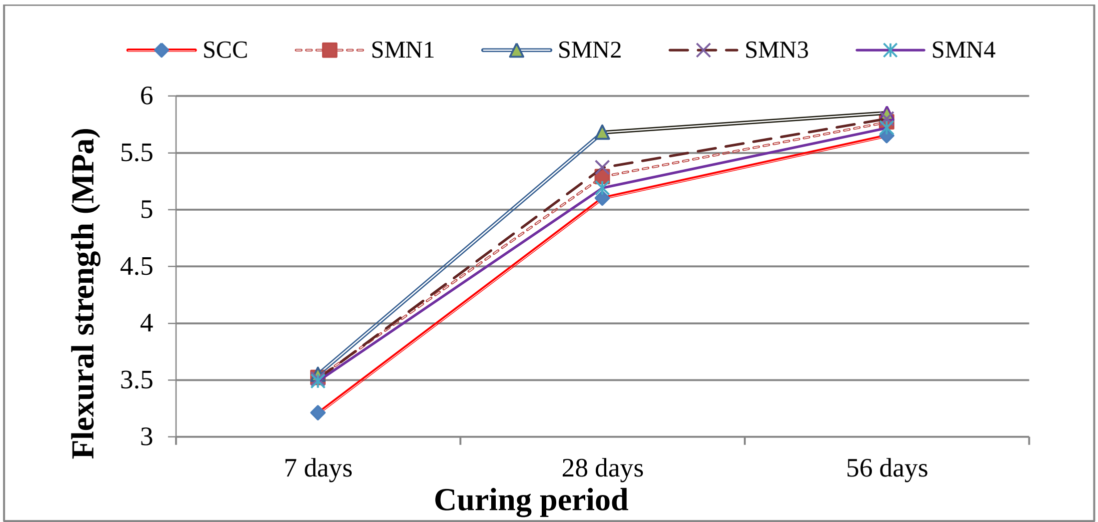

Fig 6. Flexural strength vs Curing period

C. DURABILITY PROPERTIES

Along with that of the various admixtures, the SCC's resistance to abrasion, chemical assault, and weathering action is investigated. Water absorption test, acid resistance test, alkaline resistance test, rapid chloride penetration test (RCPT), and sorptivity test for 28 and 56 days of curing period are some of the tests to determine the durability properties. Due to the reduced pore size and connectivity in the concrete, the percentage weight loss for water absorption was found to be decreased by 56.52%, acid resistance by 39.82%, and alkaline resistance by 44.02%. In comparison to the alkaline medium, the acid medium showed a greater amount of weight loss.

Table 6. Durability Tests on SCC

S.No	Concrete Mixes	Water absorption test		Acid resistance test (H_2SO_4)		Alkaline Resistance Test (Na_2SO_4)	
				Percentage weight loss			
		28 days	56 days	28 days	56 days	28 days	56 days
1.	SCC	0.69	0.73	0.55	1.622	0.29	0.552
2.	SMN1	0.6	0.64	0.492	1.287	0.21	0.517
3.	SMN2	0.53	0.57	0.431	1.153	0.25	0.41
4.	SMN3	0.42	0.45	0.382	1.07	0.21	0.351
5.	SMN4	0.3	0.32	0.331	1.016	0.17	0.309

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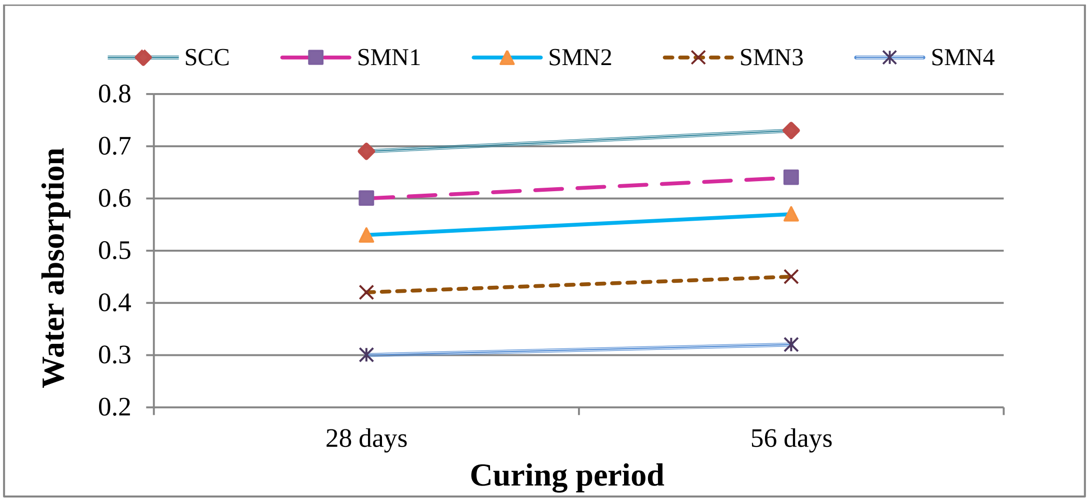

Fig 7. Water absorption vs Curing period

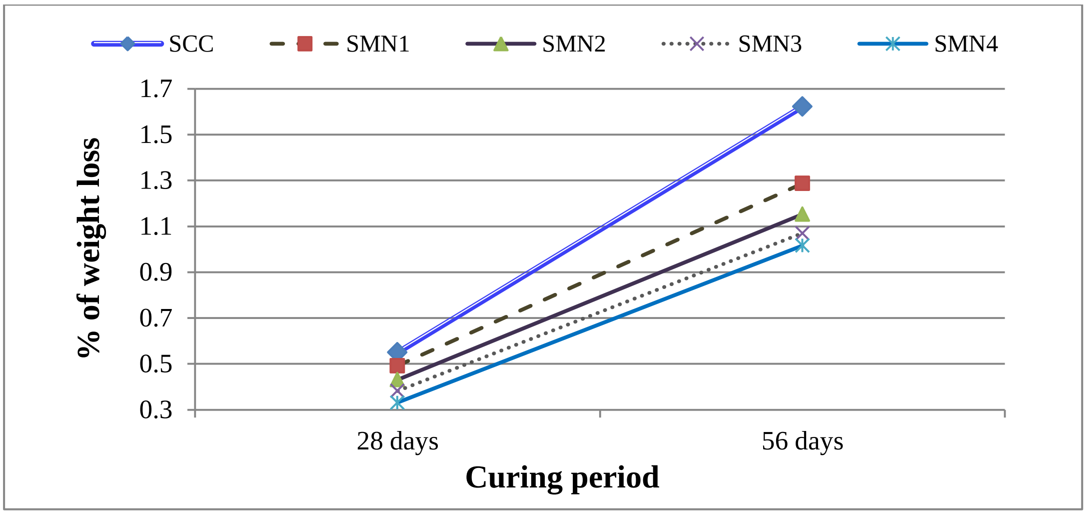

Fig 8. Percentage weight loss vs Curing period for acid

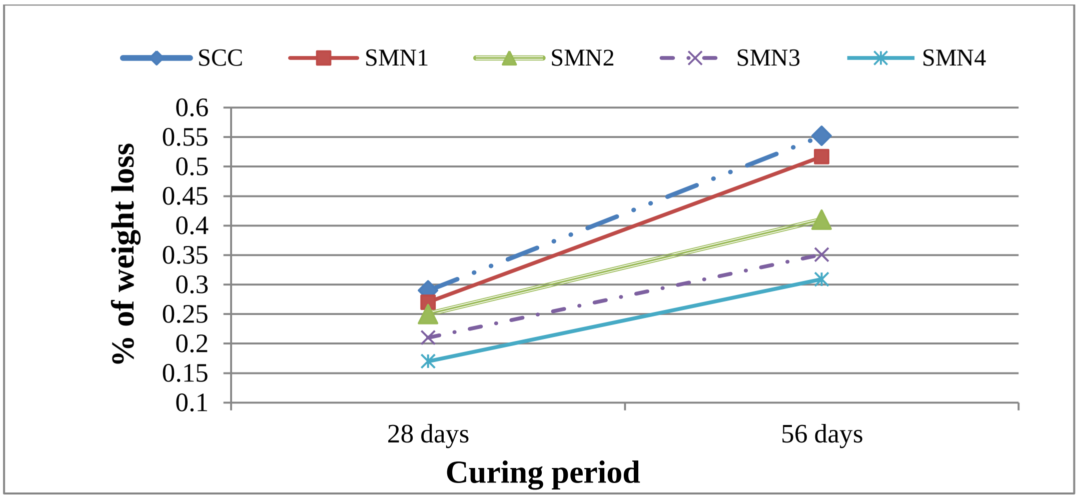

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Fig 9. Percentage weight loss vs Curing period for alkaline test

RAPID CHLORIDE PENETRATION TEST (RCPT):

Due to its simplicity and speed, the rapid chloride permeability test (RCPT-ASTM 1202) was employed to assess the resistance of concrete to chloride ion intrusion. For SCC, as shown in Table 7, the highest chloride ion penetration was discovered. due to the specimen's poor permeability to chloride ions when compared to mixes with micro and nano silica during cure days of 28 and 56 days.

SORPTIVITY TEST

By measuring the capillary rise absorption rate on sufficiently homogeneous material, the

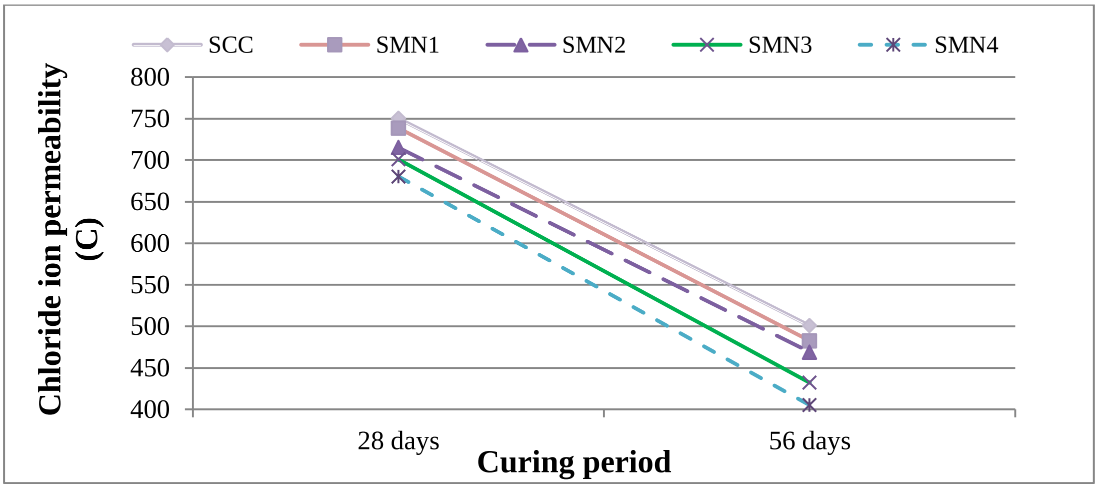

Fig 10. Chloride ion permeability vs Curing period

sorptivity can be ascertained. Table 8 displays the calculated beginning and final absorption values. The absorption rate was found to be high for SCC with nano silica of 2% for both 28 and 56 days of curing due to the reduction of pore size of the concrete.

Table 8. Sorptivity test results

S.No	Concrete Mixes	Initial Absorption (mm/√s)		Final Absorption (mm/√s)	
		28 days	56 days	28 days	56 days
1.	SCC	0.00061	0.00051	0.00041	0.00010
2.	SMN1	0.00062	0.00052	0.00042	0.00020
3.	SMN2	0.00063	0.00053	0.00043	0.00030
4.	SMN3	0.00060	0.00050	0.00040	0.00009
5.	SMN4	0.00059	0.00049	0.00039	0.00008

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6. CONCLUSIONS

- The experimental inquiry above led to the following conclusions: From workability test results on fresh concrete, it is seen that normal SCC and SCC possessing micro and nano silica have appropriate filling ability and passing capacity.
- When compared to regular SCC, it was shown that SCC with 15% replacement of micro silica in cement exhibited the best compressive strength. This finding establishes the ideal proportion of micro silica to be added to SCC for future research.
- Comparing normal SCC to that with 2% nano silica added and the ideal percentage of micro silica replaced, it has been observed that the former exhibits higher compressive strength, flexural strength, split tensile strength, water absorption, acid resistance, alkaline resistance, chloride ion permeability, and sorptivity.
- In contrast to regular SCC, the mechanical properties of SCC with an ideal percentage of 15% micro silica and 2% nano silica showed increases in split tensile strength of 8.99% at 7 days, 4.34% at 28 days, and 6.99% at 56 days, as well as increases in compressive strength of 4.64% at 7 days, 11.37% at 28 days, and 3.53% at 56 days.
- The percentage of weight loss for sorptivity, water absorption, acid resistance, alkaline resistance, and chloride ion permeability were all found to be reduced in the engineering properties of SCC with an optimal percentage of micro and nano silica when compared to normal SCC.

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