A STUDY ON STRENGTH PROPERTIES OF CONCRETE CONTAINING MICRO-SILICA AND NANO- SILICA

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Abstract

This paper presents an experimental investigation on the influence of Nano-Silica (NS) on various strength characteristics of concrete containing Micro-Silica (MS). Micro-Silica and Nano-Silica are used as partial replacement of cement for the preparation of concrete. In the present investigation cement is partially replaced by 5% and 10% of Micro-Silica and 1.5% and 3% of Nano-Silica by weight. The combined application of Micro-Silica and Nano-Silica on various properties of M30 and M40 grades of concrete is investigated. The various properties of concrete under investigation include the compressive strength, split tensile strength and flexural strength. The test results of M30 and M40 grades of concrete prepared using different proportions of Micro-Silica and Nano-Silica are compared with that of controlled concrete. Based on the test results, concrete prepared with a combination of 10% Micro-Silica and 1.5% Nano-Silica possesses improved strength properties compared to the controlled concrete.

Keywords: *Micro-Silica, Nano-Silica, Particle Packing, Combination and Strength of Concrete.*

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1. INTRODUCTION

Concrete is the most commonly used material in various types of construction, from the flooring of a hut to a high rise structure, from pathway to an airport runway, from an underground tunnel and deep sea platform to high-rise chimneys and TV Towers. The construction industry uses concrete to a very large extent. Cement is one of the important components of concrete. The cement industry produces about 5% of global man-made CO2 emissions, of which 50% is from the chemical process, and 40% from burning fuel. Hence, to reduce the consumption of cement, the application of Pozzolana materials is increasing day-by-day in the form of partial cement replacement for concrete preparation. Previous studies indicated that the use of micro-silica leads to the reduction in cement consumption and also helps to increase the strength and durability of concrete (Mazloom *et al* 2004 and Bhanaja and Sengupta 2002).

The modern concrete construction industry uses nano materials as supplementary materials to improve the performance of concrete. Recent developments in Nano-technology and the availability of nano-silica find its applications in concrete. Due to the smaller particles size and high surface area compared to the micro-silica, the use of nano-silica enhances the compressive strength of concrete more effectively than micro-silica. Hence, the influence of combined application of micro-silica and nano-silica in concrete preparation needs to be investigated.

2. OBJECTIVE

The main objective of the present experimental investigation is to obtain the influence of the combined application of micro-silica and nano-silica on various strength properties of M30 and M40 grades of concrete. 5% and 10% of Micro-Silica and 1.5% and 3% of Nano-Silica by weight of cement replacement is adopted. Compressive strength, split tensile strength and flexural strength of the two grades of concrete prepared using different proportions nano-silica and micro-silica are to be obtained and the results are to be compared with that of controlled concrete.

3. EXPERIMENTAL INVESTIGATION

3.1Properties of Materials

3.11 Cement

In the present investigation Ordinary Portland Cement (OPC) of 43 Grade confirming to IS specifications was used. The properties of cement are shown in Table.1.

Table1. Properties of Cement

S.No	Property	Value
1	Specific Gravity	3.13
2	Normal Consistency	32 %
3	Setting Time a) Initial Setting time b) Final setting time	 120 Min 6 hours

3.12 Fine Aggregate

Locally available river sand confirming to IS specifications was used as the fine aggregate in the concrete preparation. The properties of fine aggregate are shown in Table.2.

Table2. Properties of Fine Aggregate

S.No	Property	Value
1	Specific Gravity	2.69
2	Fineness Modulus	2.9
3	Bulk Density (Loose)	15.75 kN/m^3
4	Grading of Sand	Zone – II

3.13 Coarse Aggregate

Crushed granite metal of nominal size 20 mm and 10 mm obtained from the local quarry and confirming to IS specifications were used. The properties of coarse aggregate are shown in Table.3. The coarse aggregate used for the preparation of concrete is a combination of 20 mm and 10 mm size aggregates in ratio 1.5: 1.0

Table3. Properties of Coarse Aggregate

S.No	Property	Result
1	Specific Gravity	2.60
2	Bulk Density (Loose)	14.13 kN/m^3
3	Water Absorption	0.4%
4	Fineness Modulus	7.2

3.14 Micro-Silica

Micro-Silica is very fine non-crystalline silica, produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon. The typical particle size is less than $1\mu m$, hence can be considered as an excellent material fills the space between the cement particles. Micro-silica can also be considered as a supplementary cementitious material. In this experimental investigation, 5% and 10% of micro-silica was used as cement replacement by weight. The properties of Micro-Silica are shown in Table 4

Table4. Properties of Micro – Silica

S.No.	Property	Value
1	SiO_2	90.20 %
2	Moisture	0.20 %
3	Pozzolana Activity Index	127 %
4	Specific Surface Area	21 m^2/gm
5	>45 Microns	0.20 %

3.15 Nano-Silica:

Nano-Silica is a new pozzolanic material in the form of water emulsion of colloidal silica. It appears to be potentially better than micro-silica because of higher content of amorphous silica (>99%) and the reduced size of its spherical particles (1-50*nm*). In this experimental investigation cement is replaced by 1.5% and 3% of nano-silica by weight. The properties of nano-silica are shown in Table 5.

Table.5. Properties of Nano-silica

S.No.	Property	Actual Analysis
1	Nano solids	39.5-41%
2	PH	9 -10
3	Specific Gravity	1.29-1.31
4	Texture	Milky White Liquid
5	Dispersion	Water

3.16 Water

Water used for casting and curing of concrete test specimens is free from impurities which when present can adversely influence the various properties of concrete.

3.17 Super Plasticizer

Super plasticizer (Glenium-D) is used to achieve the required workability. The dosage of super plasticizer is 1% by weight of cement in case of concrete prepared with only micro-silica and 2% by weight of cement for the concrete prepared with micro-silica and nano-silica combination.

3.20 Concrete Mix Proportion

In the present experimental investigation the influence of combined application of micro-silica and nano-silica as partial replacement of cement on M30 and M40 grades of concrete is studied.

Table.6 (a) Quantities of Ingredients per cum of M30 Grade Concrete

Concrete	Cement (kg)	Micro-Silica (kg)	Colloidal Nano-Silica (Lit)	Water (lit)
Control	350	0	0	140
MS 5%	332	18	0	140
MS 10 %	315	35	0	140
MS 5% + NS 1.5 %	326.7	18	5.25	136.85
MS 10% + NS 1.5 %	309.7	35	5.25	136.85
MS 5% + NS 3 %	321.5	18	10.5	133.7
MS 10% + NS 3 %	304.5	35	10.5	133.7

M30 and M40 grades of concrete were designed as per the Indian Standard code of practice. The various ingredients for one cubic meter of M30 and M40 grades concrete are shown in Table 6 (a) and Table 6 (b). As the Nano-silica is available in the colloidal form, the quantity of water required for making concrete is adjusted to account for the water available in colloidal Nano-silica. The quantities of fine aggregates are 725 kgs and coarse aggregates of 1246 kgs per cum of M30 grade concrete with a water cement ratio of 0.40. For M40 grade of concrete the quantities of fine aggregates are 625 kgs and coarse aggregates of 1210 kgs are adopted.

Table.6 (b) Quantities of Ingredients per cum of M40 Grade Concrete

Concrete	Cement (kg)	Micro-Silica (kg)	Colloidal Nano-Silica (lit)	Water (lit)
Control	380	0	0	152
MS 5%	361	19	0	152
MS 10 %	342	38	0	152
MS 5% + NS 1.5 %	355.3	19	14.25	143.45
MS 10% + NS 1.5 %	336.3	38	14.25	143.45
MS 5% + NS 3 %	349.6	19	28.5	134.9
MS 10% + NS 3 %	330	38	28.5	134.9

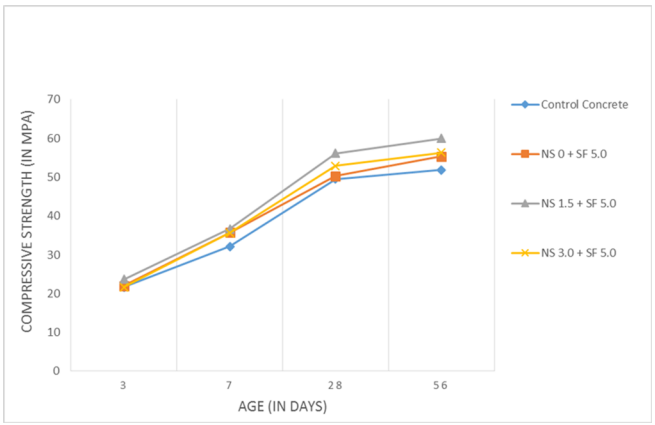
3.3test Specimens

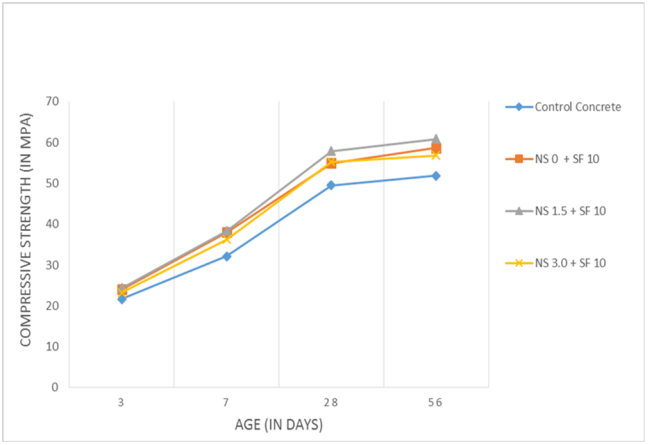
Concrete test specimens consist of 150 mm × 150 mm × 150 mm cubes, cylinders of 150 mm diameter and 300 mm height and 100 mm × 100 mm × 500 mm prisms. Concrete cube specimens were tested at 3, 7, 28 and 56 days of curing to obtain the compressive strength of concrete. Cylindrical specimens were tested at the age of 28 days to obtain the compressive strength and split tensile strength of concrete. The prisms were tested at the age of 28 days to obtain the flexural strength of concrete. The rate of loading is as per the Indian Standard specifications.

4. RESULTS AND DISCUSSIONS

4.1compressive Strength

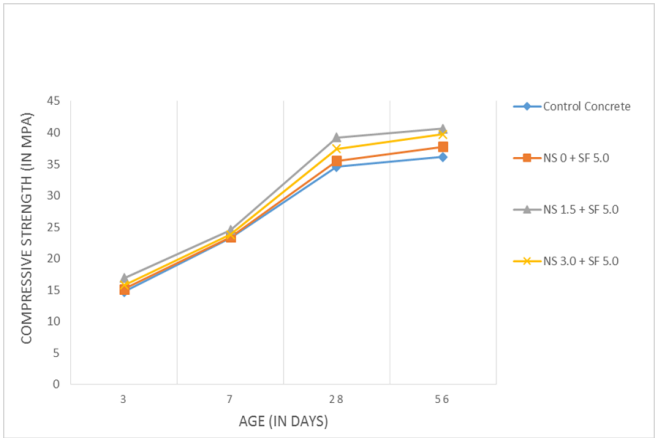
The variation of the cube compressive strength with the age of M30 and M40 grades concrete prepared using the various proportions of micro-silica and nano-silica is shown in Fig.1. Each value of the cube compressive strength indicates the average of three test results. It can be observed that the compressive strength of nano-silica concrete exhibits more than the control concrete up to 1.5% of nano-silica and with further increase in nano-silica the strength decreases for the given micro-silica content. Similar trend is observed in the two grades of concrete M30 and M40.

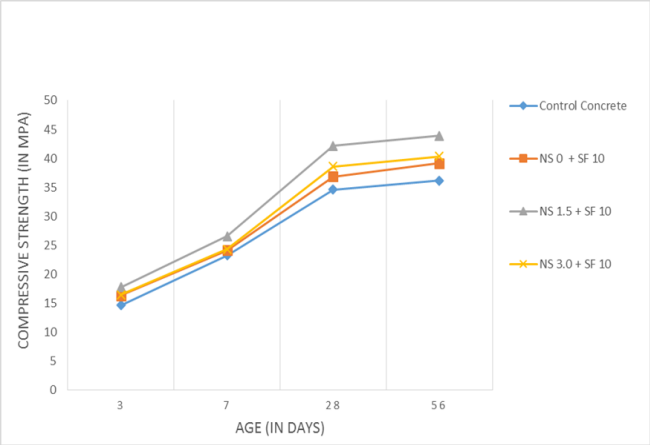




(i) 5% Micro-Silica (ii) 10% Micro-Silica

Fig. 1(a). Variation of Cube Compressive Strength of M40 Grade Concrete with age for different percentages of Micro-silica and Nano-Silica.

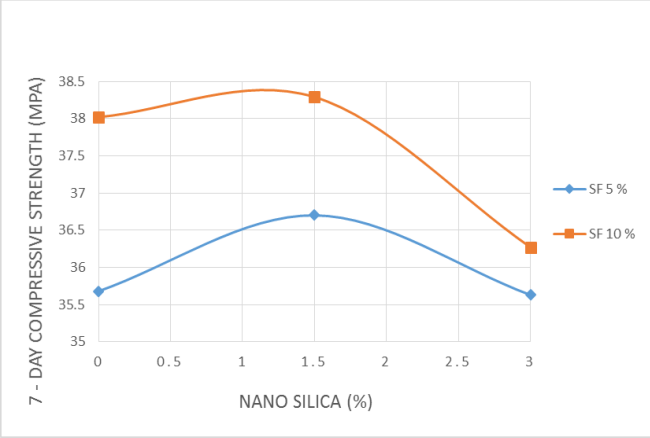


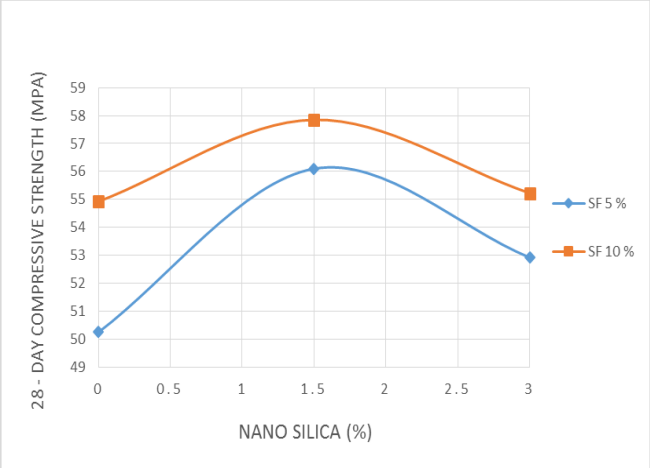


(i) 5% Micro Silica (ii) 10% Micro Silica

Fig. 1(b). Variation of Cube Compressive Strength of M30 Grade Concrete with age for different percentages of Micro-silica and Nano-Silica.

The variation of 7 days and 28 days cube compressive strength of M30 and M40 grades of concrete prepared with nano-silica containing different percentages of micro-silica is also shown in Fig.2 (a) & 2(b). The compressive strength of concrete initially increases up to 1.5% nano-silica and then the strength decreased with increase in nano-silica for 5% and 10% micro-silica.

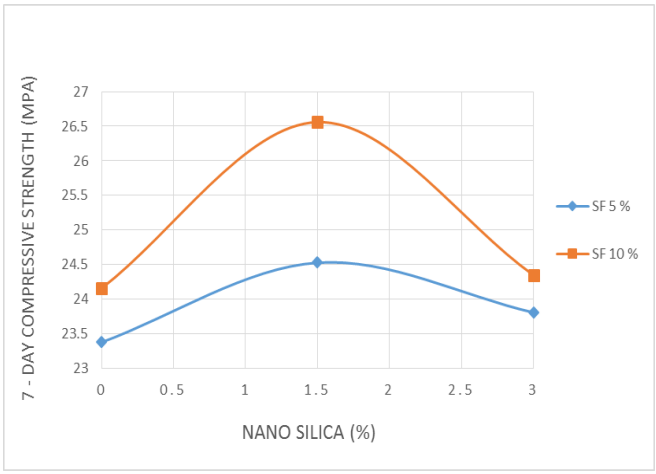


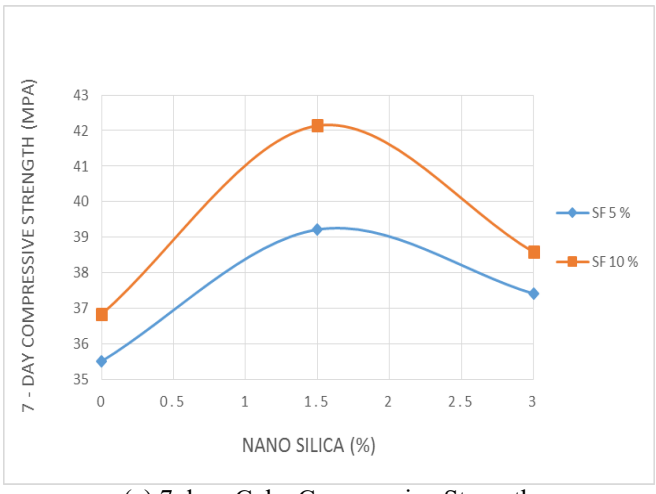


(a) 7 days Cube Compressive Strength
(b) 28 days Cube Compressive Strength

Fig. 2 (a) Variation of 7 days and 28 days Cube Compressive Strength of M40 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica

The 7 days and 28 days cube compressive strength of M40 grade control concrete is 32.10 N/mm^2 and 49.49 N/mm^2 respectively. The increase in 7 days and 28 days cube compressive strength concrete with 1.5% nano-silica and 10% micro-silica combination is 18.44% and 16.89% respectively.





(a) 7 days Cube Compressive Strength
(b) 28 days Cube Compressive Strength

Fig. 2 (a) Variation of 7 days and 28 days Cube Compressive Strength of M30 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica

The 7 days and 28 days cube compressive strength of M30 grade control concrete is 23.29 N/mm^2 and 34.60 N/mm^2 respectively. The increase in 7 days and 28 days cube compressive strength concrete with 1.5% nano-silica and 10% micro-silica combination is 14.04 % and 21.80% respectively.

Comparison is also made between the 28 days cube compressive strength and cylindrical compressive strength of concrete containing various percentages of micro-silica and nano-silica.

The test results are shown in Table 7. The ratio of cube strength to the cylinder strength is found to be around 0.95 for concrete containing micro-silica and nano-silica.

Table: 7(a) & 7(b). Comparison Between 28 days Cube and Cylinder Compressive Strength of Concrete Prepared with Micro-Silica (MS) and Nano-Silica (NS)

S.No.	Concrete	M30 Grade		
		Cube Compressive Strength (N/mm^2) σ_{Cube}	Cylinder Compressive Strength (N/mm^2) $\sigma_{Cylinder}$	$\sigma_{Cylinder}/\sigma_{Cube}$
1	Controlled	34.60	32.04	0.93
2	MS 5%	35.52	34.30	0.97
3	MS 10%	36.84	35.58	0.97
4	MS 5% + NS 1.5%	39.22	36.90	0.94
5	MS10% + NS 1.5%	42.14	40.02	0.95
6	MS 5% + NS 3%	37.42	36.12	0.97
7	MS 10% + NS 3%	38.59	36.80	0.95

S.No.	Concrete	M40 Grade		
		Cube Compressive Strength (N/mm^2) σ_{Cube}	Cylinder Compressive Strength (N/mm^2) $\sigma_{Cylinder}$	$\sigma_{Cylinder}/\sigma_{Cube}$
1	Controlled	49.49	44.23	0.89
2	MS 5%	50.26	48.97	0.97
3	MS 10%	54.93	52.07	0.95
4	MS 5% + NS 1.5%	56.1	52.83	0.94
5	MS10% + NS 1.5%	57.85	56.26	0.97
6	MS 5% + NS 3%	52.93	50.27	0.95
7	MS 10% + NS 3%	55.23	51.33	0.93

4.2split Tensile Strength

The variation of split tensile strength of M30 and M40 grades of concrete with increase in Nano-silica is shown in Fig. 3. The split tensile strength of M30 and M40 grades of control concrete is 2.72 N/mm^2 and 4.06 N/mm^2 respectively.

The split tensile strength of concrete initially increases up to 1.5% of Nano-silica and with further increase in the nano-silica content the split tensile strength decreases. Similar trend can be observed with the concrete containing 5% and 10% Micro-silica. The increase in the split tensile strength of M30 and M40 grades of concrete with 1.5% nano-silica and 10% micro-silica combination is 13.05% and 15.44% respectively.

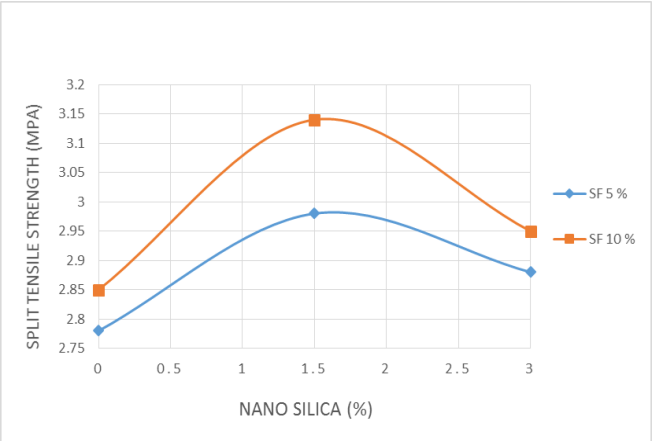


Fig.3 . Variation of Split Tensile Strength of M30 and M40 Grades of Concrete with different percentages of Micro-Silica and Nano-Silica.

4.3 Flexural Strength

The variation of flexural strength of M30 and M40 grades of concrete containing various proportions of micro-silica and nano-silica is shown in Fig.4. The flexural strength of M30 and M40 grades of control concrete is 4.40 N/mm^2 and 6.46 N/mm^2 respectively. The flexural strength of concrete initially increases up to 1.5% percentage of Nano-Silica and then with further increase in the Nano-Silica the flexural strength decreases for different percentage of Micro-Silica content. The increase in the flexural strength of M30 and M40 grades of concrete with 1.5% nano-silica and 10% micro-silica combination is 17.5% and 17.49% respectively.

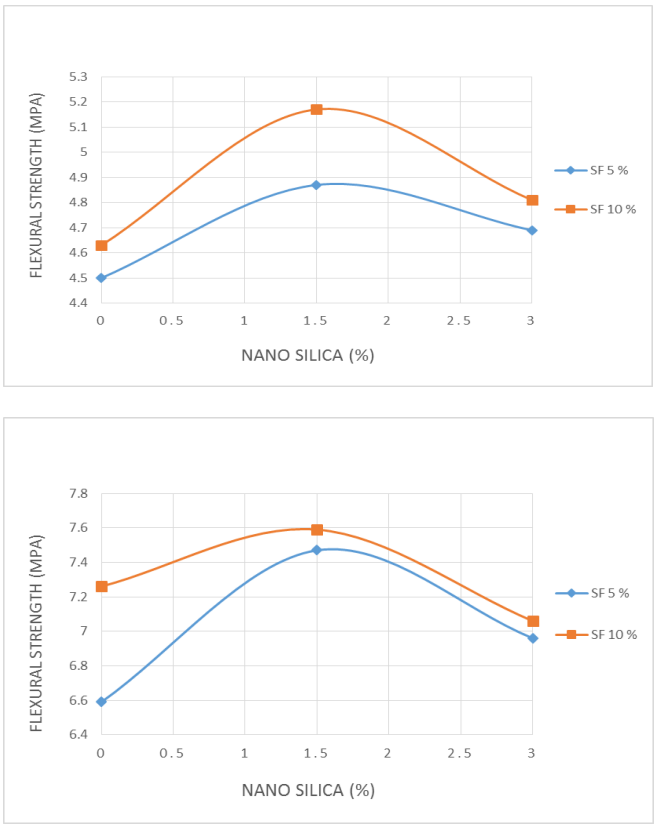


Fig.4 . Variation of Flexural Strength of M30 and M40 Grades of Concrete with different percentages of Micro-Silica and Nano-Silica.

5. CONCLUSIONS

Using the results of the experimental investigation, it can be concluded that with the increase in the percentage of nano-silica the various strength characteristics of concrete are increased up to 1.5%, with further increase in the nano-silica the strength of concrete is decreased for various percentages of micro-silica. The split tensile strength and flexural strength of M30 and M40 grades of concrete also indicated the similar trend.

The increase in the strength of concrete containing micro-silica and nano-silica can be the result of availability of additional binder in the presence of nano-silica and micro-silica. Nano-silica has high amorphous silicon dioxide content and is a very reactive pozzolana material. During the hydration of cement along with CSH gel, calcium hydroxide will also be formed. The nano-silica and micro-silica reacts with the calcium hydroxide to form additional binder. The availability of additional binder improves the paste-aggregate bond and results in the increase in strength characteristics of concrete with nano silica and micro-silica. The decrease in the strength properties of concrete is due to the poor quality of binder in the presence of high percentage of micro-silica and nano-silica.

Based on the experimental investigation the strength properties of concrete can be improved by the addition of 1.5% of nano-silica and 10% of micro-silica by weight of cement. Hence, it can be concluded that the cement content can be reduced for the preparation of concrete by the use of nano-silica and micro-silica as cement replacement and considerable percentage increase in various strength properties of concrete can be obtained.

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