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EXPERIMENTAL INVESTIGATION ON BEHAVIOUR OF NANO SILICA IN CONCRETE

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Abstract - Concrete is the largest utilized material in the world, as a construction material. Also it has occupied an indispensable place in construction industry. In present investigation, a method to reduce cement content in concrete mixtures has been developed. Also it is difficult to produce the high strength concrete meeting its ideal requirements such as economy, high performance, resistance to weathering & chemicals, etc. Also high strength concrete possess low tensile strength and low durability properties. So to achieve these requirements, we had used nano silica (0%, 5%, 10%, 15%, 20% and 25%) as partial replacement to cement and its effect on workability and mechanical properties (compressive strength, split tensile strength, flexural strength) of concrete was investigated and the results were compared with the normal concrete.

Key Words: Concrete, Nano-silica, Compressive Strength, Tensile Strength, Flexural Strength, Workability, M60

1. INTRODUCTION

Concrete is the largest utilized material in the world, as a construction material. Also it has occupied an indispensable place in construction industry. Utilization of such huge mass of concrete results in the depletion of natural sources, by using raw materials for cement production, river sand and coarse aggregate, etc. Cement emits very high volume of CO_2. About 5% to 7% of total CO_2 emissions are due to cement, which needs special attention. So we have to find some ways to overcome these problems to retain a sustainable environment.

In recent years, researchers have focused on the modification of concrete in respect with performance, cement content, mechanical properties, etc., so as to minimise depletion of natural resources, CO_2 emissions and to increase its performance and quality. So a new concept of nanotechnology was developed. Nanotechnology deals with the production and application of physical, chemical and biological systems at scales ranging from few nano-meters to sub-micron dimension. The application of nano materials is limited in the field of civil engineering due to the insufficient knowledge.

In present study, a method to reduce cement content in concrete mixtures has been developed. Also it is difficult to produce the high strength concrete meeting its ideal requirements such as economy, high performance, resistance to weathering & chemicals, etc. Also high strength concrete possess low tensile strength and low durability properties. So to achieve these requirements, we had used mineral admixtures like nano silica. Nano silica, with particle size in the range of nano level, is expected to further improve the properties of concrete by improving hydration and pore filling effect. So our initial step will be consisting of introducing nano silica in various proportions as a partial replacement of cement in M60 concrete and studying its effect on normal concrete.

In the research work, we had investigated effect of nano silica as partial replacement to the cement regarding workability by slump cone test on fresh concrete and density, compressive strength, splitting tensile strength, flexural strength of hardened concrete having characteristic compressive strength of 60 N/mm^2.

2. OBJECTIVES

The objectives of this research project are to study-

- The project deals with M60 grade of concrete.
- To study the nano technology in concrete.
- To study the feasibility of using nano silica as partial replacement to cement in improving the performance of concrete
- To study the effect of nano silica on fresh and hardened concrete.

3. LITERATURE REVIEW

Recently nano technology is being used or considered in many applications and it has receiving increasing attention in building materials. At present, a significant number of research works dealing with the use of nano silica in cement based materials are available in literature. However, there is a limited knowledge of nano silica regarding its effect on setting time, workability, mechanical properties, etc. on concrete. So, to deal with this obstacle some researches which was done by other researchers was studied and their conclusions are summarized as follows.

Saddamhusen Bandi, Chetan G. Solanki (May, 2018), investigated the mechanical properties of nano concrete such as compressive strength, tensile strength and flexural

strength of M60 and M80 grade of concrete with use of nano silica and nano alumina (0%, 1%, 2%, 3%, 4%, 5%) as a potential replacement of cement was carried out. The results of investigation can be summarized as follows:

1. Nano silica performed better performance than nano alumina.
2. Optimum dosage of nano silica as a partial replacement to cement was found to be 3% by weight of cementitious material. Further addition of nano silica decreases the mechanical properties of concrete.
3. Concrete containing nano silica increases compressive strength by 19.30% and 7.23% for M60 & M80 concrete, tensile strength by 38.34% and 20.36% for M60 & M80 concreteand flexural strength by 33.21% and 19.26% for M60 and M80 concrete respectively.

Deepika Rana, Dr. G. P. Khare, Mr. Dushyant Sahu (January, 2018), investigated compressive strength and workability of M20 and M30 grade of concrete using nano silica (0%, 0.5%, 1.5%, 2% and 2.5%) as a partial replacement of cement. The results of investigation can be summarized as follows:

1. Workability of concrete with partial replacement of nano silica decreases with increase in amount of nano silica.
2. Concrete with partial replacement of cement with 2% of nano silica showed improved result than other mixes.
3. By partial replacement of nano silica, showed improved compressive strength than conventional concrete mix.

Saloma, Amrinsyah Nasution, Iswandi Imran, Mikrajuddin Abdullah (2015), investigated the effect of nano silica as a partial replacement of cement on durability properties of concrete. The purpose of this study was to investigate compressive strength and to check the durability properties of concrete by exposing it to sulphate attack by using nano silica as a partial replacement to cement. In this investigation, cement is partially replaced by nano silica by 10%. The results of investigation can be summarized as follows:

1. Nano silica is capable of improving performance of concrete.
2. Replacement of 10% nano silica with cement showed better resistance to sulphate attack than normal concrete.
3. By partial replacement of nano silica with cement showed 20% increase in compressive strength, tested as the age of days.

4. MATERIAL PROPERTIES

4.1 Cement:

In this experimental work, ordinary Portland cement (53 grade) conforming to IS 8112:1989 was used. The cement was of Dalmia cement obtained from Diamond ready mix concrete plant. The properties of cement are given in table 4.1.

Table 4.1 Properties of cement

Sr. No.	Test Particulars	Results Obtained
1.	Specific Gravity	3.15
2.	Standard Consistency	28%
3.	Initial setting time	35 minutes
4.	Final setting time	540 minutes
5.	Fineness	3%
6.	Soundness	4 mm
7.	Compressive strength (3Days)	36 MPa
8.	Compressive strength (7Days)	48 MPa
9.	Compressive strength (28Days)	63 MPa

4.2 Sand:

In present study, crushed stone sand conforming to grading zone II of BIS 383:1970 was used as fine aggregate. The properties of sand are given in table 4.2.

Table 4.2 Properties of crushed stone sand

Sr. No.	Test Particulars	Values
1.	Fineness Modulus	2.92
2.	Specific Gravity	2.70
3.	Dry Rodded Bulk Density	1060 Kg/m^3
4.	Water Absorption	1%
5.	Void Content	27.40%

4.3 Coarse Aggregate:

In present study, crushed stone aggregate of 10 mm maximum size belonging to grading zone II were used as coarse aggregate. The properties of coarse aggregate are given in table 4.3.

Table 4.3 Properties of coarse aggregate

Sr. No.	Test Particulars	Values
1.	Grading Zone	II
2.	Specific Gravity	2.75
3.	Dry Rodded Bulk Density	1690 Kg/m^3
4.	Water Absorption	0.98%
5.	Aggregate Crushing Value	8.55%
6.	Aggregate Impact Value	6.20%
7.	Aggregate Abrasion Value	13.23%
8.	Flakiness Index	13%
9.	Elongation Index	0.08%

4.4 Water:

For the present investigation, potable water available at Diamond Ready Mix Concrete plant was used for mixing and curing of concrete.

4.5 Chemical Admixture:

For the present investigation, 'BASF Master Glenium 8522 SKY' polycarboxylic ether based superplasticizer conforming to IS 9103:1999 was used. The properties of BASF Master Glenium 8522 SKY are given in table 4.4.

Table 4.4 Properties of superplasticizer

Sr. No.	Property	Values
1.	Aspect	Reddish Brown Liquid
2.	Relative Density	1.10 ± 0.02 at 25°C
3.	pH	≥6 at 25°C
4.	Chloride ion content	< 0.2%

4.6 Nano Silica:

For the present investigation, powdered nano silica was used and their properties are given in table 4.5.

Table 4.5 Properties of nano silica

Sr. No.	Properties	Value
1.	Particle size	80 – 200 nm
2.	Specific gravity	1.3-1.35
3.	Specific surface area	190 – 200 m^2/gram

5. PLANNING FOR INVESTIGATION:

6.

Present investigation was designed to compare the workability and mechanical properties of concrete for M60 grade of concrete with partial replacement of cement with nano silica with various percentages such as 0%, 5%, 10%, 15%, 20% and 25%. The optimized value is determined for the investigation. Comparative study of nano concrete and normal concrete was carried out.

Table 5.1 Batches of concrete mix

Mix Designation	% nano silica replacement to cement
NS0	0%
NS05	5%
NS10	10%
NS15	15%
NS20	20%
NS25	25%

7. PROPOSED MIX DESIGN:

8.

Mix design was done as per ACI method for high strength concrete.

Table 6.1 Mix Proportion

Ingredients	Weight/m^3 of concrete (Kg)
Cementitious content	439.47
Sand	773.85
Coarse Aggregate	1098.5
Water	149.42
Superplasticizer	2.42

9. RESULT

Workability of concrete

Workability of fresh concrete was measured by slump cone test and it is described below:

Table 7.1 Slump cone test results

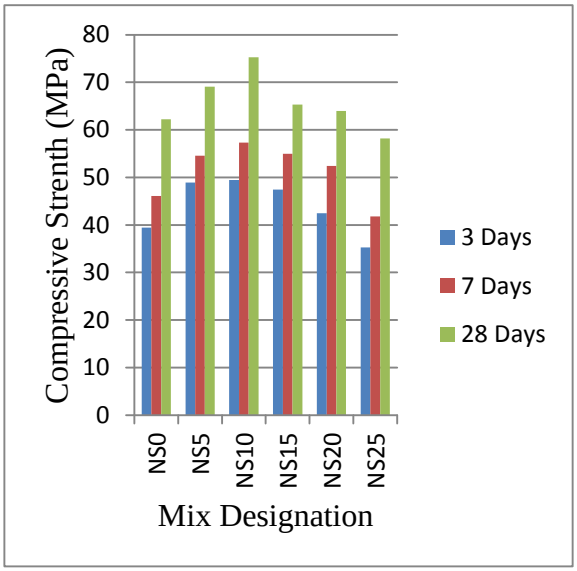
Sr. No.	Mix Designation	Slump (mm)	Density (Kg/m^3)
1.	NS00	74	2666.67
2.	NS05	68	270.22
3.	NS10	61	2725.92
4.	NS15	55	2731.82
5.	NS20	49	2743.7
6.	NS25	41	2746.67

Compressive strength of concrete

The compressive strength test was carried out with 150 mm x 150 mm x 150 mm cube specimens as per IS 516:1959 specifications. For each trial mix combination, three cubes were tested at the age of 3, 7 and 28 days of curing using compression testing machine of 2000 KN capacity.

Table 7.2 Compressive strength test results

Sr. No.	Mix Designation	Compressive Strength (N/mm^2)		
		3 Days	7 Days	28 Days
1.	NS00	39.41	46.07	62.22
2.	NS05	48.89	54.45	69.11
3.	NS10	49.48	57.33	75.26
4.	NS15	46.41	54.96	65.33
5.	NS20	42.45	52.44	64
6.	NS25	35.26	41.78	58.22



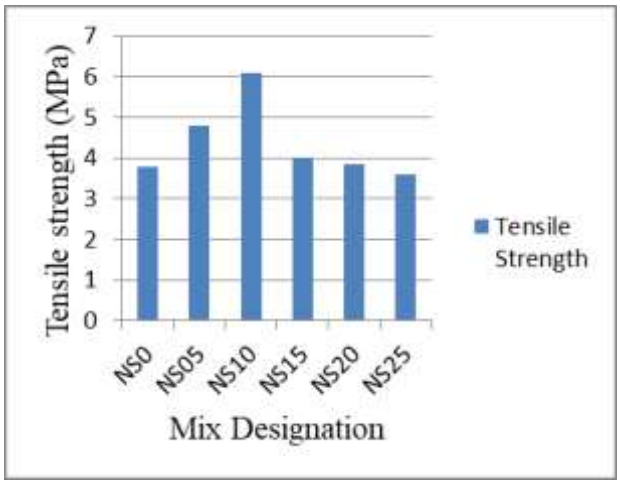
Graph 7.1 Results of compressive strength

Split-tensile strength of concrete

The splitting tensile strength of concrete was determined at the age of 28 days of curing using 150 mm diameter and 300 high cylinders as per IS 10086:1982.

Table 7.3 Splitting tensile strength test results

Sr. No.	Mix Designation	Tensile strength (N/mm²)
1.	NS00	3.80
2.	NS05	4.81
3.	NS10	6.10
4.	NS15	4.02
5.	NS20	3.86
6.	NS25	3.61



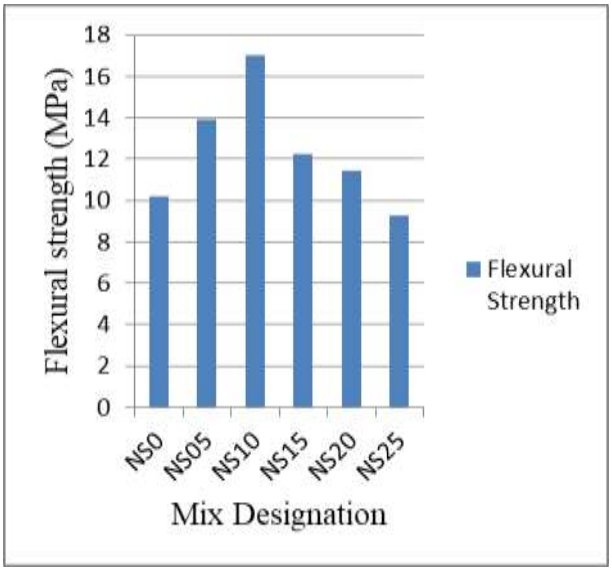
Graph 7.2 Results of split tensile strength

Flexural strength

The flexural strength of concrete was determined as per IS 516:1959 specifications at the age of 28 days using universal testing machine. For each trial mix, 3 beams were tested, each of 700 mm x 150 mm x 150 mm, to determine the flexural strength of concrete. The specimen was subjected to two point loading with necessary support conditions.

Table 7.4 Flexural strength test results

Sr. No.	Mix Designation	Flexural strength (N/mm²)
1.	NS00	10.21
2.	NS05	13.89
3.	NS10	17
4.	NS15	12.22
5.	NS20	11.45
6.	NS25	9.26



Graph 7.3 Results of flexural strength

10. CONCLUSIONS

- The workability of concrete with partial replacement nano silica decreases by increase in amount of nano silica.
- Optimum dosage of nano silica was 10%, which resulted in better performance than other combinations or mixes.
- Increase in density of approximately 2.22% was observed upon addition of 10% nano silica due to higher specific surface area and particle packing capacity.
- The percentage increase in compressive strength for 10% replacement of cement with nano silica was observed to be increased by 20.95% as compared to strength obtained from normal high strength concrete.
- The percentage increase in splitting tensile strength for 10% replacement of cement with nano silica was observed to be increased by 60.52% as compared to strength obtained from normal high strength concrete.
- The percentage increase in flexural strength for 10% replacement of cement with nano silica was observed to be increased by 66.50% as compared to strength obtained from normal high strength concrete.

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