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An Experimental Study on Strength Characteristics of High Strength Concrete Blended with Nano Silica and Slag Sand

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Abstract:

The basic concept behind using this material is to improve characteristic strength and durability characteristics of concrete at early ages, improves hydration characteristics and reduces the porosity of concrete. The water absorption in the concrete mix when compared with the conventional cementitious material. The disposal of fly ash has become a considerable environmental problem, because it as a waste material may cause substantial environmental hazards. To increase the usage rate, large quantities of fly ash are proposed to be incorporated in the structural and paving concrete mixes. Nanosilica is a new material and is also known to promote concrete behavior and the size of nano silica is 49.7nm. Here we are adding Nano silica to a certain percentage for increasing the strength and durability characteristics in concrete and by improving the crack resistance, ductility and energy absorption characteristics. Slag sand is considered as one of the waste materials which can have a promising future in the construction industry as a partial or full substitute of conventional sand. For each ton of steel production, about 2.2 tonnes of slag is generated. The main aim of this project is to investigate the possible effects of nano silica on strength characteristics of concrete by partially replacing the cement with nano silica with 0, 5, 10,15 and 20% by weight of cement and fine aggregate with slag sand respectively for M60 grade concrete.

Keywords: Nano Silica, Slag Sand, Strength, Cement, Concrete.

1. Introduction

1.1 General:

The uses of industrial waste as a substitute material helps save a large share of natural resources and protect the environment. Recycling or reuse of industrial by-products and wastes is economically and/or ecologically very important. The aggregates typically account for 70–80% of the concrete volume and play a substantial role in different concrete properties such as workability, strength, dimensional stability and durability. Aggregates are usually obtained from natural rocks, either crushed stones or natural gravels. According to some estimates after the year 2010, the global concrete industry will require annually 8 to 12 billions metric tons of natural aggregates .During the past 25 years, the production of crushed stone has increased at an average annual rate of about 3.3 percent.

1.2 Objectives of Research:

The main objectives of the present study are as below:

To study the effect of Nano Silica replacing Cement by 0%,5%,10%,15%,20% on

1. Compressive Strength of Concrete
2. Split Tensile Strength of Concrete
3. Flexural Strength of Concrete
4. Workability of Concrete.

2.Review of Literature

1**.** Maheswaran S et al.(2012) conducted a study on ”The Influence Of Nano Silica In Concrete And A Research Initiative”. This paper shows the influence of nano silica on the properties of the concrete. Nano science and technology is a new field of emergence in materials science and engineering, which forms the basis for evolution of novel technological materials. Nano technology finds application in various fields of science and technology. This article

presents a critical review of the literature on the influence of nano silica in concrete and its application for the development of sustainable materials in the construction industry and to study the pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects. Thus, there is a scope for development of crack free concrete towards sustainable construction.

2. SreeKrishnaPerumal Thanga Ramesh et al.(2013) conducted a study on "Use of furnace slag and welding slag as replacement for sand in concrete". In this project, a study was made to obtain low cost building materials using industrial wastes (welding and furnace slags). The objective of the study is to use these wastes in low-cost construction with adequate compressive strength. Different fine aggregate replacements have been studied by substituting 5%, 10%, and 15% of slag. The waste material was substituted for replacement of fine aggregates and for the preparation of concrete blocks. The preliminary studies were conducted by mixing the slag with the cement concrete cubes of standard sizes. The building material specimens were analyzed for compressive strength as per IS codes.

3. Bibhuti Bhusan Mukherjee et al.(2014) conducted a study on "Influence of Nano-Silica on the properties of recycled aggregate concrete". This paper shows the effect of incorporation of colloidal Nano-Silica on the behavior of concrete containing 100%recycled coarse aggregate. In this study, concrete mixes containing both natural and recycled aggregate are produced by replacing a fraction of Portland cement 0.75%, 1.5% and 3% of colloidal Nano-Silica respectively. The results of the experimental investigation depict that compressive strength, tensile strength and Non-Destructive parameters are enhanced due to addition of NS. Moreover, the study reveals that the characteristics of recycled aggregate concrete resembles that of natural aggregate concrete with the addition of little (3%) of Nano-Silica.

4. A. Narender Reddy et al.(2017) conducted a study on "Performance Of Nano Silica Concrete" .This paper provides an overall review of the influence of Nano-Silica in concrete and its applications for sustainable development. Limited work has so far been done incorporating Nano silica (NS) in concrete. This review presents the influence of Nano silica in concrete, its pore filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects.

5. İsa Yüksel et al.(2017) conducted a study on "Review of steel slag usage in construction industry for sustainable development". This paper reviews utilization of steel slag (SS) in the construction industry by considering current and possible future utilization fields, advantages of SS usage, and problems associated with its use. Strength and durability evolution of concretes or mortars containing SS in different ratios as aggregate or cement replacement material, combined use of ground granulated blast furnace slag with SS, and some relatively new fields of utilization of SS are also addressed. Improvements in and results of SS utilization in cement and concrete are discussed by addressing its beneficial effects. This article could help researchers to understand the recent developments in evaluation of SS in the construction Industry. 3.Experimental Work 3.1Materials:

❖**Ordinary Portland Cement:**

Ordinary Portland Cement (OPC) of grade 53 was used throughout the course of investigation. Necessary precautions were taken to ensure that the cement is fresh and without any lumps. Cement was tested to determine its physical properties such as specific gravity, fineness etc. Measures were taken to store the cement properly in order to prevent deterioration of its properties due to contact with moisture.

❖ **Fine Aggregate:**

Slag Sand is used as fine aggregate . The solid material which is generated by the interaction of impurities and flux during the making and refining of steels is called steel slag. Slag Sand is ecofriendly and economically liable.Various tests like Specific gravity , Bulking ofsand ,Sieve Analysis were conducted to determine it's properties.

❖ **Coarse Aggregates:**

Coarse aggregate passing through 20mm nominal size sieve and 12mm size sieve was used in this study. Sieve analysis was conducted to opt the oarse aggregate sample. Coarse aggregates were

subjected to various experiments to determine the water absorption of coarse aggregate, specific gravity, and bulk density etc. The results obtained were within the range of Indian standards.

❖ **Water:**

Water is an important and the least expensive ingredient used in concrete. A percentage of water used is utilized in the hydration process of cement to form the binding matrix in which the inert aggregates are held in suspension until the matrix hardens. If water is fit for drinking it is fit for making concrete. Water would be compared with similar concrete made with pure water. If the pH value of water lies between 6 - 8 and water is free from organic matter, then it is acceptable to use in mixing of concrete. In the present investigation, tap water is used for both mixing and curing purposes.

3.2 Mineral admixtures.

Nano Silica:

Nano-silica is a white soft and fluffy powder containing amorphous SiO2. Effect of Nano Silica replacing Cement by 0%, 5% , 10% ,15% , 20% had been studied.

3.3 Chemical Admixture:

A. Super Plasticizer:

Super Plasticizer named FOSROC (Water Reducing Chemical Admixture) is added Superplasticizers (SPs), also known as high range water reducers, are additives used in making high strength concrete. Plasticizers are chemical compounds that enable the production of Concrete with approximately 15% less water content. Superplasticizers allow reduction in water content by 30% or more.

3.4 Mix proportions: Mix proportion of different ingredients of Concrete used in the present study is as per the Table below.

Materials	Units	0%	5%	10%	15%	20%
Cement	Kg	33	31.35	30	28	26
Fine Aggregate (Slag Sand)	Kg	67	67	67	67	67
Coarse Aggregate	Kg	95	95	95	95	95
Water	Litres	12	11	10.5	10	9.1
Nano Silica	Kg	0	1.65	3	5	7
Chemical Admixture	millilitres	328	313	300	280	260

3.5 Testing methods

3.5.1. Compressive Strength test:

Cubes of size 150mm X 150mm X 50mm were casted for determination of compressive strength under different percentages. Total number of 30 specimens were casted for testing at each selected age. Cubes are taken out of the curing tanks and dried before testing. Grit is wiped off from the specimen. Cube specimens are placed in the machine in a manner that the load is applied to the opposite side of casted surface. The axis of the specimen shall be carefully aligned with the center of thrust of the spherically seated platen. No packing shall be used between the faces of the test specimen and the steel platen of the testing machine. The load is applied without shock and increases continuously at a rate of approximately 70kN/min specified in IS: 516 - 1959 until the resistance of specimen increases load, breakdown and no greater load can be sustained. The maximum load applied to the specimen then recorded and the appearance of the concrete and any unusual feature to the type of failure is noted.

3.5.2 Split Tensile Strength:

Determination of split tensile strength of Concrete was carried out by casting cylindrical specimens of size 150mm X 300mm.Total no. of 30 specimens were casted with different percentages of Nano Silica to conduct testing at each selected age. The

split tensile test is a well-known indirect test used for determining the tensile strength of concrete. This test is performed on cylinders by splitting.

3.5.3 Flexural Strength Test:

Determination of flexural strength of Concrete was carried out by casting beams of size 500mm X 100mmx100mm.Total no. of 30 specimens were casted with different percentages of Nano Silica to conduct testing at each selected age. It evaluates the tensile strength of concrete indirectly. Both Center Point Load Test and 2 Point Load Test are conducted to determine Modulus of Rupture. The test should be conducted on the specimen immediately after taken out of the curing condition so as to prevent surface drying which decline flexural strength. Place the specimen on the loading points. The hand finished surface of the specimen should not be in contact with loading points. This will ensure an acceptable contact between the specimen and loading points. Center the loading system in relation to the applied force. Bring the block applying force in contact with the specimen surface at the loading points. Load the specimen continuously without shock till the point of failure at a constant rate (Indian standard specified loading rate of 400 Kg/min for 150mm specimen and 180kg/min for 100mm specimen.

4 Test Result and Discussions

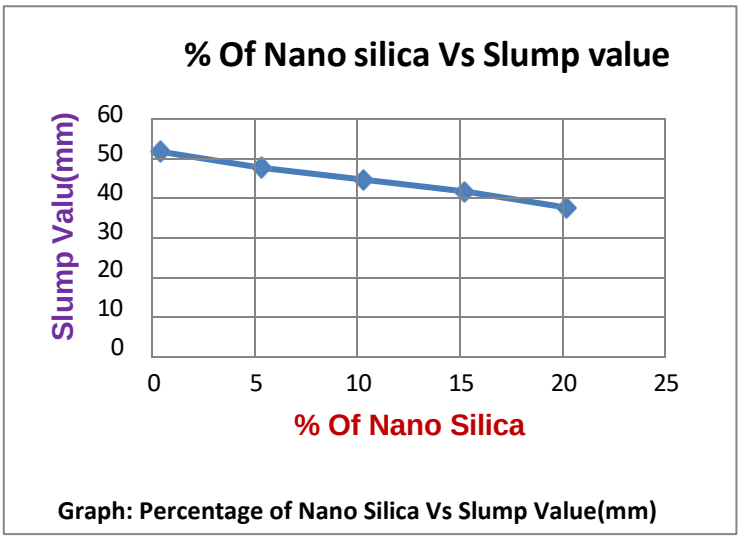
4.1. Workability:

4.1.1 Slump Cone Test:

The shape of the concrete slump determines the workability and quality of concrete.

Slump test:

% Of Nano Silica	Slump Value(mm)
0%	53
5%	49
10%	46
15%	43
20%	39



Graph: Percentage of Nano Silica Vs Slump Value(mm)

VARIATION OF SLUMP VALUE AT DIFFERENT PERCENTAGE OF NANO SILICA: From the above test results, it is observed that the Slump Value decreases as percentage of Nano silica replacing cement increases. However, the Workability is decreased with increase in percentage of Nano silica from 0%to20% of partial replacement of cement by weight.

4.1.2 Compaction Factor Test:

Compaction factor test is a laboratory test carried out to find the workability of concrete. The compaction factor is the ratio of weight of partially compacted concrete to weight of fully compacted concrete.

4.1.3 Compressive strength:

To study the effect on compressive strength, 30 cubes (each of size 150mm x 150mm x 150mm) are casted for calculated material weight for different percentage of Nano Silica and tested at 3,7, 28 days.

4.1.4 Split tensile strength:

To study the effect of tensile strength, 30 cylinders (size 150mm x 300mm) each for calculated material weight for different percentage of Nano silica were casted and tested at 3,7, and 28 days.

4.1.5 Flexural strength:

To study the effect on flexural strength, 30 beams (each of size 500mm x 100mm x 100mm) are casted for calculated material weight for different percentage of Nano Silica and tested at 3,7, 28 days.

Conclusion:

The present study was undertaken to investigate the Strength and Workability characteristics of concrete cubes ,cylinders and beams containing different percentages of Nano Silica replacing Cement. Cubes, cylinders and beams were tested at 3 days, 7 days and 28 days.

On the basis of the present study, following conclusions are: -

1. **From Workability tests following inferences can be made with respect to Workability:**

- Slump Value obtained in Slump cone test is gradually decreasing from 0%- 20%, which means Workability also decreasing from 0%-20% of percentage partial replacement of Cement by Nanosilica.
- Compaction Factor obtained in Compaction test is gradually decreasing from 0%- 20%,which means Workability also decreasing from 0%-20% of Nanosilica replacing Cement.
- Vee Bee Time obtained in Vee Bee Consistometer test is gradually increasing from 0%-20%, which means Workability is decreasing from 0%-20% of Nanosilica replacing Cement.

2.Following inferences can be made from 0% Mix i.e; Concrete in which fine aggregate is replaced with Slag Sand completely

- Compressive Strength of concrete at 28 days attained is 69.32N/mm2 which is greater than Characteristic compressive strength(60N/mm2) and Target Mean strength (68.25N/mm2).
- Split Tensile Strength of Concrete at 28 days attained is 4.13N/mm2 which is greater than that calculated using formula (fcts = 0.5*(fck)0.5 = 3.87 N/mm2).
- Flexural Strength of Concrete at 28 days attained is 5.3N/mm2 which is greater than that calculated using formula (fct = 0.64*(fck)0.5 = 4.95 N/mm2).

3.**Following inferences can be made with respect to strength characteristics of concrete:**

By the partial replacement of Cement with Nano Silica, with increase in percentage of Nano silica from 0%-15%.

- Compressive Strength of Concrete is increased from 69.32N/mm2 to 74.6N/mm2 .
- Split Tensile Strength of Concrete is increased from 4.13N/mm2 to 4.95N/mm2.
- Flexural Strength of Concrete is increased from 5.3N/mm2 to 8.22N/mm2.
- With increase in % of Nano silica beyond 15%,i.e; at 20% Compressive strength, tensile strength, and flexural strength of concrete are decreased.
- **Optimum percentage replacement of Cement by Nanosilica is 15% as we can attain maximum Compressive, tensile and flexural strength of concrete.**

References:

[1] IS 10262 (2009): Guidelines for concrete mix design proportioning is used as a reference

[2] Is 456-2000 Plain and Reinforced Concrete – Code of Practice is an Indian Standard code of practicefor general structural use of plain and reinforced concrete is used as a reference

[3] IS 383 : 2016. Coarse and Fine Aggregate for

Concrete - Specification is used as a reference

[4] We used the following references to conduct laboratory tests to determine the properties of various ingredients of Concrete. IS: 2720-part 3 is used as the reference to find specific gravity of cement.

[5] IS:4031 Part-1 1996 is used as the reference to find fineness of cement.

[6] IS:4031-Part 4 1988 is used as reference to find Normal consistency of cement.

[7] IS:4031 Part 5 1988 is used as reference to find setting time of cement.

[8] IS:4031 Part 3 1988 is used as reference to find Soundness of cement.

[9] IS:1199 1959 –Methods of sampling and analysis of concrete-Workability tests

[10] IS:2386- part- 3(1963) is used as reference to find specific gravity, water Absorption, Bulk density.

[11] IS: 2386- part- 1(1963) is used as reference for sieve analysis, flakiness and elongation Index

[12] IS:516 1959 – Method of tests for strength of concrete.