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An Experimental Study on High Performance Concrete Containing Nano Silica as a Partial Replacement of Cement and Manufactured Sand as Fine Aggregate

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Abstract - *In recent day the demand of river sand is increasing due to its lesser availability. Because of excessive sand mining from river cause the degradation of riverbeds and affect environmental therefore river mining is restricted in some area. Hence replacing of river sand with manufacture sand (M sand) is taking economical and environment advantages. And some research mentioned that Nano silica used as replacement of cement to produce the high-performance concrete. Because of nano silica act as pozzolan when added to the concrete so that to accelerate the hydration process and mechanical properties of concrete can be increase. And also, nano silica is fine material therefore due to its fineness stiffness, strength and durability improve. For this purpose, an experimental study on high performance concrete carried out by nano silica as partial replacement to cement in proportion of 0% ,1%, 2%. And manufactured sand as partial replacement to natural sand in proportion of 0%, 25%, 50%. therefore, high performance concrete compressive strength, split tensile strength, flexural strength test is conduct at 7,28 days and various durability test are conduct at 56 days.*

Key Words: High Performance Concrete, Nano Silica, M Sand, Compressive Strength, Durability

1. INTRODUCTION

Concrete has played a critical role in the evolution of human civilization. With the advancement of human civilization, it is widely assumed that concrete will continue to be the most common building material in the future. A combination of concrete with high toughness and strength is referred to as high performance concrete. Sand is used to make two of the most popular building materials: cement concrete and mortar. The indiscriminate mining of sand from riverbeds poses a significant danger to the ecosystem, resulting in riverbed and bank degradation, landslides, the loss of vegetation along riverbanks, and the lowering of the underground water table, among other things. As a result, manufactured sand, which is made by crushing rocks, is gaining popularity as a viable alternative to river sand. To manufacture high-performance concrete, nano silica was used in place of cement for strength and durability. As nano silica is applied to concrete, it acts as a pozzolan, speeding up the hydration process and improving the mechanical properties. To compensate for the disadvantages of pozzolans, nanomaterials are currently being researched. They can be used as a binder.

The work technique is characterized by the experimentation of required tests on the material prior to concrete casting. Various concrete test methodologies, such as fresh concrete and hardened concrete, are defined in accordance with IS standards. Various properties of the ingredients of any concrete work should be measured according to specifications. Until performing concrete mix design, various test procedures such as cement setting time, aggregate sieve analysis, aggregate specific gravity, water absorption, and fineness modulus are measured and used. Mix design should be carried out after the basic tests have been completed per IS:10262-2019.

High performance concrete Applications:
High strength and better durability characteristics of High-Performance Concrete have already been utilized in many structural applications. Some of the applications of High-Performance Concrete are:

- Bridges
- High rise buildings
- Tunnels
- Pavements
- Nuclear structures
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Nano silica average particle size is 12nm used and surface area of particle is 208m2/kg. Nano silica is product of AEROSIL@200 tested according to ISO 9277, ISO787.

Table - 1: Physical Properties of Nano Silica

Physical value	Value
Colour	WHITE
Specific gravity	2.4
Surface area	208 m2/gm
Particle size	12 nm
Ph value	4.1
Bulk density	45

2. OBJECTIVES

- To evaluate the mechanical characteristics of HPC by incorporating M sand as replacement of fine aggregate and nano silica replacement of cement.
- To determine durability properties of HPC concrete with nano silica as replacement of cement and M sand as replacement of sand
- To determine the optimum level of nano silica replacement of cement and M sand as fine aggregate replacement.

3. BACKGROUND LITERATURE

According to this paper "Influence of different types of nano-sio2 particles on properties of high-performance concrete" by Alireza khaloo, Mohammad Hussein mobini uses of various nano-sio2 particles with different unique surface areas (200 and 380 m2 /g) and three different water to binder ratios (0.25, 0.30, and 0.35). highest compressive strength and split tensile strength was reached with the replacement of 1.5% Nano silica 200 m2/kg surface area.

According to this research paper "Effect of nano silica on durability and mechanical properties of high-strength concrete" by Prakasam Ganesh, avadhanam ramachandra murthy. the effect of nano silica particles on the mechanical properties and durability of two high-strength concrete (HSC) mixes was investigated in this research paper. Comparing the mechanical properties of HSC mixtures with 0%, 1% and 2% replacement of cement by nano silica, it was found that the properties increased with an increase in nano silica content for the same water to cement ratio.

According to this research paper "Strength and Durability Studies on High Performance Concrete with Manufactured Sand As Fine Aggregate by T. Shamuyarira, Dr.R.N. Uma. study that strength& durability of high-performance concrete by using locally available material with manufactured sand as fine aggregate and with 7.5% replacement of cement by silica fume. The aim of this study is to use engineered sand to replace natural sand in various percentages (0 percent, 20 percent, 40 percent, 60 percent, 80 percent and 100 percent).

The optimum percentage of natural sand replacement by M-Sand is 60% in presence of replacement of cement by 7.5% of silica fume for achieving maximum compressive, split tensile and flexural strength and showed higher values of acid resistance and sea water resistance.

4. MATERIAL

4.1 Cement

Ordinary Portland Cement (OPC) is the most widely used cement in the world for producing concrete, mortar etc. Ordinary Portland Cement has 3 grades based on its strength namely 33, 43 and 53 grade that indicates the compressive strength obtained after 28 days of setting.

4.2 Fine Aggregate (river sand)

River sand available from local sources with size of less than 4.75mm having a specific gravity is 2.62. and also conforming to IS 383:2016 was used as fine aggregate in this study.

4.3 Coarse Aggregate

Crushed aggregate available from local sources with size of 10mm and 20 mm having a specific gravity is respectively 2.96 and 2.89 and also conforming to IS 2386:1963 was used as coarse aggregate in this study.

4.4 Nano silica

Nano silica average particle size is 12nm used and surface area of particle is 208m2/kg. Nano silica is product of AEROSIL@200 tested according to ISO 9277, ISO787.

4.5 M sand

Manufactured sand is crushed fine aggregate produced from a crushing of rocks. Production generally involves crushing, screening and possibly washing. M sand available from local sources with size of less than 4.75mm having a specific gravity is 2.69. and also conforming to IS 383:2016 was used as fine aggregate in this study.

5. EXPERIMENTAL STUDY

5.1 Mix design

Mix design was done for M70 High performance concrete as per Indian standard IS10262:2019. Initially all material test were done then mix design calculation prepare. After various mix proportion created then various mechanical and durability test conducted.

Water	Cement	FA	CA	Total
138	522	724	1196	2577
0.27	1.00	1.39	2.30	

Table - 5.1: Mix Proportion for 1m^3

5.2 Testing of Specimens

Compressive strength was completed in accordance with IS 516-1959. The moulds of size having 150x150x150mm are used. Compaction is done either by mechanical vibrator or by hand tamping. Each layer of the concrete should be compacted well and the compaction should not be less than 35 strokes per layer using tamping road then test at 7 and 28 days in universal testing machine. The determination of tensile strength can be done by split tensile strength test of concrete. This test was done as per IS 5816-1999. A cylindrical mould of having standard size of 300mm length and 150mm diameter is used for the test. Specimen tested at 28 days in universal testing machine. The flexure strength test is the optimal tool for calculating tensile strength. the standard size of beam specimen is 150x150x700mm and tested at 28 days in universal testing

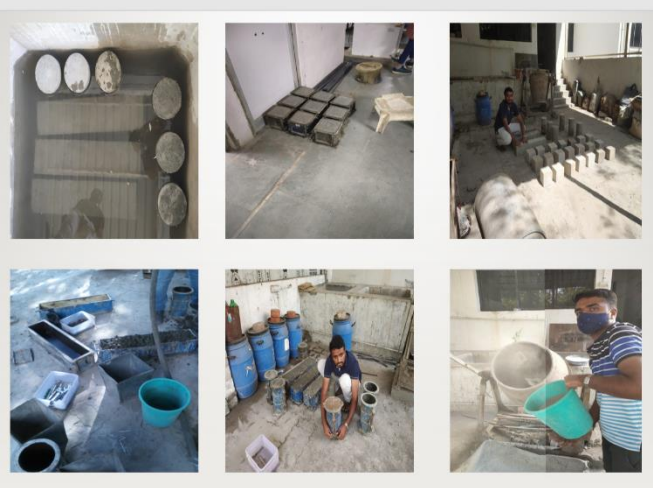


Fig-5.1 Casting Process

6. TEST RESULT AND DISCUSSION

6.1 Compressive Strength Test:

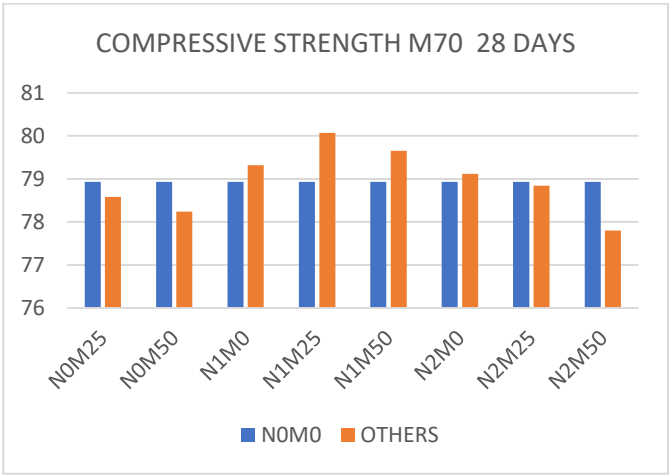
The Compressive Strength Test is used to determine the concrete's compressive strength. It was completed in accordance with IS 516-1959. The moulds of size having 150x150x150mm are used.

The compressive strength can be calculated as per the following formula.

Compressive Strength (MPa) = (Failure load) / (c/s area of cube specimen**)**

Table-6.1: Compressive Strength for M70 grade High performance Concrete

Nano silica (%)	M sand (%)	Avg Strength at 28 days
0	0	74.82
0	25	73.85
0	50	72.42
1	0	75.5
1	25	76.11
1	50	74.92
2	0	74.28
2	25	75.24
2	50	73.34



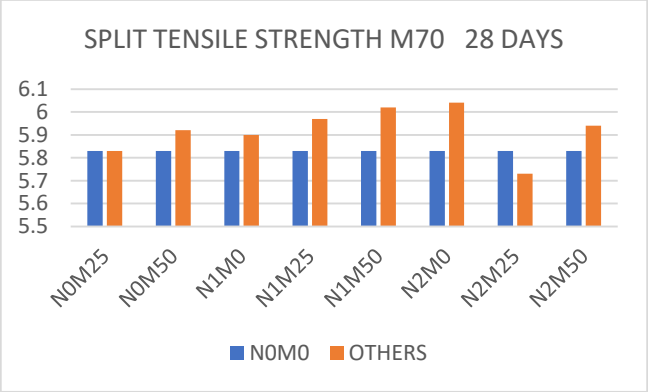
Charts-6.1: Compressive Strength of Cube

6.2 Split Tensile Strength Test

This test was done as per IS 5816-1999. A cylindrical mould of having standard size of 300mm length and 150mm diameter is used for the test. Specimen tested at 28 days in universal testing machine.

Table-6.2: Split Tensile Strength for M70 grade Concrete

Nano silica (%)	M sand (%)	Avg Strength at 28 days
0	0	5.83
0	25	5.86
0	50	5.92
1	0	5.90
1	25	5.97
1	50	6.02
2	0	6.04
2	25	5.73
2	50	5.94



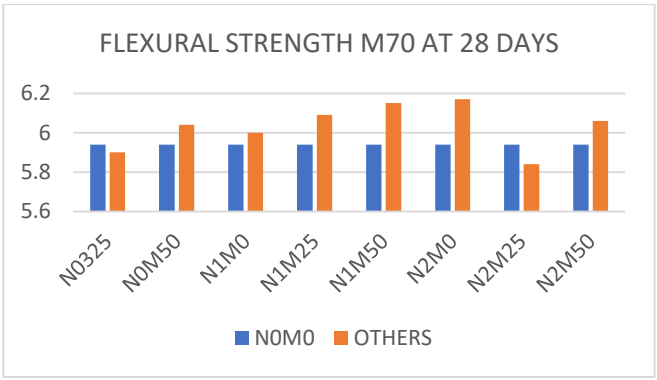
Charts-6.2: Split Tensile Strength of Cylinder

6.3 Flexural Test:

The flexure strength test is the optimal tool for calculating tensile strength. the standard size of beam specimen is 150x150x700mm and tested at 28 days in universal testing machine.

Table-6.3: Flexural Strength for M70 Grade Concrete

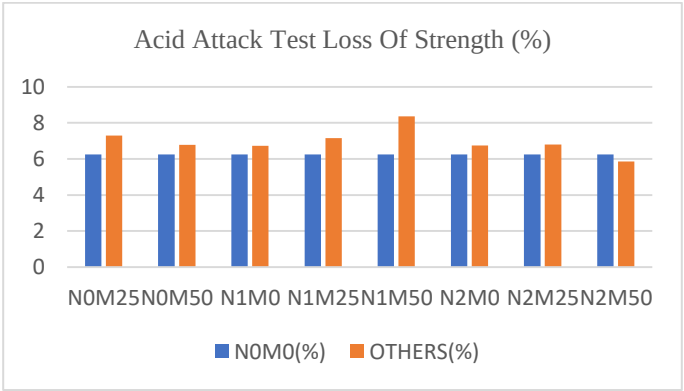
Nano silica (%)	M sand (%)	Avg Strength at 28 days
0	0	5.94
0	25	5.90
0	50	6.04
1	0	6.00
1	25	6.09
1	50	6.15
2	0	6.17
2	25	5.84
2	50	6.06



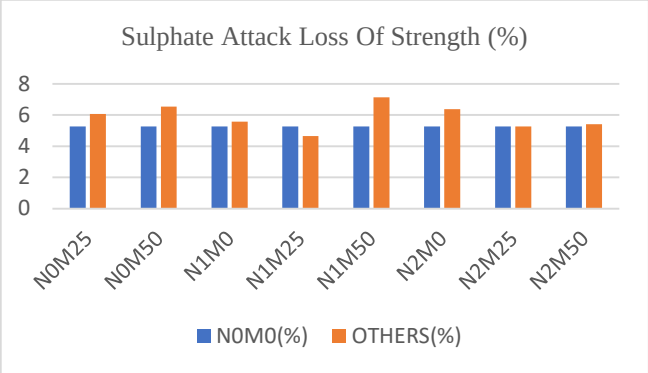
Charts-6.3: Flexural Strength of Beam

6.4 acid attack and sulphate attack test

The most significant characteristics of High-Performance Concrete are its superior toughness over standard concrete. The resistance of concrete to acid attack can be studied by determining the loss of compressive strength at 56 days or variation in compressive strength of concrete cubes after 28 days and at 56 days immersed in Sulphuric acid (H2SO4) and for sulphate attack in (Na2SO4).



Charts-6.4: acid attack test



Charts-6.5: sulphate attack test

Fig-6.1 Testing of Specimen

7. CONCLUSIONS

- The mechanical properties like compressive strength, flexural strength, and split tensile strength of M70 grade of concrete can also be achieved by using nano silica as replacement of cement and M sand as replacement of fine aggregate.
- For 1% nano silica and 25% M sand respectively replacement of cement and sand gives optimum dosage which gives 8% higher compressive strength than normal concrete.
- As per durability test result conclude that loss of compressive strength at 56 days maximum changes 8 % when 1% nano silica and 50% M sand replacement.
- As per cost comparison of concrete we can conclude that cost of 1 m3 concrete can saved upto 2.15% by replacing 50% M sand as fine aggregate.

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IS code:

Is 10262:2019 for mix design of high strength concrete

Is 2386:1963 method of test for aggregate for concrete