EFFECT OF NANO SILICA & OTHER INDUSTRIAL WASTES ON STRENGTH AND ECONOMY OF CONCRETE

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Abstract. The application of Nanotechnology in concrete has added a new dimension to improve its properties. Nano-materials, by virtue of their very small particle size can affect the concrete properties by altering the microstructure. In this study an attempt is made to analyze the effect of Nano-Silica on the strength of control concrete and replaced cement concrete. In replaced cement concrete, cement is partially replaced with the dolomite powder and fine aggregate with granite fine in different percentages. Workability and Strength tests were conducted on both the control concrete and concrete with Nano-Silica, dolomite and granite powder.

The replace percentage of dolomite powder 15% and 20% of granite fine gave good results, more than this percentage of mix the strength of concrete decreased. Nano-silica of different percentages 0%, 0.5%, 1%, 1.5%, 2%, 2.5% and 3% added to this selected mix (15% DP and 20% GP) and control concrete. The test results reveal that the replacement of Nano-silica from the replacement percentage of 0.5, the strength of concrete significantly increases with increasing percentage of Nano-silica upto 2.5%. The Cost of the replaced concrete increased as well as the strength also with reference to control concrete. However this is valid upto certain point, later the strength decreases with increase in cost.

1. Introduction
Concrete is the most commonly using material in present as well as in future. The wide use of concrete in structures, from buildings to factories, from bridges to airports, makes it one of the most investigated materials of the 21st century. Due to the rapid population explosion and the technology boom to cater to these needs, there is an urgent need to develop the strength and durability of concrete. Out of the different materials utilized within the generation of concrete, cement plays a major part due to its measure and cement property. So, to deliver concrete with progressed properties, the component of cement hydration needs to be considered properly and superior substitutes to it ought to be proposed. Distinctive materials known as supplementary cementitious materials or SCMs are included to concrete move forward its properties. Of the different advances in utilize, Nano-technology looks to be a promising approach in making strides the properties of concrete.

Nano-Materials
Nano-materials are very small sized materials with particle size in Nanometers. These materials are extremely useful in altering the properties of concrete at the ultrafine level by the virtue of their extremely small size. These Nano-materials improve the strength and permeability of concrete by filling up the minute voids and pores in the microstructure.

Nano-Silica
Nano-silica is a breakthrough in Nano materials that has been applied in ultra high performance concrete (UHPC). In general, Nano-silica was produced from micro based silica. The positive reactions created by Nano-silica in ultra-high performance concrete are similar to silica fume or micro silica which is in terms of performance strength and durability enhancement studies. Concrete with addition of Nano-silica gained early strength as compared to that of silica fume, and also the addition of Nano-silica in concrete improved workability of concrete while the addition of super plasticizers is
at a minimum dosage. About 20%–30% of cement content can be reduced by Nano-silica. However, the disadvantage of Nano-silica is its price and availability in certain countries. Some countries have to import Nano-silica to be used in concrete industry.

2. Literature Review
Upto now various admixtures are used in concrete to improve its strength and durability properties. In present investigation mineral admixtures such as Nano-silica, dolomite powder, and granite powder are used to study the strength properties of concrete. The following related information is base for this study.

Nadine Hani et.al. (2017) observed the effect of increasing water/binder ratio on the fresh and hardened properties of self-compacting concrete containing Nano-silica with different percentages. Selected 12 different mixes with different water binder ratios of 0.41, 0.45 and 0.5% and Nano-silica 0%,0.25%, 0.50% and 0.75% replaced by weight of cement. Tests were conducted on fresh and hardened properties of self-compacting concrete. Test results concluded that mixes with 0.75% Nano-silica compressive strength improved by 26.9%, 32.7% and 48.8% for w/b of 0.41, 0.45, and 0.5 respectively.

Qinyong Ma et.al. (2017) experimentally investigated the microstructure and compressive and tensile properties of Nano-silica concrete containing basalt fibers. Compressive, split tensile tests were conducted on mix with the addition of different percentages of Nano-silica and basalt fibers, 0, 0.6, 1.2, 1.8 percentages by weight of cement and 0 kg/m$^3$, 2kg/m$^3$, 3kg/m$^3$, 4kg/m$^3$, 5kg/m$^3$ by volume of concrete. Results concluded by Adding an appropriate amount of Nano-SiO2 and basalt fiber to concrete improves both its compressive strength and splitting tensile strength. The strength enhancement is greatest when the Nano-SiO2 and basalt fiber dosages are 1.2% and 3 kg/m$^3$, respectively, and the compressive strength and splitting tensile strength increased by 9.64% and 17.42%, respectively, compared with those of plain concrete.

Peng Zhang et.al. (2017) studied Application of Nano-SiO2 (NS) particles to reinforce high performance concrete (HPC). He mainly focused on Effect of Nano SiO2 on the fresh properties, microstructure, mechanical and durability properties of high performance concrete. The replacement of Nano-Silica in place of cement increases the compressive and flexural strength of concrete, setting time, durability properties of concrete. Finally, concluded replacement of Nano-Silica up to 5% increased fresh, mechanical and durability properties of HPC greatly.

Dr.G.PrinceArulraj et.al. (2013) experimentally investigated on the effect of granite powder partially replaced with sand by weight with different percentages 0, 5, 10, 15, 20 and 25%.on mix Compressive and split tensile tests were conducted. Tests results shown that is 15% replacement of granite powder gives a good results compared to other mixes.

Manasseh Joel et.al. (2010) Investigated the Suitability of Crushed granite fine (CGF) to replace river sand in concrete with different percentages 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100%. Slump, compressive and split tensile strength tests were conducted on fresh and hardened concrete for 7, 14, 28 days’. compressive and split tensile strength results 40.70N/mm$^2$ and 2.30N/mm$^2$at 28 days of respectively was obtained, with the partial replacement of river sand with 20% crushed granite fine, as against values of 35.00N/mm$^2$ and 1.75N/mm$^2$, obtained with the use of river sand as fine aggregate. Based on economic analysis and results of tests, river sand replaced with 20% crushed granite fine is recommended for use in the production of concrete for use in rigid pavement.
3. Materials and Methodology

Materials
In this present investigation materials like Cement, Nano-Silica, dolomite powder, granite powder and Coarse aggregate are used. The description of properties for each of these materials were evaluated in the following sections. The materials used in this experimental investigation are tested to obtain their properties as per the relevant Indian Standard Codes.

3.1 Cement
The cement used in this entire experimental investigation was commercially available Ordinary Portland cement (OPC) of 53 grade manufactured by Sagar cement company confirming to IS: 12269. Physical properties of cement tested are Normal consistency, fineness of cement, specific gravity, Initial and final setting times.

Results obtained for these tests are tabulated below:

| S.No | Characteristics       | Experimental values | As per IS: 4031 |
|------|-----------------------|---------------------|-----------------|
| 1    | Specific gravity      | 3.141               | 3.10 – 3.16     |
| 2    | Fineness of cement    | 3.356 %             | Less than 10%   |
| 3    | Normal consistency    | 32 %                | 30 – 35%        |
| 4    | Initial setting time  | 75 min              | Not less than 30 min |
| 5    | Final setting time    | 550 min             | Not more than 600 min |

3.2 Nano-Silica
Nano-Silica is one of the newest technologies in Nano process, it consumes calcium hydroxide during the pozzolanic reaction which has been used as an alternative to silica fume. Nano-Silica has large surface area and acts as good filler material in concrete. Nano-Silica increases the strength and durability of concrete.

| Test Items                    | Standard Requirements | Test Results |
|-------------------------------|-----------------------|--------------|
| Specific surface area         | 200+20                | 202          |
| PH value                      | 3.7 – 4.5             | 4.12         |
| Loss on drying @ 105°C (%)    | < 1.5                 | 0.47         |
| Loss on Ignition @ 100°C (%)  | < 2.0                 | 0.66         |
| Sieve Residue (%)             | < 0.04                | 0.02         |
| Tamped Density (g/l)          | 40 – 60               | 44           |
| SiO2 Content (%)              | ≥ 99.8                | 99.88        |
| Carbon Content (%)            | ≤ 0.15                | 0.06         |
| Chloride Content (%)          | ≤ 0.0202              | 0.009        |
| Al2O3                          | ≤ 0.03                | 0.005        |
| TiO2                          | ≤ 0.02                | 0.004        |
| Fe2O3                         | ≤ 0.003               | 0.001        |
| Specific Gravity              | 2.2 – 2.4 (GENERALISED) |            |
| Particle Size                 | 17 NANO               |              |
3.3 Dolomite Powder
Dolomite powder has some similar characteristics of cement. Usage of dolomite powder in concrete can reduce the cost of concrete and may increase the strength to some extent.

Table 3 Properties of dolomite powder

| S.No | Property   | Dolomite powder |
|------|------------|-----------------|
| 1    | Formula    | CaMg(CO₃)₂      |
| 2    | Specific gravity | 2.75-2.85 |
| 3    | Colour     | White           |
| 4    | Tenacity   | Brittle         |
| 5    | Moisture content | Nil   |
| 6    | Crystal system | Trigonal |
| 7    | Sieve analysis | Zone III |

3.4 River Sand
The sand used in this investigation for preparation of concrete samples is natural river sand conforming to grading zone-III as per IS: 383-1970 with specific gravity 2.488 and having fineness modulus as 3.096. The testing of sand is done as per IS: 2386 – 1963.

3.5 Granite Powder
Granite powder belongs to igneous rock family, obtained from the polishing unit of granite factories. Density of granite powder is between 2.64 to 2.75 g/cm³ and the compressive strength will be greater than 200Mpa. It is a waste material obtained during polishing process of granite rocks. This waste material is creating problems in the process of disposal and it creating environmental hazards.

Table 4 Properties of granite powder

| S.No | Properties      | Values          | Permissible limits as per IS 456 |
|------|-----------------|-----------------|----------------------------------|
| 1    | Specific gravity | 2.64            |                                  |
| 2    | Water absorption | 23%-25%         |                                  |
| 3    | Fineness        | 88%             | less than 10%                    |
| 4    | Chloride content | 0.0098%         | less than 0.025%                 |
| 5    | Sulphate content | 0.052%          | less than 0.2%                   |

3.6 Coarse Aggregate
Aggregates are the most important constituent in concrete. They aggregate to the concrete, reduce shrinkage and effort economy. The fact is that the aggregates occupy 70%-80% of the volume of concrete. Coarse aggregate available locally were used in casting of concrete cubes, cylinders. The aggregate used in this project mainly of gravel which comes under normal weight category 20 mm size aggregates were used for the entire work.

Table 5 Physical properties of coarse aggregates

| S.No | Characteristics | Experimental values | As per IS 4031 |
|------|-----------------|---------------------|----------------|
| 1    | Specific gravity | 2.967               | 2.5 to 3       |
| 2    | Water absorption | 1.80 %              |                 |
| 3    | Fineness modulus | 9.494               | Less than 10%  |

3.7 Water
Water should be free from acids, oils, alkalis, vegetables or other organic Impurities. Polluted water produces weaker concrete. Water has two functions in a concrete mix. Starting, it reacts chemically with the cement to form a cement paste in which the inert aggregates are mixed until the cement paste has hardened. Middle of the process, it serves as a vehicle or lubricant in the mixture of fine aggregates and cement.
3.8 Methodology
The test specimens were prepared and procedures adopted for the strength tests of concrete as per IS516-1959. Mix design for M30 has done as per IS10262-2009 for all the studies in this investigation.

3.8.1 Test Specimens for Compression and Tensile Test
The concrete cubes of size 150mm×150mm×150 mm were used as test specimens to determine the compressive strength. For split tensile strength cylinders of size 150mm diameter and 300mm height were used as test samples. The specimens were cast for M30 grade of concrete. The workability of fresh concrete was measured in terms of slump values by conducting slump cone test.

3.8.2 Mix Design
The Mix design was done by using IS 10262:2009 and was tabulated as follows:

| Water : | Cement : | F.A : | C.A |
|-------|---------|------|-----|
| 171   | 380     | 664  | 1242 |
| 0.45  | 1       | 1.74 | 3.2 |

4. Results and Discussions

4.1 Compressive Strength
Compressive strength values of the cube specimens were tested at 7, 14 and 28 days for all the mixes. It is observed that the compressive strength of concrete increased with a little percentage of Nano-Silica in mixes, Control Concrete and concrete with Dolomite and Granite powder. Upto 2.5% addition of Nano-Silica, compression strength values of concrete are increasing and beyond that the value gets decreased. At a percentage of dolomite powder (DP) 15% and granite powder (GP) 20%, the concrete gave good results.

| Control Concrete:
| Type of concrete | Compressive strength of control concrete |
|------------------|-----------------------------------------|
|                  | 7days | 14days | 28 days |
| Control concrete | 19.50 | 28.45  | 35.77   |

Concrete with Dolomite powder and Granite powder

Table 7. 28 Days Compressive Strength of Concrete with Dolomite and Granite Powder

| Granite powder percentage | 5% DP | 10% DP | 15% DP | 20% DP | 25% DP |
|---------------------------|-------|-------|--------|--------|--------|
| 0%                        | 30.9  | 32.8  | 35.9   | 31.3   | 29.3   |
| 10% GP                    | 33.2  | 35.2  | 38.5   | 34     | 31.8   |
| 15% GP                    | 35.2  | 37.2  | 39.8   | 34.3   | 33     |
| 20% GP                    | 37.8  | 39.6  | 41.8   | 37.2   | 35.5   |
| 25% GP                    | 33.4  | 35.8  | 37.3   | 33.9   | 31.6   |
| 30% GP                    | 30.4  | 33.9  | 36.1   | 32.9   | 30.1   |
It was found from the above table and figure that at 20% GP and 15% DP Concrete provided good results. These percentages were fixed for further investigations in concrete with and without Nano-silica.

Concrete with Nano-Silica

Table 8. 28 Days Compressive Strength of Concrete with & without Nano-silica

| Nano-Silica | Compressive Strength of Concrete N/mm² |
|-------------|---------------------------------------|
|             | Control Concrete | Concrete with Dolomite and Granite Powder |
| 0%          | 35.77            | 41.8                                      |
| 0.5%        | 37.78            | 43.9                                      |
| 1.0%        | 39.65            | 45.85                                     |
| 1.5%        | 41.85            | 46.92                                     |
| 2%          | 43.2             | 48.97                                     |
| 2.5%        | 45.56            | 50.70                                     |
| 3%          | 43.8             | 47.85                                     |

Figure 1. 28 Days Compressive Strength of Replaced Concrete

Figure 2. 28 Days Compressive Strength of Concrete with Nano-silica

28 Days Compressive Strength of Concrete
It was found from the above table that, with 20% GP, 15% DP and 2.5% Nano-Silica, Concrete provided good results.

4.2 Split Tensile Strength
Split Tensile strength of the cylinder specimens were tested at 7 and 28 days for all concrete mixes with Dolomite and Granite powder. It is also observed that the tensile strength of concrete increased with increasing percentage of Nano-Silica in both Control Concrete and concrete with Dolomite and Granite powder upto 2.5%.

Control Concrete

| Type of concrete | Split Tensile Strength of Concrete (N/mm²) |
|------------------|------------------------------------------|
|                  | 7 days | 28 days |
| Control Concrete | 2.30   | 3.85    |

Concrete with Dolomite powder and Granite powder

| Granite Powder percentage | 5% DP | 10% DP | 15% DP | 20% DP | 25% DP |
|---------------------------|-------|--------|--------|--------|--------|
| 0% GP                     | 2.89  | 3.35   | 3.65   | 3.12   | 2.96   |
| 10% GP                    | 3.20  | 3.52   | 3.87   | 3.30   | 3.12   |
| 15% GP                    | 3.42  | 3.82   | 4.20   | 3.75   | 3.59   |
| 20% GP                    | 3.76  | 4.25   | 4.59   | 3.97   | 3.69   |
| 25% GP                    | 3.15  | 3.60   | 3.89   | 3.42   | 3.19   |
| 30% GP                    | 2.81  | 3.29   | 3.62   | 3.16   | 2.87   |

Figure 3. 28 Days Split Tensile Strength of Concrete with Nano-silica
It was found from the above table that, at **20% GP and 15% DP** Concrete provided good results with respect to Split tensile strength also.

**Concrete with Nano-Silica**

| Nano-Silica Percentage | Control Concrete (N/mm²) | Concrete with Dolomite and Granite powder (N/mm²) |
|------------------------|--------------------------|--------------------------------------------------|
| 0%                     | 3.85                     | 4.59                                             |
| 0.5%                   | 3.97                     | 4.7                                              |
| 1.0%                   | 4.2                      | 5.12                                             |
| 1.5%                   | 4.6                      | 5.3                                              |
| 2%                     | 4.95                     | 5.57                                             |
| 2.5%                   | 5.6                      | **5.92**                                         |
| 3%                     | 5.1                      | 5.36                                             |

**Figure 4. 28 Days Split Tensile Strength of Concrete with Nano-Silica**

It was found from the above table that, with **20% GP, 15% DP and 2.5% Nano-Silica**, Concrete provided good results with respect to Split Tensile Strength also.
4.3 Economy

The variation of cost with variation of strength of the replaced concrete with reference to control concrete was presented below:

| Type of mix | Control concrete | 0.5% N.S | 1% N.S | 1.5% N.S | 2% N.S | 2.5% N.S | 3% N.S |
|-------------|------------------|----------|--------|----------|--------|----------|--------|
| Percentage of cost variation (increase) with control concrete | 0 | 7.68 | 15.36 | 23.04 | 30.73 | 38.42 | 46.06 |
| Percentage of strength variation (increase) with control concrete | 0 | 5.6 | 10.84 | 16.99 | 20.77 | 27.36 | 22.4 |

![Figure 5. Percentage of Strength Variation VS Cost Variation of Concrete with Nano-Silica with Reference to Control Concrete](image)

Table 12 Percentage of Strength Variation VS Cost Variation of Concrete with Nano-Silica with Reference to Control Concrete

| TYPE OF MIX | 15%DP+20%GP | 0.5%NS+15%DP+20%GP | 1%NS+15%DP+20%GP | 1.5%NS+15%DP+20%GP | 2%NS+15%DP+20%GP | 2.5%NS+15%DP+20%GP | 3%NS+15%DP+20%GP |
|-------------|-------------|-------------------|------------------|-------------------|------------------|------------------|------------------|
| Percentage of cost variation (increase) with control concrete | -8.16 | 0.48 | 7.22 | 11.57 | 22.5 | 30.25 | 37.93 |
| Percentage of strength variation (increase) with control concrete | 16.85 | 22.7 | 28.18 | 31.17 | 36.9 | 41.73 | 33.77 |
5. CONCLUSIONS

The following conclusions were made after carrying out test on four concrete mixes (Control Concrete, concrete with Dolomite and Granite powder, Control Concrete with Nano-Silica, Dolomite and Granite powder replaced concrete with Nano-Silica):

1. The test result of concrete with Dolomite and Granite powder with different percentages shows that, at replacement percentages of dolomite with 15% and granite with 20%, the compressive strength is increased by 16.85%.

2. The compressive strength of concrete with Dolomite and Granite powder of 15%, 20% and 2.5% of Nano-silica, is increased by 11.28%.

3. The test results of split tensile strength showed the same pattern as that of the compressive strength results i.e., at replacement percentages of dolomite with 15% and granite with 20%, the split tensile strength is increased by 19.22%.

4. It is observed that the split tensile strength of concrete with Dolomite and Granite powder of 15%, 20% and 2.5% of Nano-silica, is increased by 5.71%.

5. It is observed that the strength of concrete started increasing with just 0.5% replacement of cement with Nano-silica in the concrete mix.

6. As a result, the cost was found to be increased by 30.25% at (2.5%NS+...
15%DP+20%GP) for reaching Maximum Strength, but can be utilized in lesser percentages also based on the Economy and applications of Concrete.

6. REFERENCES

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