STUDY AND PERFORMANCE OF HIGH STRENGTH CONCRETE USING WITH NANO SILICA AND SILICA FUME

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ABSTRACT

Concrete is the most commonly used material in various types of construction, from the flooring of a hut to a multi-storied high-rise structure from pathway to an airport runway, from an underground tunnel and deep sea platform to high-rise chimneys and TV Towers. In the last millennium concrete has demanding requirements both in terms of technical performance and economy while greatly varying from architectural masterpieces to the simplest of utilities. It is difficult to point out another material of construction which is as versatile as concrete. Concrete is one of the versatile heterogeneous materials, civil engineering has ever known. With the advent of concrete civil engineering has touched the highest peak of technology. Concrete is a material with which any shape can be cast and with any strength. It is the material of choice where strength, performance, durability, impermeability, fire resistance and abrasion resistance are required. Cement concrete is one of the seemingly simple but actually complex materials. The properties of concrete mainly depend on the constituents used in concrete making. The main important materials used in making concrete are cement, sand, crushed stone and water. The properties of Cement, Sand, crushed stone and water influence the quality of concrete. In addition to these, workmanship, quality control and methods of placing also play the leading role on the properties of concrete. Compressive strength of concrete comes primarily from the hydration of alite and belite in Portland cement to form C-S-H gel. Alite hydrates rapidly to form C-S-H and is responsible for early strength gain; belite has a slower hydration rate and is responsible for the long-term strength improvements.

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1. BACKGROUND
In modern concrete technology, adding mineral admixtures to cement is a well-established practice. Mineral admixtures are added to concrete for various purposes such as:
- Improving compressive strengths at early ages
- Increasing durability of hardened concrete
- Enhancing mechanical properties of concrete
- Reducing heat generation and temperature rise of concrete for hot weather concreting. Producing greener concrete for environmental sustainability

2. HIGH STRENGTH CONCRETE
High strength concrete is used extensively throughout the world like in the oil, gas, nuclear and power industries are among the major uses. The application of such concrete is increasing day by day due to their superior structural performance, environmental friendliness and energy conserving implications. Apart from the usual risk of fire, these concretes are exposed to high temperatures and pressures for considerable periods of times in the above mentioned industries.

3. OBJECTIVES
The objectives of this research project are to study
- The projects deals with two concrete grades M 40, M 50.
- Effects of Silica Fume dosages on Compressive Strength, Tensile Strength, Flexural Strength of concrete
- Effect of combined application of Nano Silica and Silica Fumeon Compressive Strength, Tensile Strength, Flexural Strength of concrete
- Comparison of the test results of Conventional Concrete and Silica Fume concrete
- Comparison of the test results with Conventional Concrete and Nano Silica &Silica Fume concrete

4. SCOPE
- Dosages of the Silica Fume used are 5.0 % and 10 % of the total cementitious material.
- Dosages of the Nano Silica used are 1.5 % and 3% of the total cementitious material.
- Combined application of SF 5% + NS 1.5%, SF 10% + NS 1.5%& SF 5% + NS 3%, SF 10% + NS 3%

Properties of concretes and test methods are as follows for M40, M50 Grades
- Compressive Strengths of concrete at 3, 7, 28, 56 days
- Tensile Strength of concrete at 28 days
- Flexural Strength of concrete at 28 days
- Compressive Strength of Cylinders at 28 days
Effect of Silica Fume

Characteristics of Silica Fume
Silica fume is fine non-crystalline silica produced in electric arc furnaces as a by-product of the production of elemental silicon or alloys containing silicon (ACI 116R1 (2000)). Silica fume consists of spherical particles with mean size of about 100 nm which is about 100 times finer than Portland cement. It typically contains 85% or more silica (Fidjestol and Lewis 2003).

Mechanisms by which Silica Fume Improve Concrete Strength
Silica fume increases the compressive strength and durability of concrete (Grutzeck et al. 1982; Huang and Feldman 1985; Bentur et al. 1988; Mindess 1988; Godman and Bentur 1989; Gutteridge and Dalziel 1990; Goldman and Bentur 1994; Toutanji and El-Korchi 1995; Poon et al. 1999; Poon et al. 2000; Zelic et al. 2000; ACI 234R 2006; Kadri and Duval 2009) because of its physical and chemical effects together with microstructural modifications as follows:

From the physical point of view, fine particles of silica fume,
- Fill the spaces between cement grains and reduce bleeding to improve the packing of solid materials
- Provide heterogeneous nucleation sites to accelerate cement hydration.

From the chemical perspective, silica fume is a highly reactive pozzolanic material with high surface area and high amount of amorphous SiO2. It reacts chemically with CH from cement hydration at faster rates to form extra C-S-H compared with fly ash and slag.

From microstructural modification perspective, silica fume,
- Reduces the porosity of interfacial transition zone (ITZ) and accumulation of water under aggregate particles by its physical effect
- Reduces amount of CH in the ITZ by its chemical effect
- Induces a composite behaviour of aggregate and paste where aggregate acts as reinforcing filler due to the modification of ITZ.

Effect of Nano Silica on strength of Concrete

Characteristics of Nano-Silica
- Nano-silica is an amorphous material with particle size smaller than 100 nm (Sobolev and Gutierrez 2005; Campillo et al. 2007; Sanchez and Sobolev 2010), which is smaller than the mean size of silica fume. Literature reviewed in this section deals with NS with mean particle sizes ranged from 7 to 40 nm with about 99% SiO2.

Effect of Nano-Silica on Cement Paste, Mortar and Concrete
- In recent years effects of NS on the properties cement based materials have been investigated. Literature review indicates that NS can increase the strengths of cement pastes, mortars, and concretes more effectively than silica fume (Li 2004; Jo et al. 2007; Qing et al. 2007; Belkowitz and Armentrout 2009; Schoepfer and Maji 2009).
- In a comparative study, Qing et al. (2007) showed that compressive strengths of hardened cement pastes were increased with increasing amounts of the NS, and the pastes with NS had higher strengths than those with the same amount of silica fume, especially at early ages. For example, with the incorporation of 2% NS (mean particle...
size 15 nm) 3- and 28-day compressive strengths of cement pastes increased by 19 and 21%, respectively, whereas the same amount of silica fume (mean size 180 nm) did not increase the strengths significantly compared with those of control cement paste.

5. EXPERIMENTAL DETAILS

Materials

Concrete

- Concrete is a construction material composed of portland cement and water combined with sand, gravel, crushed stone, or other inert material such as expanded slag or vermiculite. The cement and water form a paste which hardens by chemical reaction into a strong, stone-like mass. The inert materials are called aggregates, and for economy no more cement paste is used than is necessary to coat all the aggregate surfaces and fill all the voids.
- The concrete paste is plastic and easily moulded into any form or troweled to produce a smooth surface. Hardening begins immediately, but precautions are taken, usually by covering, to avoid rapid loss of moisture since the presence of water is necessary to continue the chemical reaction and increase the strength. Too much water, however, produces a concrete that is porous and weak. The quality of the paste formed by the cement and water largely determines the character of the concrete. Proportioning of the ingredients of concrete is referred to as designing the mixture, produced as a dense mass which is practically artificial rock, and chemicals may be added to make it waterproof, or it can be made porous and highly permeable for such use as filter beds. An air-entraining chemical may be added to produce minute bubbles for porosity or light weight. Normally, the full hardening period of concrete is at least 7 days. The gradual increase in strength is due to the hydration of the tricalcium aluminates and silicates. The weight of concrete varies with the type and amount of rock and sand. Concrete is stronger in compression than in tension, and steel bar, called rebar or mesh is embedded in structural members to increase the tensile and flexural strengths. In addition to the structural uses, concrete is widely used in precast units such as block, tile, sewer, and water pipe, and ornamental products.

Silica Fume Properties and Reactions in Concrete

Silica fume affects both the fresh and hardened properties of concrete. The effects on concrete are a result of the physical and chemical properties of silica fume.

Chemical Properties

- Physical Properties
- Reactions in Concrete
- Comparison with Other Supplementary Cementitious Materials

Physical Properties of Silica Fume

- Particle size (typical): < 1 µm
- Bulk density
- (as-produced): 130 to 430 kg/m³
- (Densified): 480 to 720 kg/m³
- Specific Gravity: 2.6
• Specific Surface 15,000 to 30,000 m$^2$/kg

**Why Silica fume is used in Concrete?**

Silica fume is used in concrete because it significantly improves the properties of fresh and hardened concrete. The potential for the use of silica fume in concrete was known in the late 1940s, but the material did not become widely used until the development of another concrete technology.

This parallel technology is the use of powerful dispersants known as high-range water-reducing admixtures or super-plasticizers. Once these chemical admixtures became available and accepted, the use and development of silica fume in concrete became possible. Keep in mind that silica fume is a property enhancing material — it is not a replacement material for Portland cement.

Fly ash or ground granulated blast-furnace slag can be used as cement replacement materials. Note that these materials are frequently used in combination with Portland cement and silica fume.

**Silica Fume and Fresh Concrete**

- Increased Cohesion
- Reduced Bleeding

**Silica Fume and Hardened Concrete**

- Enhanced Mechanical Properties
- Reduced Permeability

**Nano Silica**

**Introduction**

Nanotechnology is the use of very small particles of material either by themselves or by their manipulation to create new large scale materials. The size of the particles, though, is very important because at the length scale of the nano-meter, 10-9m, the properties of the material actually become affected. The precise size at which these changes are manifested varies between materials, but is usually in the order of 100 nm or less.

As people involved in construction, we are very familiar with the concept of getting raw materials, bringing them together in an organized way and then putting them together into a recognizable form. The finished product is a passive machine that does not change or adapt to the surroundings or environment. It works and slowly decays as it is used and abused by the environment and the owners of the project. It gets periodic maintenance but its main goal is to survive the demands made of it until it becomes obsolete and then it is dismantled and discarded to make way for something new. This is our role in society and we have performed it well for hundreds or thousands of years. Construction then is definitely not a new science or technology and yet it has undergone great changes over its history. The industry we see today is the result of a progression in science, technology, process and business.

In the same vein, nanotechnology is not a new science and it is not a new technology either. It is rather an extension of the sciences and technologies that have already been in development for many years and it is the logical progression of the
work that has been done to examine the nature of our world at ever smaller and smaller scale.

**Nano Technology in Concrete**

Nano Technology applied to concrete includes the use of nanomaterials like nano silica, nano fibers etc. By adding the nanomaterials, concrete composites with superior properties can be reproduced. Addition of nano silica (nS) in concretes and mortars results in more efficient hydration of cement. Due to the pozzolanic activity, additional calcium silicate hydrates are formed to generate more strength and to reduce free calcium hydroxide.

This also helps in reducing the cement requirement, nS improves the microstructure and reduces the water permeability of concrete thus making it more durable. Use of nano silica in HPC and SCC improves the cohesiveness between the particles of concrete and reduces segregation and bleeding. Concretes with strengths as high as 100 MPa with high workability, anti-bleeding properties and short demoulding time can be produced. Nano silica can be used as an additive to eco concrete mixtures.

In the case of eco concrete mixtures, industrial wastes such as flyash, blast furnace slag are used as admixtures at certain percentages as replacement to cement. Certain problems like longer setting time, lower compressive strength at higher percentages can be overcome by adding nS which improves these properties. Condensed Silica fume (CSF) which is a by-product of metallurgical industries when used as a partial replacement to cement (optimum 10 to 15 percent) has been formed to contribute towards strength increase of concrete in addition to other beneficial properties.

### 6. RESULTS OF THE GENERAL OBSERVATIONS

**General Effect of Nano Silica**

With 0% nano silica the basic M40 concrete has given the design strength of 48.49 MPa at 28 days and with 5% Silica Fume the strength has gone up to 50.90 MPa and with 10% Silica Fume the strength has gone up to 54.90 MPa. To further increase the strength properties of concrete combination of nano silica with CSF is tried in the present project work. With 1.5% nano silica and 5% CSF the strength is going up to 56.10 MPa, with 1.5% nano silica and 10% CSF the strength is further going up to 58 MPa. Similarly With 3% nano silica and 5% CSF the strength is reduced to 53 MPa, with 3% nano silica and 10% CSF the strength is 55.30 MPa

![Figure 1 Variation of Cube Compressive Strength of M40 Grade Concrete with age for different percentages of Nano-Silica and 5% Micro-silica.](image-url)
Figure 2 Variation of Cube Compressive Strength of M40 Grade Concrete with age for different percentages of Nano-Silica and 10% Micro-silica.

Figure 3 Variation of 7 days Cube Compressive Strength of M40 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica

Figure 4 Variation of 28 days Cube Compressive Strength of M40 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica
Study and Performance of High Strength Concrete Using with Nano Silica and Silica Fume

Figure 5 Variation of Split Tensile Strength of M40 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica

Flexural Strength Results
With 0% nano silica and 0% CSF the basic M40 concrete has given design strength of 6.4 MPa at 28 days. With 5% Silica Fume the strength has gone up to 6.63 MPa and with 10% Silica Fume the strength has further gone up to 7.28 MPa. With 1.5% nano silica and 5% CSF the strength is going up to 7.41 MPa and with 1.5% nano silica and 10% CSF the strength is further going up to 7.62 MPa. Similarly, With 3% nano silica and 5% CSF the strength is reduced to 6.85 MPa, with 3% nano silica and 10% CSF the strength is 7.1 MPa.

Figure 6 Variation of Flexural Strength of M40 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica

General Effect of Nano Silica
With 0% nano silica the basic M50 concrete has given the design strength of 57.67 MPa at 28 days and with 5% Silica Fume the strength has gone up to 59.2 MPa and with 10% Silica Fume the strength has gone up to 54.90 MPa. To further increase the strength properties of concrete combination of nano silica with CSF is tried in the present project work. With 1.5% nano silica and 5% CSF the strength is going up to 56.10 MPa, with 1.5% nano silica and 10% CSF the strength is further going up to 58 MPa. Similarly, With 3% nano silica and 5% CSF the strength is reduced to 53 MPa, with 3% nano silica and 10% CSF the strength is 55.30 MPa.
Figure 7 Variation of Cube Compressive Strength of M50 Grade Concrete with age for different percentages of Nano-Silica and 5% Micro-silica.

Figure 8 Variation of Cube Compressive Strength of M50 Grade Concrete with age for different percentages of Nano-Silica and 10% Micro-silica.

Figure 9 Variation of 7 days Cube Compressive Strength of M50 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica.
Study and Performance of High Strength Concrete Using with Nano Silica and Silica Fume

Figure 10 Variation of 28 days Cube Compressive Strength of M50 Grade of Concrete with different percentages of Micro-Silica and Nano-Silica.

Split Tensile Strength Results
With 0% nano silica and 0% CSF the basic M50 concrete has given design strength of 4 MPa at 28 days. With 5% Silica Fume the strength has gone up-to 4.20MPa and with 10% Silica Fume the strength has further gone up to 4.38MPa. With 1.5% nano silica and 5% CSF the strength is going up to 4.45 MPa and with 1.5% nano silica and 10% CSF the strength is further going up to 4.56MPa. Similarly With 3% nano silica and 5% CSF the strength is reduced to 4.27 MPa, with 3% nano silica and 10% CSF the strength is 4.40 MPa.

Flexural Strength Results
With 0% nano silica and 0% CSF the basic M50 concrete has given design strength of 6.4 MPa at 28 days. With 5% Silica Fume the strength has gone up-to 6.63MPa and with 10% Silica Fume the strength has further gone up to 7.28MPa. With 1.5% nano silica and 5% CSF the strength is going up to 7.41 MPa and with 1.5% nano silica and 10% CSF the strength is further going up to 7.62MPa. Similarly With 3% nano silica and 5% CSF the strength is reduced to 6.85 MPa, with 3% nano silica and 10% CSF the strength is 7.1 MPa.
7. CONCLUSIONS

Based on the present experimental investigation, the following conclusions are drawn

1. While using the nano silica solution in concrete the original water cement ratio of concrete mix is to be corrected by the amount of water available in nano silica solution.

2. Cement replacement with 10% Silica Fume leads to increase in Compressive Strength, Split Tensile Strength and Flexural Strength.

3. For M40 Grade with Silica Fume 10% the percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength are 13.21%, 9.5% and 13.75% respectively

4. For M50 Grade with Silica Fume 10% the percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength are 6.46%, 4.62 % and 5.17 % respectively

5. There is an increase in Youngs Modulus of Concrete for M40 & M50 with Silica Fume 10% is 20.16% and 26.38% respectively higher than Conventional Concrete

6. 1.5 % nano silica appears to be the optimum in the Standard concrete mix like M40 without any admixtures. The highest compressive strength with 1.5 % nano silica and 10% CSF appears to be the optimum in the present blended concrete mixes.

7. For M40 Grade with Nano Silica 1.5% and Silica Fume 10% the percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength are 19.6 %, 14 % and 19.06 % respectively

8. For M50 Grade with Nano Silica 1.5% and Silica Fume 10% the percentage increase in Compressive Strength, Split Tensile Strength and Flexural Strength are 21.79 %, 15.19 % and 17.3 % respectively

9. There is an increase in Youngs Modulus of Concrete for M40 & M50 with Nano Silica 1.5% and Silica Fume 10% is 50.70 % and 58.88 % respectively higher than Conventional Concrete

10. The Compressive Strength of Cylinders for M40 & M50 with Silica Fume 10% is 17.14% and 11.07 % respectively higher than Convectional Concrete

11. There is an increase in Compressive Strength of Cylinders for M40 & M50 with Nano Silica 1.5% and Silica Fume 10% is 27.12 % and 24.91 % respectively higher than Conventional Concrete
REFERENCES


[7] Abdul Wahab, B. Dean Kumar, M. Bhaskar, S Vijaya Kumar, B.L.P. Swami “Concrete Composites With Nano Silica, Condensed Silica Fume And Fly Ash – Study of Strength Properties”


[11] Lewis RC. Ensuring long term durability with high performance micro silica concrete,


