Studies on Application and Effects of Silica Fume and Nano Silica on The Compressive Strength of Concrete

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***Abstract* - The application of nanotechnology in the concrete adds new efforts to improve its performance. Due to the very small size of nano materials, the properties of concrete can be influenced by changing its microstructure. The study involved the use of Silica fume (3%,6%,9%) and nano-silica (1%,2%,3%). As the percentage of Silica fume and nano silica increases, there is an increase in strength. The widespread use of concrete in structures, from buildings to factories, bridges and airports makes it one of the most searched materials. Due to rapid population explosion and the rise of technology to meet these needs, there is an urgent need to improve the strength and durability of the concrete. Among the various materials used in concrete production, cement plays an important role in the construction sector due to its size and adhesive properties. Consequently, to produce improved concrete, the cement humidification mechanism should be studied properly, and better alternatives should be proposed. In this study, the cement is replaced by silica fume and nano silica materials. We also determined the number of predictions of cubes in the program. This work explores the standard optimization ratio for silica fume and nano-silica to get the best compressive strength. Further to meet the Indian standards, all the concrete mixtures were tested. These tests include performing Slump and the Compressive strength test. 24 cubes were moulded for the compressive strength, and the curing ages of 7 and 28 days were applied in this work. The result proved an increase in compressive strength, durability, and various other properties of concrete by adding nano silica and silica fume in concrete.**

***Index Terms* - Silica fume, Nano silica, Concrete.**

I.INTRODUCTION

Concrete is a construction material constituted of cement, fine aggregates and coarse aggregates mixed with water. It has the ability to get cast in any form and shape. All the basic ingredients of concrete are of natural origin. But the properties of concrete can be changed by adding some distinctive natural or synthetic ingredients. Although concrete has a decent compressive strength, specific gravity, and durability, but it has some negative properties, like low tensile strength, lower impact strength, less resistance to cracking, heavy weight etc. Still concrete is better pick than any other accessible materials for civil engineering constructions. Some remedial measures can be taken to minimize these negative properties and for increasing compressive strength and other properties of concrete. Distinct materials are added to concrete in order to improve its properties and these materials are known as supplementary cementitious materials. A few of these are fly ash, rice husk, blast furnace, silica-fume, and nano silica, in which silica-fume and nano silica looks to be favourable approach in enhancing the properties of concrete.

1.2 Silica-Fume

Silica-fume, a derivative of silicon metal and ferrosilicon has one of the uttermost uses in concrete due to its chemical and physical properties. It is a highly dynamic volcanic ash. Concrete consisting silica fume can have very stout strength and can be extremely durable. Silicon powder which is available from concrete additive suppliers can be easily added during concrete manufacturing.

In the electric furnace silicon metals and alloys are manufactured. Quartz, coal, and wood chips are its raw materials. The fumes generated by the operation of the furnace are not collected in landfills but are collected and sold as silicon powder. Perhaps the most essential use of this material is as a mineral admixture in concrete.

Silica fume predominantly comprises of amorphous silica (SiO_2). The discrete particles are small, about 1/100th size of the ordinary cement particles. Because of the fine particles, high SiO_2 content and large surface area silica fume is a highly active volcanic ash in nature.

Silica fume for concrete can be supplied wet or dry. As shown, it is usually added during concrete production in a concrete plant. Silica-fume concrete has been effectively constructed in the dry batch plants and central / wet mixing plants. It is advantageous in all the aspects of silicon powder handling and is used to produce consistent superior concrete.

Figure 1.1 Image of silica fume

1.3 Effects of Silica-Fume in Concrete

Various types of cementitious materials have been used in construction practices. With the advent of ordinary Portland cement (OPC), construction activities have changed dramatically. However, due to some drawbacks and cost factors associated with the properties of cement and manufactured building materials using OPC, utilizing other materials for economic construction and improved mortar and concrete properties. In addition, various industrial activities generate a large amount of waste. At present, attempts are being made to use these wastes or industrial by-products in construction events to solve environmental pollution problems and safer, more economical construction. Silica fume is one such industrial by-product that is used and tested to obtain stronger and more durable concrete. It is one of the pozzolanas with very large surface area, which results in a superior and constant utilization of the

calcium hydroxide (Ca(OH)2) released during hydration of the OPC. Furthermore, because of its very fine size, it acts as a filler material between cement gel particles.

1.4 Effects of Silica-Fume on the Properties of Concrete

The effect of silica fume on the concrete mixing ratio were studied, and the experimental results of workability, compressive strength and permeability of concrete in different ratio were studied. It has been found that micro silica increases the process ability of fresh concrete until a certain limit of trace silica addition (up to 20%) is used as a cement substitute. The compressive strength also increases after the addition of the micro silica. The ultrasonic pulse rate result shows that UPV increases slightly during initial compression but decreases as the compressive load further increases. When the load reaches about 75-80% of the maximum strength, UPV drops sharply. From this study, it was found that the addition of a small amount of silica (up to 20%) to concrete reduces the permeability by 35% to concrete.

1.5 Effect of Silica fume on mechanical properties of Concrete

In the last few decades, the activities of the construction have increased over and over in almost all developing countries of the world. Due to the increasing demand of cement, it is becoming a scarce commodity worldwide. It takes an era to find the substitute materials so that it can partially or completely replace the cement that was used in concrete or mortar without influencing its quality, strength, or other properties. The use of supplemental cementations materials (SCM) or special materials is important for the development of low-cost structures. The addition of several pozzolanic materials can improve various properties of the concrete, i.e workability, durability, strength, crack resistance and permeability. Silicon smoke was known to improve the mechanical properties and durability of concrete. The main physical role of silica fume in concrete is the filler other than volcanic ash activity. Because of its fineness, it can adapt the space between the cement particles, as is the space between the sand-filled coarse aggregate particles and the cement particles. Due to the reactivity of silica fume, this highly reactive pozzolanic responds faster than the normal volcanic ash. The reason for same is high surface area and high content of amorphous silica present in the silica fume.

1.6 Nano-silica

Nano silica, a by-product which is produced by the production of iron-silicon alloys and silicon metal. The size of nano silica materials is very small such that the particle size 3 is in nanometre range. By changing the properties of concrete these materials are efficient by virtue of their minute size. The tinier the particle size the greater is the surface area. In simple the desired results can be achieved by replacing a small amount of cement. In conclusion, nano materials can enhance the strength and permeability of concrete by packing up the voids and pores in the microstructure.

Figure 1.2 Image of nano-silica.

With increase of nano silica in concrete mix there is an increase in the compressive and tensile strength of concrete. After the hydration, Nano silica mixed with cement can create nanocrystals of C-SH gel. These nano crystals acclimatize the pores of the cement concrete; therefore, it enhances the strength and permeability of the concrete.

1.7 The Effects of nano-silica addition on mortar and concrete properties

In particular, the practice in some special applications is characterized by the addition of amorphous microcrystalline silica, which also consists of high proportion of nano particles. Micro-silicon (MS) works at 2 different levels in cement-based systems. The first is the chemical effect and the pozzolanic reaction between silica and calcium hydroxide that forms additional C-S-H gel in the final step. The second function is physical because micro-silicon particles are about 100 times smaller than the cement. Micro silica can fill the residual voids, partially hydrated cement slurry and thus can increase their final density (Sakka and Kosuko, 2000). Several researchers (Qing et al., 2007; Dunster, 2009; L. Senff et al., 2009) have found that adding one kg of micro silica can reduce cement by approximately 4 kg. Another possibility is to optimize the particle packing by using fillers to manage the content of cement at stable levels but achieve a wide PSD (particle size distribution) range. Optimizing the PSD to advance NS in cement slurry will improve the performance (strength, durability) of the concrete. Adding nano silica to cement slurry or concrete has various effects (Fig. 1.4). The principal mechanism of this working principle is that it is linked to the large surface area of nano silica and acts as a nucleation site for C-S-H gel precipitation.

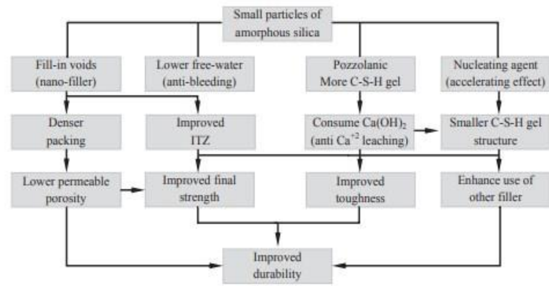


Figure 1.4 Schematic representation of the effects of adding nano-silica in mortar and concrete.

1.8 Effect of Nano silica on mechanical properties of concrete.

The highly documented effect of the nano-silica addition on the concrete and mortar is that of the mechanical properties. The influence of nano silica addition on properties of concrete includes decrease in porosity, increase in density and development in the bond between matrix and aggregate of cement. As a result of these, concrete shows higher compressive strength and flexural strength (Sobolev and Ferrara, 2005b; Nano forum Report, 2006). At high nano silica concentrations, self-shrinkage increases with self-drying, which results in a higher probability of cracking. To avoid this effect, it is necessary to add a large amount of fluidizer and water and apply a suitable curing method (Bjönstromet al., 2004).

1.9 Application of nano-silica in concrete.

For self-compacting concrete, the application of nano-silica is essential. Some of the experimental applications of nano-silica in specialized mortars for rock matching grouting, immense performance well in cementing slurries etc. can be found. Both in infrastructure and in buildings, the applications of these concrete were found anywhere. In HPC and SSC concrete, when added- nano silica acts mainly as an anti-bleeding agent. It is also essential catalyst when segregation tendency needs to be reduced and when rise in the cohesiveness of concrete is required. Additionally, the application of nano silica is its use as an additive in eco-concrete mixtures. Eco – concrete are those mixtures where waste materials mainly sludge ash, fly ash, or others supplementary waste materials were interchanged for cement. Long setting period and low compressive strength were the complications of these mixtures, and such shortcoming is resolved by addition of nano-silica to attain higher compressive strength.

1.10 Objectives

- To obtain the highest compressive strength and to find the optimizing ratio of silica fume and nano silica.
- Plot graph and correlate the compressive strength within 7 days, 14 days, and 28 days of time.
- As per the Indian requirement, stabilize the standards for the concrete.
- For the universal reason evaluate the strength to construct the automated console.
- After-effects of silica fume and nano silica on Compressive Strength and durability properties of concrete material.
- Investigate Compressive Strength of the concrete with addition of silica-fume and nano-silica.

II. REVIEWS OF LITERATURE

2.1 Optimizing ratio of silica and fume

High-performance concrete is usually composed of ternary admixture of silicon powder, fly ash, or other volcanic ash and Portland cement. However, the specifications for the proportions of these components were still unknown. One of the purposes may be to add enough volcanic ash to consume any excess calcium hydroxide produced during hydration of Portland cement. In case of a cement-chemical ternary phase diagram, this means finding the point of intersection between the line connecting the cement composition and the fly ash composition and boundary line of the calcium hydroxide stability region. Boundaries can be found by assuming that the final balanced mineral combination is a mixture of C-S-H gel and calcium aluminate hydrate. To determine the relating line, it is essential to know the composition of fly ash and Portland cement. Because not all the fly ash is reactive, and reaction kinetics proceed at a limited rate.

1. Joe Paulson. et al. (2017) study on the best alternative research of silica fume cement by different mixing ratio method. The best way to replace the cement reported in the previous work module with silicon powder is 13%. The degree of substitution applies to various mixing ratio methods such as the Indian method, the Pumping concrete method, the American method, and the British method. This study was conducted to study the modes of cubic compressive strength using the best alternative. For all the above mix ratio methods, cubes were cast to obtain alternative compressive strengths of 0% and 13%.

2. Shamsad Ahmad et al. (2014) study on Effects of key mixing parameters on the shrinkage of reactive powder concrete (RPC), also known as ultra-high-performance concrete (UHPC), is water, Portland cement, silica fume, fine silica sand, quartz powder, fluidization, manufactured by mixing agents and steel fibers. Very low water to binder ratio (0.15 to 0.20), high cement content (800 to 1100 kg / m3), high silicon powder content (20 to 25% of cement weight), fine-grained sand quartz powder (coarse)
Aggregates) and steel fibers (about 6% by volume of RPC). The dense microstructure and the presence of steel fibers in the RPC mixture provide superior mechanical properties (high strength, ductility, and toughness) and durability as compared to conventional high-performance concrete. However, because of the use of large amounts of cement and silica fume in the preparation of RPC mixtures with very low water to binder ratios, the risk of premature high self-shrinkage cannot be excluded.

3. Ahmed M. Ashteyat et al. (2012) introduced to concrete strength development model of silica fume as a substitute for fine aggregate was introduced. Several experiments have been conducted to study the strength development of concrete in which fine aggregate is partially replaced by silicon powder. A mathematical model was developed using statistical methods to predict the compressive strength of this concrete. The ratio of water to cement varies between 0.50 and 0.60, and the substitute level of fine aggregate is between 0 and 15%. The compressive strength tests were performed on days 7 and 28. The results show that the compressive strength of the concrete made with silica fume as a substitute for fine aggregate is higher than that of the control concrete. The developed model provides a closed form estimate of concrete compressive strength. These models can be used as a useful guide for mixing silicon powder and mixtures as an alternative to fine aggregate. This concrete can be successfully used in structural applications with economic and environmental advantages.

2.2 Effects of Nano silica on Compressive Strength and Durability

Addition of different nano silica doses (0.5%, 1% and 1.5% to cement) to the compressive strength and durability of concrete with water / binder ratio of 0.65, 0.55 and 0.51 examined the effect. The absorptivity of water was measured, and the chloride ion diffusion coefficient, the electrical resistivity and the carbonization coefficient of concrete were observed. As a result, the compressive strength was appreciably improved in the case of water / binder = 0.65, and no change was spotted in the case of water / binder = 0.5. With increasing nano silica content, the adsorption of water only reduces water / binder = 0.55. The addition of 0.5% nano silica reduced the water / binder apparent chloride ion diffusion coefficient = 0.65 and 0.55. However, higher nano silica doses did not reduce it to baseline values. For all water / binder ratios, the resistivity increases by 0.5% nano silica, and for water / binder = 0.5, the resistivity increases by 1.5% nano silica. The carbon nanotube coefficient was not significantly affected by the increased nano silica dose, and even the adverse effect of water / binder = 0.65was observed. Further information on the microstructure is also provided by rendering techniques such as thermos gravimetric examination, X-ray diffraction (XRD), mercury intrusion porosimetry (MIP) and scanning electron microscopy (SEM). The lower intensity mixtures of nano silica doses are more pronounced, but for higher intensity mixtures it is less effective.

4. Satyajit Parida in 2015 studied the effects of the compressive strength of concrete due to nano silica addition. The application of nanotechnology in concrete was to progress its performance. Owing to very small particle size of nanomaterials, it can affect concrete work by altering the microstructure. To improve the compressive strength of concrete, a size of 236nm nano-silica is employed. By replacing cement with 0.3 %, 0.6 % and 1 % b.w.c of nano silica various experiments were carried out. In early tests the compressive strength is virtually improved, and in overall the compressive strength of the concrete is slightly increased. Increase of nano silica amount is directly proportional to its strength.

5. Mukharjee and Barai in 2014 designed the improvement in the compressive strength and differentiating the Interfacial Transition Zone (ITZ) of concrete containing recycled aggregates and nano silica.

6. G. Dhinakaran et.al. in 2014 surveyed the microstructure and strength properties of concrete with the Nano silica. The silica was crushed in the planetary ball mill until a nano size level was reached and it was then mixed in concrete with 5 %, 10 % and 15 % b.w.c.

7. Sattawat Haruehansapong in 2017 studied effect of nano silica particle size on permeability, abrasion resistance, drying shrinkage and repair performance of nano- SiO2 cement mortar This study shows nano silica particle size for durability and repair performance of cementations mortar containing nano silica (nS) describes the impact of three different nS particle sizes of 12, 20 and 40 nm were used and compared to cement mortar without nS and cement mortar containing silicon powder (SF). The interesting result is that the particle size of nS directly affects the wear resistance and permeability. The 40 nm particle size nS is the optimum size with the highest abrasion resistance and permeability. For repair performance, cement mortars containing nS (12 and 20 nm) and SF have higher drying shrinkage than cement mortars not containing nS, and then crack behaviour between cement mortar and concrete substrate and Peeling occurs. Cement mortars with an nS of 40 nm have the lowest drying shrinkage, the lowest number of cracks and the highest adhesive strength. These results indicated that the particle size of nS does not only affect the durability and repair performance of cement mortar.

8. Forood Torabian Isfahani et al. in 2016 studied influence of nano silica under different water binding ratio on compressive strength and endurance of concrete. Different nano silica doses for compressive strength and durability of concrete with water / binder ratio of 0.65, 0.55 and 0.5 The effect of the addition (0.5%, 1% and 1.5% on cement) was investigated. The absorptivity of water was measured, and the chloride ion diffusion coefficient, the electrical resistivity and the carbonization coefficient of concrete were observed. As a result, the compressive strength was

significantly improved in the case of water / binder = 0.65, and no change was observed in the case of water / binder = 0.5. As the nano silica content is increased, the water adsorption rate only reduces water / binder = 0.55. The reduction of 0.5% nano silica
reduces the apparent chlorine diffusion coefficient = 0.65 and 0.55 of water / binder. However, higher nano silica doses did not reduce it to baseline values. For all water / binder ratios, the resistivity increases by 0.5% nano silica, and for water / binder = 0.5, the resistivity of nano silica increases by 1.5%. The carbon nanotube coefficient was not significantly affected by the increased nano silica dose, even for water / binder = 0.65.

2.3 Mechanical properties with Nano Silica.
9. S. Tanveer Hussain et.al. in 2014 found the strength of concrete with the varying percentages ratio of nano silica at 0, 1, 1.5, 2, and 2.5 % with the partial replacement of cement. They check the compressive strength at 28 days with M40 grade of concrete. The compressive strength of concrete continues to increase up to 2%.

10. Satyajit Parida in 2015 studied the compressive strength of concrete with silica fume at 7 days and 28 days. The addition of silica fume was 0, 0.3, 0.6, and 1% for M25 grade of concrete. The compressive strength was maximum at 1% addition of NS in both 7 and 28 days. For 7th day at 1% it was 34.59 MPa and at 28th day it was 39.82 MPa.

11. H. Li et.al. in 2004 experimentally reviewed the mechanical properties of nano Fe2O3 and nano SiO2 cement mortars where they found that the 7- and 28-day strength was much higher as compared to plain concrete. The microstructure analysis revealed that the nano particles fill up the pores along with reducing calcium di-hydroxide via the pozzolanic reactions.

12. M. Iyappan et.al. in 2014 studied the properties of HSSCC (High strength self-compact concrete) with addition of NS after 7 and 28 days. The addition of nano silica is 0, 5, and 10%. The maximum increase in compressive strength with nano silica was at10% both on 7thand 28th days. On 7th day at 10% the strength was 38.7 MPa and 28th day it was 58.5 MPa.

2.4 Compressive Strength of concrete with silica fume
This paper describes the results of experimental research to determine the suitability of silica fume in concrete production. When utilized as a partial replacement for OPC, it has been observed that the optimum dose of silicon powder is 5% by weight. Silicone inclusions greatly improve the workability and strength of concrete.

13. Hasan et al. in 2014 Comparative study on the properties of nano silica, silica soot and fly ash cement mortar Fourier transform infrared spectroscopy (FTIR) of nano silica (nS), silicon powder (SF) and fly ash, thermo gravimetric analyzer-differential thermal gravimetric analyzer (TG) -DTG) and compared by scanner. (FA) Structural features of impregnated cement mortars Electron microscope (SEM). The mechanical strength of the samples was measured at early (day 7) and standard (day 28) cure age. The compressive and flexural strengths generated in mortar samples containing NS particles were found to be significantly higher than the corresponding SF and FA samples, exceeding the control samples at both ages. The results of FTIR, TG-DTG and SEM analysis were consistent with the significant increase in mechanical strength of the NS mortar. These increases in mortar strength with NS can be attributed to the large surface area of the Nano sized particles and NS. Nano-sized particles act as nucleating agents to promote the hydration of C3S and C2S and the formation of the C-S-H phase. The multiple active sites on the surface of the NS particles trigger their pozzolanic activity and the degree of bond formation between the NS particle and free CSH.

14. Surya Abdul Rashid et.al. in 2011 analyzed the effect of Nano SiO2 particle. They analyzed it on both mechanical properties like compressive, split, tensile and flexural strength and on physical properties like water permeability, setting time and workability. Their experiments showed that binary blended concrete along with nano SiO2 particles (2%) has noticeably superior compressive, flexural potency and split tensile strength when compared to the normal concrete. Alternative elucidation was that partial replacement of nano SiO2 deteriorates the workability and time of setting of fresh concrete for the samples that are cured in the lime solution.
15. S. Suresh Sankara narayannan et al. in 2016 did a comparative study by exploiting Nano Silica powder

of high-performance fly ash concrete on different mixtures. The experimental outcomes of high-volume fly ash (HVFA) concrete were reviewed. In first instance utilizing various variations of silica smoke like percentage variation (1%, 2% wt% etc.), estimation of compressive strength of cement was investigated. The composition that had peak compressive strength is then utilized for high volume fly ash concrete which contains 30 % and 50 % grade of fly-ash. Overall, the conclusion drawn was that the addition of 1 % of different silica fumes potentiates the compressive strength of the concrete.

III. MATERIALS & METHODS

The current study carried here aimed to design M25, M30 and M40 grades of the concrete. Both the curing properties and the rheology of these developed mixtures were analyzed. In order to obtain our aimed grades, the cement was swapped by silicon powder and /or the nano-silica material. In addition, to develop the techniques and methods for casting tubes is also proposed. The aimed hybrid design is based on the ACI (American Concrete Institute) approach due to its flexibility and the percentage substitutions decided are 1%, 2%, 3% for nano silica and 3%, 6%, 9% for silica fumes.

3.2 Experimental Program

The experimental technique involves assessment of base material in the laboratory. Generally, design combinations use elementary material test results and the American Concrete Research Institute method and then development ratio as the mix ratio. At this mixing ratio, the cement was replaced with nano silica and silica fume. All mixtures developed have been studied and tested for fresh and hardened properties. A total of 24 samples were cast in the laboratory and then tested for the compressive strength. Details of the mentioned samples are shown in the Table I.

Table I. Different percentages of Nano silica and silica fumes used for cubes.

Mixtures	Silica-fume replacement (%)	Nano-silica addition (%)	Cubes	
			7 days	28 days
Cont. mix.	5	0	3	3
1	5	1	3	3
2	5	2	3	3
3	5	3	3	3
	Samples		12	12

3.3 Materials Used

1. Cement: In this experimental work the conventional Portland cement called as OPC having a grade of 43 as per IS8112-1989 was utilized. The cement utilized here is super high-tech cement obtained from an agent locally.
2. Fine aggregate: River sand available in the zone 2 of IS383-1970 is used for this project proposal.
3. Coarse aggregate: Both the Quarry granite and gravel granite are used as coarse aggregates. As per Indian standards, there is an appreciable reduction in the size as well as specific gravity of the 20mm coarse pellet.
4. Water: Generally, the water that is suitable for drinking is considered suitable for concrete production as well. However, precautions like presence of alkalis or acids or other organic impurities must be taken into account. Water is a very important component for concrete mixtures because it helps in two different ways: First it acts as a carrier/lubricant and secondly it reacts chemically to result in the formation of slurry.
5. Nano Silica: All the characteristics of the nano silica used in this article are listed in Table II.
6. Silica fume:

The most frequently used mineral admixture in high strength concrete is silica fumes. Adding them to a concrete mixture can greatly improve the workability. The characteristic properties of silica fume utilized along with its chemical composition are depicted in Tables 3.3 and 3.4 below, respectively.

Table II. Properties of Nano Silica.

Properties	Requirements	Results
Surface area	200 + 20	201
SiO_2 (%)	>99.80	99.88
pH value	3.7 – 4.5	4.37
Chlorides (%)	<0.020	0.011
Al_2O_3	<0.030	0.007
TiO_2	<0.020	0.006
Fe2O3	<0.003	0.001

Table III. Properties of Silica Fume.

Properties	Results
Particle-Size	15μm
Specific gravity	2.61
SiO_2 Content	98.89%

Table IV. Chemical Composition of Silica Fume.

Chemical Composition	Typical values (%)
SiO_2	99.5
Al_2O_3	0.08
TiO_2	0.04

CaO	0.01
MgO	0.29
Alkalies	800µ

3.4 Mix design

Mix design is the process of selecting the suitable ingredients of concrete and to determine their properties. The main objective is to produce concrete of certain maximum strength and durability. The idea is also to have concrete that is as cheap /economical as possible.

Mix design of concrete of M25 grade.
a) Grade designation=M25
b) Type of cement=OPC grade 43
c) Maximum nominal size of aggregate=20mm
d) Cement content=320 kg/m
e) Water cement ratio=0.45
f) Workability=100-120mm slum pg) Coarse aggregate (20mm) =1162.18 kg/m^3
h) Fine aggregates (crusher dust) =810.64 kg/m^3

Target strength for mix proportioning
f'ck = fck + 1.65 s Where f'ck = target average compressive strength at 28 days.
fck = characteristic compressive strength at 28 days.
fck = 25Mpa and s = standard deviation.
From table 1 of 10262-1982, standard deviation = 4 N/mm^2. Therefore, target strength = 25 + 1.65 × 4 = 31.6 N/mm^2.

Mix design of concrete of M30 grade.
a) Grade designation=M30
b) Type of cement=OPC Grade 43
c) Maximum nominal size of aggregate=20mm
d) Cement content=360 kg/m^3
e) Water cement ratio=0.45
f) Workability=100-120mm slump
g) Coarse aggregate (20mm) =1136.88 kg/m^3
h) Fine aggregates (crusher dust) =792.98 kg/m^3

Target strength for mix proportioning
f'ck = fck + 1.65 s Where f'ck = target average compressive strength at 28 days
fck = characteristic compressive strength at 28 days
fck = 30Mpa and s = standard deviation.
From table 1 of 10262-2009, standard deviation = 5 N/mm^2. Therefore, target strength = 30 + 1.65 × 5 = 38.25 N/mm^2

Mix design of concrete of M40 grade.
a) Grade designation=M40
b) Type of cement=OPC Grade 43
c) Maximum nominal size of aggregate=20mm
d) Cement content=438 kg/m^3
e) Water cement ratio=0.46
f) Workability= 100-120mm slump
g) Coarse aggregate (20mm) =1132.92 kg/m3
h) Fine aggregates (crusher dust) =727.02 kg/m^3

Target strength for mix proportioning
f'ck = fck + 1.65 s Where f'ck = target average compressive strength at 28 days.
Fck = characteristic compressive strength at 28 days
fck = 40Mpa and s = standard deviation.
From table 1 of 10262-2009, standard deviation = 5 N/mm^2. Therefore, target strength = 40 + 1.65 × 5 = 48.25N/mm^2.

IV. RESULTS & DISCUSSION

4.1 Fresh Concrete Tests

4.1.1 Slump-cone testing: The slump cone test is the well-known test that is used for determining the workability of concrete. This testing machine consists of a cone with a base diameter of 200mm (8 inches), a top diameter of100mm (4 inches), and a height of 300mm (12 inches). First the cone is filled with concrete. Then the cone is removed. After removal of cone the concrete shape is evaluated to determine its workability. The workability tests are performed as per IS1199–1959. The slump interpretation is done by visualizing and analyzing different shapes (true slump, zero slump, collapsed slump, and shear slump). However, not all slumps are measured except the true slump.

Mixing of the concrete components is done for the desired mix proportion M30 and M40 grade by adding Nano silica (1%, 2%, 3%) and silica fume (3%, 6%, 9%) by weight of the cement. The results of slump are shown in the Table (V and VI) for M30 and M40 grades.

Table V. Slump test values for M30 grade of concrete.

Serial Number	Grade	Nano silica %	Silica fume %	Slump (mm)
1	M30	0.0	0.0	112
2		1.0	3.0	124
3		2.0	6.0	135
4		3.0	9.0	145

Table VI. Slump test value for M40 grade of concrete.

Serial Number	Grade	Nano silica %	Silica fume %	Slump (mm)
1	M40	0.0	0.0	122
2		1.0	3.0	130
3		2.0	6.0	143
4		3.0	9.0	148

Upon interpretation, it appears that when the percentage of Nano silica and Silica fumes goes up the slump values drop.

4.2 Tests carried on Hardened Concrete.

In this section details of study of the mechanical properties of the normal versus silica fume or nano silica added concrete to that of weight of the cement are listed. Concrete mixes are specified in the previous section. Addition of ingredients is done for the mix proportion for M30 and M40 grade mixes by addition of Nano silica percentages (1%, 2%, 3%) and Silica fume percentages (3%, 6%,9%).

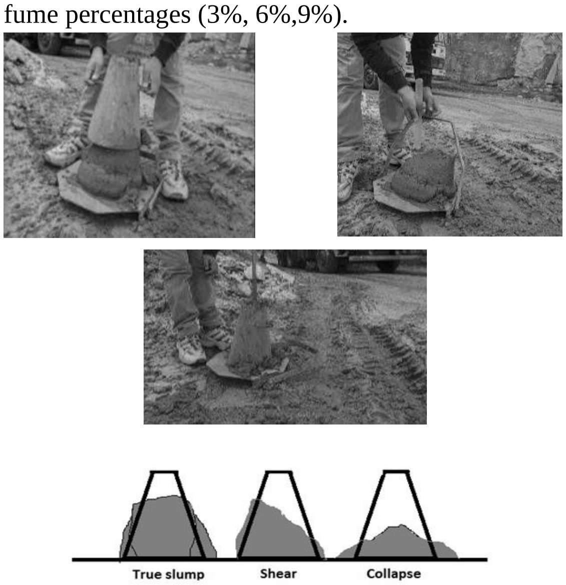


Figure 4.1 Figures of slump cone test

4.2.1 Cube Compressive Strength test.

The central characteristic of concrete is its compression strength. Such strength features a definite relationship with all alternative properties of concrete. This means that these properties are improved with the enhancement in the compressive power. Compressive strength of concrete depends on many aspects such as cement strength, water-cement ratio, quality of concrete material and quality control during production of concrete etc. The size of the mould usually used is 150 x 150 x 150 mm. This concrete is then poured in the mould and is then tempered appropriately so as there are not any voids. These moulds are then removed after 24 hours, and the test specimens are put in water for the purpose of curing. The top surface of these specimen must be made flat. This is achieved by putting cement paste and then smoothly spreading it on the whole area. The concrete cubes are tested for 7 days and 28 days (as per Indian Standard IS516-1959). The cubes are afterwards also examined in a compression testing machine. For a typical category, three specimens are tested and then the mean compressive strength is measured as the compressive strength of that specified category.

Table VII. Compressive Strength OF M25 Concrete Cubes Without Silica fume and Nano silica for 7 days.

Concrete Grade	Age Days (D)	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)
M-25	7 D	460 KN	20.33	20.48
M-25	7 D	490 KN	21.22	
M-25	7 D	450 KN	19.89	

Table VIII. Compressive Strength OF M25 Concrete Cubes with Silica fume and Nano silica for 7 days.

Concrete Grade	Age In Days (D)	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength(N/mm^2)
M25	7 D	630 KN	30.44	30.89
M25	7 D	650 KN	31.33	
M25	7 D	640 KN	30.89	

Graph 4.1: Bar chart showing the difference of strength with and without nano silica and silica fume for 7 days of M25 grade of concrete.

Table IX. Compressive Strength OF M25 Concrete Cubes Without Silica fume and Nano silica for 28 days.

Concrete Grade	Age Days	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength(N/mm^2)
M-25	28 D	660 KN	29	30.11
M-25	28 D	680 KN	30.22	
M-25	28 D	700 KN	31.11	

Table X. Compressive strength of M25 concrete cubes with silica fume and Nano silica for 28 days.

Concrete Grade	Age Days (D)	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength(N/mm^2)
M-25	28 D	710 KN	31.22	32.33
M-25	28 D	730 KN	32.44	
M-25	28 D	750 KN	33.33	

Graph 4.2. Bar chart showing the difference of strength with and without nano silica and silica fume for 28 days of M25 grade of concrete.

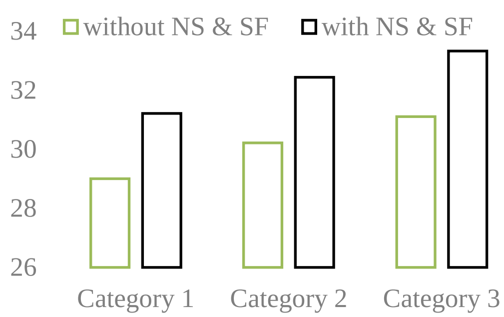


Table XI. Compressive Strength OF M30 Concrete Cubes without Silica fume and Nano silica for 7 days.

Concrete Grade	Age Days (D)	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength(N/mm^2)
M30	7 D	500 KN	25.67	25.95
M30	7 D	460 KN	24.98	
M30	7 D	510 KN	27.22	

Table XII. Compressive Strength OF M30 Concrete Cubes with Silica fume and Nano silica for 7 days.

Concrete Grade	Age In Days	Crushing Load (KN)	Strength (N/mm^2)	Avg. Compressive Strength(N/mm^2)
M30	7 Days	530	28.44	27.77
M30	7 Days	490	26	
M30	7 Days	540	28.89	

Graph 4.3. Bar chart showing the difference of strength with and without nano silica and silica fume for 7 days of M30 grade of concrete.

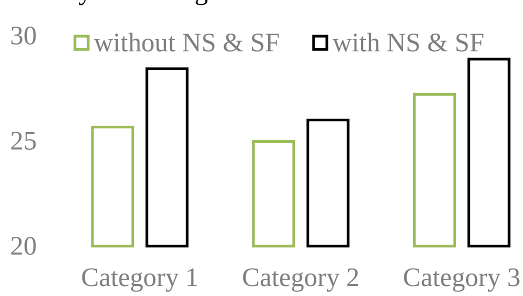


Table XIII. Compressive Strength OF M30 Concrete Cubes without Silica fume and Nano silica for 28 days.

Concrete Grade	Age In Days	Crushing Load	Strength (N/mm^2)	Avg. Compressive strength(N/mm^2)
M-30	28 D	700 KN	34.55	35.14
M-30	28 D	710 KN	35	
M-30	28 D	730 KN	35.89	

Table XIV. Compressive Strength OF M30 Concrete Cubes with Silica fume and Nano silica for 28 days.

Concrete Grade	Age In Days	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength(N/mm^2)
M-30	28 D	750 KN	36.78	37.37
M-30	28 D	760 KN	37.22	
M-30	28 D	780 KN	38.11	

Graph 4.4. Bar chart showing the difference of strength with and without nano silica and silica fume for 28 days of M30 grade of concrete.

Table XV. Compressive Strength OF M40 Concrete Cubes Without Silica fume and Nano Silica for 7 days.

Concrete Grade	Age Days	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)
M-40	7 D	750 KN	36.78	36.03
M-40	7 D	710 KN	35	
M-40	7 D	740 KN	36.33	

Table XVI. Compressive Strength OF M40 Concrete Cubes with Silica fume and Nano Silica for 7 days.

Concrete Grade	Age In Days	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)
M-40	7 D	790 KN	38.55	37.81
M-40	7 D	750 KN	36.78	
M-40	7 D	780 KN	38.11	

Graph 4.5. Bar chart showing the difference of strength with and without nano silica and silica fume for 7 days of M40 grade of concrete.

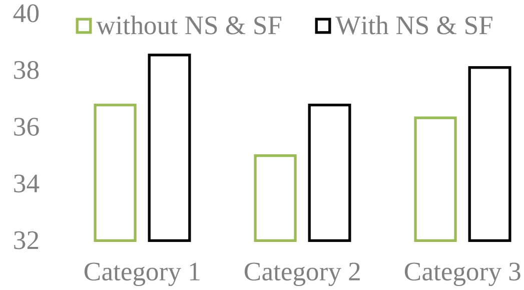


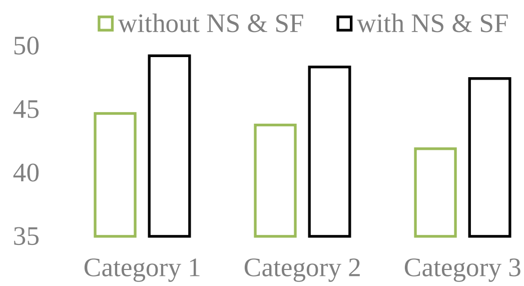
Table XVII. Compressive Strength OF M40 Concrete Cubes Without Silica fume and Nano Silica for 28 days.

Concrete Grade	Age In Days	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)
M-40	28 D	950 KN	44.67	43.44
M-40	28 D	930 KN	43.78	
M-40	28 D	910 KN	41.89	

Table XVIII. Compressive Strength OF M40 Concrete Cubes with Silica fume and Nano Silica for 28 days.

Concrete Grade	Age In Days	Crushing Load	Strength (N/mm^2)	Avg. Compressive Strength (N/mm^2)
M-40	28 D	1030 KN	49.22	48.33
M-40	28 D	1010 KN	48.33	
M-40	28 D	990 KN	47.44	

Graph 4.6. Bar chart showing the difference of strength with and without nano silica and silica fume for 28 days of M40 grade of concrete.



V. CONCLUSION

From the test results done, the following conclusions were drawn.

1. Using nano silica and silica fume in concrete improves the hardened properties, durability characteristics and contrarily reduces the workability.
2. The results of slump cone test are suggestive of the fact that escalation in the percentage of Nano silica and Silica fume leads to the decrease of slump values.
3. The results of compressive strength are suggestive of the fact that increase in compressive strength of concrete upon supplement of a certain minimum quantity of Nano silica and Silica fume is observed. The increase in strength is highest for NS 3 % b.w.c and minimum for NS 1 % b.w.c and similarly highest for SF 9 % b.w.c and minimum for SF 3 % b.w.c.
4. The cube compressive strength test carried out shows that the compressive strength of concrete with Nano silica and Silica fume is above than that of concrete that is lacking any additive Nano silica.

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