SYNERGISTIC EFFECTS OF FLY ASH AND NANOSILICA ON THE STRENGTH DEVELOPMENT OF CONCRETE

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ABSTRACT

The use of supplemental cementitious materials (SCMs) in concrete is becoming more popular as a result of the search for sustainable and high-performing building materials. With an emphasis on their combined impact on mechanical qualities including compressive, split tensile, and flexural strength, this research explores the synergistic impacts of fly ash and nanosilica on the strength development of concrete. While nanosilica, with its ultrafine particle size and strong reactivity, improves early-age strength and microstructural refinement, fly ash, a byproduct of burning coal, adds to long-term strength via its pozzolanic activity.

Different amounts of fly ash and nanosilica were added to concrete mixtures in order to partially substitute them for regular Portland cement. To evaluate the time-dependent strength properties, the specimens were evaluated at various curing intervals. Comparing the hybrid inclusion of fly ash and nanosilica to control specimens and single-admixture mixes, the experimental findings showed a considerable improvement in strength performance. The improvement is ascribed to decreased porosity, densified microstructure, and improved pozzolanic reactions.

According to the study's findings, using fly ash and nanosilica together has a complimentary impact that maximises strength improvements over the long run while reducing cement use and promoting environmental sustainability. These results offer credence to the further use of mixed nanomaterials in contemporary concrete technology for long-lasting and environmentally responsible infrastructure.

I. INTRODUCTION

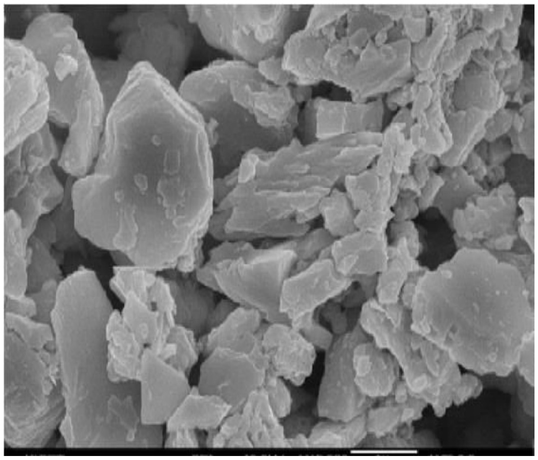
The most used building material in the world, concrete is prized for its strength, durability, and adaptability. Ordinary Portland Cement (OPC), its main binding ingredient, is linked to substantial carbon dioxide emissions and high energy usage, which raises environmental issues. To improve concrete's performance and lessen its environmental impact, engineers and researchers have resorted to supplemental cementitious materials (SCMs).

The pozzolanic qualities of fly ash, a byproduct of coal-fired power plants, make it a popular SCM that helps concrete gain strength and durability over time. By recycling industrial waste, fly ash, when used as a partial substitute for cement, not only increases workability and lowers heat of hydration but also encourages sustainability. Fly ash by itself, however, can result in a delayed early strength development, which might be a drawback in building projects that move quickly.

Nanosilica has become a very successful nanomaterial addition to compensate for this delay and improve the microstructure of concrete. Because of its large surface area and very small particles, nanosilica improves the interfacial transition zone (ITZ), fills in gaps in the cement matrix, and speeds up the hydration process. This contributes to strength and durability by improving the microstructure's early-age strength and densification.

The purpose of this research is to investigate how fly ash and nanosilica interact to affect concrete's strength properties. Utilising fly ash's long-term pozzolanic activity and nanosilica's quick reactivity, the study explores whether the two ingredients might work in concert to maximise concrete's performance. The compressive, tensile, and flexural strengths of a range of concrete mixtures containing differing proportions of fly ash and nanosilica were evaluated at various curing ages.

It is anticipated that the results of this research will provide insightful information on creating sustainable, high-performance concrete mixes that strike a compromise between short-term and long-term strength needs. By creatively using industrial waste and nanotechnology, this study advances the larger objective of green building techniques.



(a) Portland Cement

(b) Fly Ash

Figure1 SEM micrographs (8,000×)

Comparing fly ash to various alternative Pozzolonic materials, it has the best ability to reduce water. Using fly ash has an initial impact on the rheological characteristics and the structure of hardened cement. Because the minerals in the combination are crystalline and in powdered form, the morphological effect creates the structural and surface qualities. Additionally, the morphological effect is responsible for the particle size distribution. The use of fly ash as a replacement material in cement has the effect of carrying out the three crucial steps of filling, lubricating, and well-distributing the concrete. These three concrete processes vary depending on factors like size and form. Concrete's characteristics are likewise impacted by this.

The following characteristics represent the next step forward:

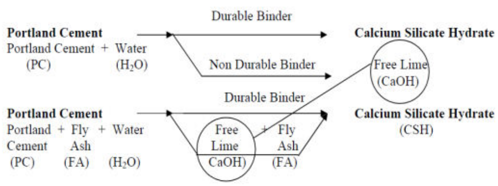
1) Adding fly ash to concrete, the most popular design technique, purposefully increases the amount of binder in the mix and facilitates compaction.
2) Heat is produced during the cement's hydration process, and this may be significantly reduced by substituting fly ash for cement in concrete mixes up to a particular amount.

1-2 ORIGIN OF FLY ASH:

When building the Hoover Dam, the United States of America employed fly ash for the first time in place of cement. The onset of exothermic heat from the hydration of ordinary Portland cement was anticipated to be a problem since it is a bulk volume structure. The heat generated during the internal hydration of cement will have a negative impact on the strength of concrete. Experimental evidence has shown that adding fly ash to a concrete mix instead of regular Portland cement would result in the same strength outcomes, but it would also significantly reduce the internal heat generated by the cement's hydration. If Portland cement is substituted with fly ash for the production of the concrete mix utilising this assimilation approach, Hoover Dam will almost never experience a cold ambient temperature again.

Fly ash was used in the concrete mix manufacturing process by the Cleveland Electric Illuminating Company and the Detroit Edison Company. For the first time, a team of associates and Davis prepared a concrete mix utilising fly ash at the University of California in 1937. Aside from extensive research conducted up to the 1960s to enhance the use of fly ash in construction firms, some little victories have been made in both developed and developing nations. However, the first study on the use of fly ash in the manufacture of concrete was conducted in India under the Central Building Research Institute (CBRI) in Roorkee. This research was conducted by Australian and American researchers. On the other hand, mass concrete dams and hydraulic constructions have begun to use fly ash in lower amounts. According to ASTM (American Society for Testing and Materials) C125, it is an alumina and siliceous substance that is either non-cementitious or partially cementitious in value, with a finely divided form. At room temperature, it also combines with Ca(OH)2¬ to form a cementitious compound when moisture is present. Fly ash is regarded as an efficient component of concrete as it primarily enhances workability and strength while also aiding in the development of strength. Additionally, it has been frequently utilised to substitute cement in both regular and high-strength concrete mixes. Due to its great fineness, fly ash reduces air gaps (pores) in the concrete mix and increases compressive strength, which is the initial goal of utilising it.

The following formula illustrates how the addition of fly ash alters the reaction.



Ca(OH)2, which is released from the hydration of cement owing to the Pozzolanic impact of fly ash, forms hydrated gel by activating the unstable states of Al2O3 and SiO2 in fly ash. This hydrated gel is created to fill in the air holes or pores in the concrete, which primarily increases the concrete's strength and often contributes to the development of long-term strength. Utilising waste material has been given particular priority since releasing thermal power plant waste mineral products into the environment might have serious consequences. Waste by-products should be employed to make new goods or, more efficiently, as natural admixtures to safeguard the environment.

By forming hydrated gel (Calcium Silicate Hydrate) C-S-H, fly ash significantly reduces the permeability character of concrete. In the fresh stage of concrete, it would be preferable to replace up to 20%–30% of fly ash with regular Portland cement. The workability property of new concrete is enhanced by the tiny, spherical, and smooth fly ash particles.

Concrete flow is often facilitated by the spherical surfaces of fly ash balls. Because of its enhanced workability, the water-cement is reduced to achieve higher compressive strength. Concrete's strength and durability steadily grow in the hardened stage; this is entirely dependent on the concrete's increased setting time. The Pozzolanic reaction separates the excess Ca(OH)2, which results in the formation of the tougher C-S-H hydrated gel during the chemical process.

1-3 Fly Ash effects in concrete

The use of Class-F fly ash in the roller compacted concrete process has certain effects in addition to its benefits.

1. Due to its Pozzolanic reaction, High Fly Ash Roller Compacted Concrete (HFRCC) has poor strength in the early phases of concrete compaction and decreases as fly ash concentration increases.
2. Activating greater amounts of fly ash results in a steady increase in the strength of Fly Ash Roller Compacted Concrete (HFRCC). higher levels of FA beyond the curative age.
3. Fly Ash Roller Compacted Concrete (HFRCC) compacts quickly thanks to the Super-Substitution process and the addition of fly ash, which also reduces the crystalline state of Ca (OH)2 and its permeability qualities.
4. Fly Ash Roller Compacted Concrete (HFRCC) is a uniform material that is often rather thick. This very thick nature causes the inner structure's flexural strength to grow quickly, which is more significant than concrete's compressive strength.

1-4 NANO SILICA:

The micro-level currently offers insufficient information on the building materials. As a result, research is shifting globally to the nanoscale, which is seen to hold enormous promise for the future. The performance of the material at the nanoscale influences the basic mechanisms that control the characteristics of concrete. C-S-H gel, the primary hydration product of cement-based materials, is a naturally occurring nanostructured substance. A technique that involves manipulating tiny particles, known as nanoparticles, is utilised to create massive materials. The particle size, or nano (10-9) may have an impact on the characteristics of materials, thus it is crucial to verify whether it is typically in the range of ≤100 nm. The use of nanoparticles is not a modern technology; rather, it arose a few decades ago as a result of the fast advancement of science and technology in the study of nano, micro, and other smaller particles, as seen below,

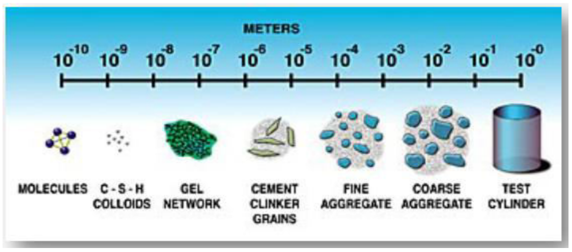


Fig.2 Particle Size variation

1-4-1 HISTORICAL BACKGROUND OF NANO SILICA:

Early in the 19th century, Richard Feynman challenged the notion of using nano-silica. Later, in the 1980s, Dr. Eric Drexler conducted extensive research on the use of nano-silica in civil engineering, both in books and speeches.

This technology allows for the creation of massive structures up to 100 nm in size. This includes wire fabrications with significant advancements in electronic beams, lithography, atomic layer depletion, electronic beams, and lithography, as well as molecular depletions. These advancements tend to the advanced techniques that are developed by using nano-sized particles in creating huge structures, and due to the rapid advancements in science, researchers have concluded that this nano-technique is a unique purpose for the development of a new era.

1-4-2 Application of Nano Technology in concrete

Implementing nanosized particles in the form of fibres or silicates is how nanotechnology is included into the manufacture of concrete. Concrete's qualities show some improvement as a consequence of the incorporation of these nanoparticles. By using nano-silica, the rate at which cement hydrates in concrete is accelerated. The calcium hydroxide in the cement hydration product is decreased by the creation of C-S-H gel, which also increases the concrete specimens' strength characteristics.

When Nano-Silica is applied, the concrete specimen's air gaps or porosity quickly decrease, leading to a partial replacement of cement due to the creation of microcrystalline structures. The development of cohesive connections between the nano-silica particles and C-S-H gel in concrete eliminates the concrete failure characteristics of bleeding and segregation of concrete specimens. The use of nano-silica in concrete as a cement substitute controls the curing time of the casting specimen, the greater workability of concrete with more than 100N/mm2, and the bleeding circumstances. Fly ash and furnace slag, two wastes or by-products from thermal industries, are being used in place of cement in the production of concrete in an effort to reduce the environmental damage caused by the massive use of cement. Nano-Silica may be used to manage the issue of concrete's declining compressive strengths as well as late curing or longer setting times, which enhances the concrete's workability and durability.

-4-3 Nano Silica (NS) Extraction

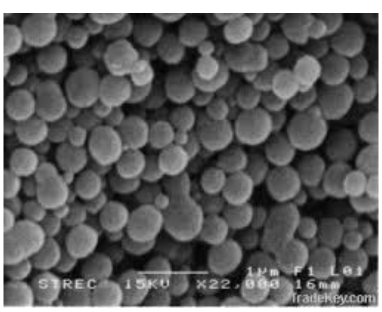
These days, very large objects are made using silica goods for industrial use. These silicates are widely utilised for concrete thickness, reinforcing, and levelling flat specimens. Around 1105 kilo tonnes of silica products were produced worldwide by 1999. The amorphous natured silicates are produced using extremely different methods. Although we know that DNA has an order of roughly 2 nanometres, and that human hair has an order of 10-4 meters, the order of 10-9 is for nanoparticles that are in a one-dimensional form.

There are two different ways to generate nano-silica (NS). The SOL-GEL procedure, which uses an organic solvent at the ideal temperature, is one of the best ways to produce nano-silica (NS). This method involves dissolving initiative constituents like sodium sulphates and metallic-organics like methyl-tetra silica (MTOS) and tetra-ethoxysilicane (TEOS) in an organic solvent. The dissolved substance's pH changes from its original state to a gel that is silica-natured. And now, this silica gel is thoroughly mixed to create XERO gel.

For use in concrete, it will be advised to further burn and dry this XERO gel with nitrogen, potassium, and ammonia (in stabilised form) to get the necessary concentration. The remaining techniques for extracting nano-silica (NS) include precipitation, biological, and thermal furnace approaches. For the manufacture of nano-silica (NS), a vapourization process at 1500–20,000 degrees Celsius is also an appropriate technique.

1-4-4 Behaviour of Nano-Silica (NS) in Concrete

The nature of nano-silica (NS) tends to speed up the cement's hydration process. The strength qualities will also be improved by substituting nano-silica for cement. By filling the air holes in the concrete specimen, Nano-Silica's (NS) spherical form improves the specimen's structure, making it more durable and impermeable. The concrete specimen's density and compressive strength both rise as a result of the gaps filled with nano-silica (NS). By using Nano-Silica (NS), concrete's workability is increased, hence controlling the two failure criteria of bleeding and segregation. Early-stage concrete cracking caused by limited workability is also reduced by using nano-silica in pavement design.



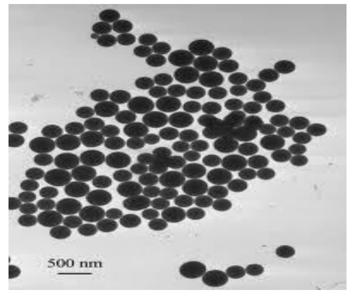


Fig: 1.3 Nano-Silica (NS) with Spherical Shape

1-5 Objectives of the Study

The goals of the current study on cement replacement using fly ash and nano-silica (NS) are as follows:

- Flexural strength, tensile strength, compressive strength, and modulus of elasticity are all measured in concrete using fly ash (FA) alone.
- Fly ash (FA) and nano-silica (NS) are used together to change the concrete's strength characteristics, such as its flexural strength, tensile strength, compressive strength, and modulus of elasticity.
- A visual representation of the comparison between controlled concrete and concrete that has had cement replaced with fly ash (FA) and nano silica (NS).

II. LITERATURE REVIEW

The first researcher to indicate that concrete strength decreases in its early phases but somewhat rises throughout curing times was "THOMAS ET AL. [1999]." In order to improve strength properties, he also used Silica-Fume, a waste by-product, as a replacement material. According to the report, the results of using Silica-Fume are better at earlier stages, and with further increases in the content of replacing material, it may produce the same results without replacing materials, especially at later stages. Therefore, he proposed that using fly ash (FA) and silica fume (SF) in lieu of cement is a better method for building strength.

"BENTZ. D ET.AL [2010]" reported on the use of fly ash in concrete in large quantities. A goal slump test result of 200 ± 5 mm is achieved by comparing these experimental tests with Controlled Concrete and Fly Ash replacement contents of 15–70%. For water cement ratios of

0.45, 0.5, 0.6, and 0.65, he used super plasticisers to decrease the water content to 18% and regulate it to the ideal level. At 7, 28, and 56 days of curing, the strength findings, setting times, and fly ash replacement content of the controlled and replaced concrete are compared.

The benefits of employing fly ash as a Supplementary Cementing Material (SCM) in fibre cement sheets were reported in "JAGADESH S [2006]". The early strength of fly ash-containing fibre cement sheets is modest, even at the ideal dose of 12–25%. There are many methods that may be used to raise the proportion of fly ash that contains calcium, including enrichment and applying calcium to coal during the burning process.

In his study on the development of strength in the early years, "CARETTE.G ET.AL [2010]" used a condensed form of fly ash and silica fume. According to the findings of the current study, concrete that has 30% fly ash added early on may become stronger with a little dose of silica fume. The amounts of silica fume applied range from 0% to 20% of the cement and fly ash weight. Following the production of concrete specimens, 180 prism specimens are used for flexural strengths testing and 240 cylinder specimens are used for compression testing. However, it was found that the concrete mix's strength qualities improved after seven, twenty-eight, and fifty-six days when 30% fly ash and 70% cement were added. However, adding more fly ash may result in a significant loss of compressive strength; hence, for water cement ratios of 0.4, 0.5, 0.55, and 0.6, 0.01 amount of condensed silica fume may be added to achieve the desired strength.

In "QUERCIA GEORGE ET.AL [2012]," he examined the effects of adding amorphous nano-silica (NS) to self-compacting concrete on its mechanical and durability characteristics. The inclusion of Nano-Silica (NS) has decreased the concrete specimen's permeable pores and increased its compression strength due to the production of C-S-H gel, which prevents the hydration process. The workability of this Nano-Silica (NS) application in concrete is examined both in its fresh condition and in its later hardened form. Concrete's density increases as a consequence of the spherical nanoparticles filling the air spaces between the particles. Based on this research, he came to the conclusion that adding nano-silica to self-compacted concrete (SCC) might significantly increase its strength and longevity.

The article "LANGAN ET.AL [2012]" He continued his research on cement hydration by substituting fly ash and silica fume. Following the successful conclusion of his investigation, he collated the cement calorimeter test findings. The hydration process is sped up by the silica fume at high water-to-cement ratios and slowed down at low ratios. However, it has been shown that fly ash speeds up the hydration process at low water-to-cement ratios and slows it down at high water-to-cement ratios. However, the use of fly ash and silica fume together will slow down the hydration process for water-to-cement ratios of 0.4, 0.45, 0.5, and 0.6.

III. MATERIAL PROPERTIES

3-1 GENERAL ASPECTS

Concrete, which is made up of cement, fine and coarse aggregates, and water, is a commonly used building material. Cement and water paste generate a stronger mass as a result of the cement's hydration. Both coarse and fine particles fill the spaces in the cement and water paste.

We are aware that cement's malleable nature makes it readily mouldable into any shape. Thus, a trowel may be used to smooth the moulded cement. Significant precautions must be taken to prevent porosity in concrete, which reduce its strength, and to slow down the quick loss of water content. Concrete controls the two effects of bleeding and segregation. The concrete specimen's quality is solely determined by the cement and water paste. The ratios we choose while designing the mix also have a significant impact on the properties of the concrete. This should be used with an air gap retarding compound to eliminate the concrete's pores and increase its density. Tri-calcium silicates found in concrete have the potential to progressively improve its strength characteristics. Nowadays, we exclusively employ rounded grains instead of the more sensible rough and angular fine particles used to prepare concrete. because the stone we're employing has a density of 2,500 kg/m3 and is angularly accessible. Because concrete's strength properties in the stress zone are poorer, steel bars or mesh are added.

3-2 CEMENT

Ordinary Portland cement of grade 43 is utilised for this inquiry in accordance with IS: 8112-1989 requirements. The cement used should be lump-free and fresh, and the results of numerous studies should meet the requirements of the Indian Standard Code, which are shown in table 1.

Table 1: Physical Properties of Cement

S.No	Property	Test result	As per IS8112:1989 (Limitations)
1	Specific Gravity	3.15	2.5-3.15
2	Normal Consistency	32%	28-35
3	Setting Time (a)Initial Setting time (b)Final setting time	120 minutes 6 hours	Not less than 30 minutes and not more than 600 minutes

3-3 FINE AGGREGATES

Sand that was readily available from the local river and complied with IS: 383-1970 was utilised as fine aggregates while making concrete. Table 2 uses the fine aggregates that pass through a 4.75mm IS sieve, and Table 3 displays the results of the sieve analysis,

Table 2: Properties of Fine aggregate

S.No	Physical property	Fine Aggregate Values
1	Specific Gravity	2.70
2	Fineness Modulus	2.8
3	Bulk Density (a)Loose State (a)Compacted State	 16.75 kN/m^3 17.15 kN/m^3
4	Grading of Sand	Zone – II

Table 3: Sieve Analysis of Fine Aggregate

Size Of Sieves	Weight Retained (gm)	Cumulative Retained %	Cumulative Passing %	Zone - Specifications as per IS:383-1970 for % Passing			
				I	II	III	IV
4.75 mm	20	2.0	98.0	90-100	90-100	90-100	95-100
2.36 mm	35	5.5	94.5	60-95	75-100	85-100	95-100
1.18 mm	350	40.5	59.5	30-70	55-90	75-100	90-100
600 µ	250	65.5	34.5	15-34	35-59	60-79	80-100
300 µ	200	85.5	14.5	5-20	8-30	12-40	15-50
150 µ	45	90.0	10.0	0-10	0-10	0-10	0-10
Pan	100	100	0	---	---	---	---

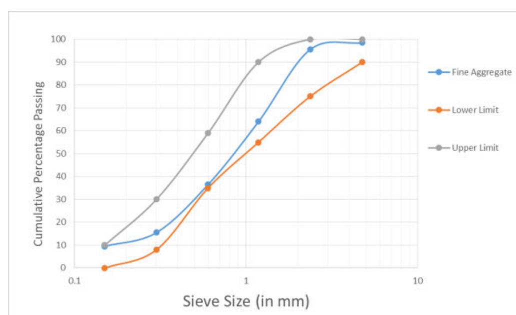


Figure 4 Particle-Size distribution of Fine Aggregate (Zone-II)

3-4 COARSE AGGREGATES

Coarse aggregates with nominal diameters of 20 mm and 10 mm that were obtained locally from quarries that complied with IS383-1970 were used in a ratio of 1.5:1.0, as shown in table 4.

Table 4: Properties of Coarse aggregate

S.No	Physical properties	Fine Aggregate Values
1	Specific Gravity	2.65
2	Bulk Density (a)Loose State (b)Compacted State	 13.15 kN/m^3 15.68 kN/m^3
3	Water Absorption	0.3%
4	Fineness Modulus	7.85

3-5 WATER

Alkalis, salts, acids, organic matter, oils, and other impurities should not be present in the water used to cast and cure concrete examples. Impurity-containing water may negatively affect concrete's strength characteristics.

3-6 FLY ASH

Fly ash of "Class-F" from the Thermal Power Plant is employed in this experiment. 20% and 30% of the cement's weight is made up of fly ash. Table 5 displays Fly Ash's physical characteristics.

Figure 5 Fly Ash Sample

Table 5: Properties of Fly Ash

S.No.	Properties	Values
1	Silica (SiO_2)	56.87 %
2	Aluminium trioxide (Al_2O_3)	27.65 %
3	Ferric oxide ($Fe_2O_3 + Fe_3O_4$)	6.28 %
4	Titanium dioxide (TiO_2)	0.31 %
5	Magnesium oxide(MgO)	0.34 %
6	Loss of ignition (LOI)	4.46 %
7	Specific gravity of Fly Ash	2.12

3-7 NANO-SILICA

The Pozzolanic colloidal silica emulsion used in this study is called nano-silica. Because of its high (>99%) amorphous silica content and smaller spherical size (order 15–50 nanometres), it is a superior pozzolanic material.

We employed 2%, 4%, and 6% nano-silica concentrations in our current study. Table 6 displays the characteristics of Nano-Silica.

Table 6: Properties of Nano-Silica

S.NO.	Properties	Actual results
1	Nano solids	39.5-41%
2	Ph	9-10.0
3	Specific Gravity of the sample	1.29-1.31
4	Sample Texture	White Liquid (Milky liquid)
5	Dispersion	Water

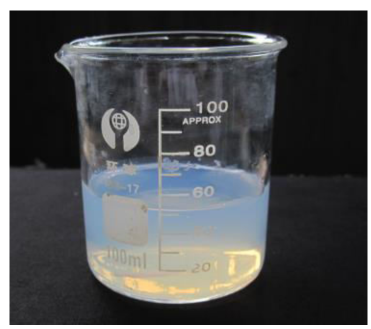


Fig 6 Nano-silica sample

IV. EXPERIMENTAL INVESTIGATION

4-1 GENERAL ASPECTS

The primary focus of our current work is the modulus of elasticity, tensile strength, compressive strength, and flexural strength of M35 grade concrete that uses fly ash (FA) and nano-silica (NS) to partially replace cement. For the current study, the recommended ratios for creating concrete specimens by weight of cement are Nano-Silica at 2.0%, 4.0%, and 6.0% and Fly Ash at 20% and 30%.

4-2 PREPARATION OF DESIGN MIX

The mix design of concrete mainly depends upon the properties of materials used for mix design. In the first step the Fly Ash and cement are mixed thoroughly and make a fine powder and then water and Nano-Silica are added with similar proportion. The two proportions are mixed uniformly and then the colour is maintained simultaneously to get required consistency and ready for casting. By the codal provisions of IS 1199:1959 the tests are to be carried i.e., Slump cone test and compaction factor test.

4-3 TEST SPECIMENS

The concrete specimens are,

a) Cubes- 150mm x 150mm x 150mm

b) Cylinders- diameter (150mm) and height (300mm)

c) Prisms – 100mm x 100mm x 500mm.

The concrete specimens are tested at different curing periods (3, 7, 28 and 56days). After the curing of specimens they are tested for various mechanical strength tests at 28 days. As per the specifications of IS516:1959 the loading rate is to be carried.

4-4 CURING PROCEDURE

The concrete specimens after casting they are kept aside for 24 hours and then the specimens are removed from mould at optimum temperature. A detailed marking is to be done on specimen to identify the specimen. After this the specimens are placed in water to keep moisture content in control. After the successful completion of curing the specimens are make ready to test for curing periods of 3, 7, 28 and 56 days of age.

4-5 TESTS ON NANO-SILICA (NS) AND FLY ASH (FA) CONCRETE COMPRESSION STRENGTH TEST

The strength property test in which the very important test is compressive strength of cube or cylinder specimens are ease to performed and also relates it to the controlled concrete confirming to the IS: 516-1959 and these specimens are underwent compression test by using CTM machine as shown below:

5.4.1 Compression Strength Testing Machine

The casted Concrete cubes of size 150mm × 150mm × 150mm were prepared for the CTM machine test and it is to be done at rate of 140kgs/Sq.cm/minutes until the cracking occurs or failure occurs and it is to be done at 7, 28 and 56 days of curing period.

SPLIT TENSILE STRENGTH TEST

At 28days of curing age the concrete specimens are prepared for Split Tensile Strength by using codal provisions of IS 5816-1999 and its specifications. The test carried on cylinder specimens of 300mm height and 150mm diameter. The load on the sample is carried out until the specimen fails with gradually applied load. The extreme load that is applied on the specimen is noted down. The splitting tensile strength (F_t) is given by the relation,

$$F_t = 2P/\pi DL$$

Where, P = Compressive load

L = Length of the cylinder

D = Diameter of the cylinder

5.4.2 Split Tensile Testing Machine

BENDING STRENGTH OR FLEXURAL STRENGTH TEST

The Tensile strength of concrete is related to the Flexural. The bending strength is the resulted in the resistance incurred by the concrete specimen without reinforcement. STM (Standard Test Method) is the method which is generally preferred to investigate the flexural strength of concrete. The flexural strength test is carried by using three beams of 100x100x500mm for three point load test in which crack may seen at any section.

Bending Strength or Flexural strength is calculated by the relation,

When crack started in the tension surface (i.e., the bottom surface) within the middle third of the beam,

$$MR = \frac{Pl}{bd^2}$$

Where, P- is the failure load,

l- is the span length,

d- is the depth of the beam, and

b- is the width of the beam. All dimensions are in mm.

(b) If fracture initiates in the tension surface (i.e., the bottom surface) outside the middle third of the beam by not more than 5% of the span length.

$$MR = \frac{3Pa}{bd^2}$$

Where, P- is the failure load,

l- is the span length,

d- is the depth of the beam, and

b- is the width of the beam. All dimensions are in mm.

5.4.3 Experimental Setup for Flexure Test

MODULUS OF ELASTICITY TEST

To get Modulus of Elasticity of cylinder specimen of 150mm diameter and 300mm long are by using compression Testing machine with dial gauge. This test mainly contains of two steel ring type arrangements which are used for clamp the specimen, gauge bars, dial gauge and a lever unit of spherical shape. The upper and lower rings are fitted by clamping the specimen. Then load applied gradual manner on the specimen and simultaneously readings are noted for increasing load values. By the load results the value of strain is noted by using gauge length and dial gauge. By this test the Modulus of Elasticity of concrete is plotted by using Stress-Strain curve.

V. RESULTS AND DISCUSSIONS

GENERAL ASPECTS

For M35 Grade of Concrete with partial replacement of cement by using Nano-Silica (NS) and Fly Ash the standard tests were conducted on hardened concrete specimens to obtain the compressive strength, flexural strength, split tensile strength and modulus of elasticity.

RESULTS AND DISCUSSION

The investigation results for various standard tests on concrete specimen i.e., Compressive Strength, Flexural Strength, Split Tensile Strength and Modulus of Elasticity are compared with Controlled concrete as mentioned below:

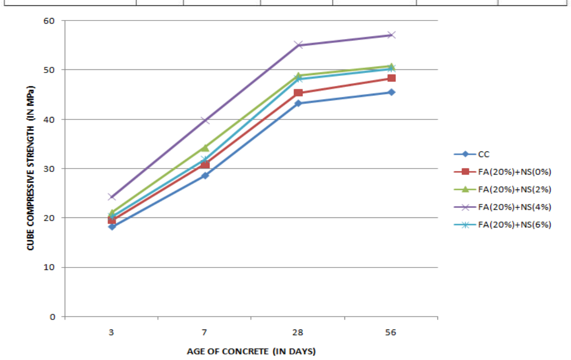
6-2-1 COMPRESSIVE STRENGTH

By the combined application of Fly Ash and Nano-Silica the compressive strength of cube specimens varies with Age of concrete in days as shown in fig-6 and the strength attained is the average of three test results.

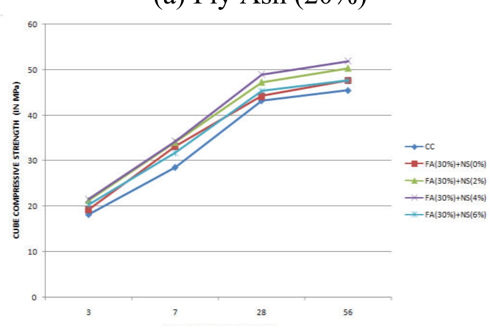
It is noticed that the compressive strength attained by the combined application exhibits more than that of Controlled concrete as shown in table 7

Table 9: Cube Compressive Strengths of M35 Grade Concrete

Concrete Mix	Fly Ash (%)	Colloidal Nano Silica (%)	Compressive Strength (MPa)			
			3 Days	7 Days	28 Days	56 Days
Control Concrete	0	0	18.17	28.55	43.25	45.50
FA 20 % + NS 0 %	20	0	19.53	30.90	45.42	48.35
FA 20 % + NS 2.0%	20	2.0	21.03	34.22	48.92	50.78
FA 20 % + NS 4.0%	20	4.0	24.25	39.70	55.13	57.14
FA 20 % + NS 6.0 %	20	6.0	20.26	31.85	48.25	50.30
FA 30% + NS 0 %	30	0	19.22	33.14	44.19	47.66
FA 30 % + NS 2.0 %	30	2.0	21.23	34.02	47.25	50.32
FA 30 % + NS 4.0 %	30	4.0	21.54	34.26	48.94	51.85
FA 30 % + NS 6.0%	30	6.0	20.39	31.72	45.32	47.62



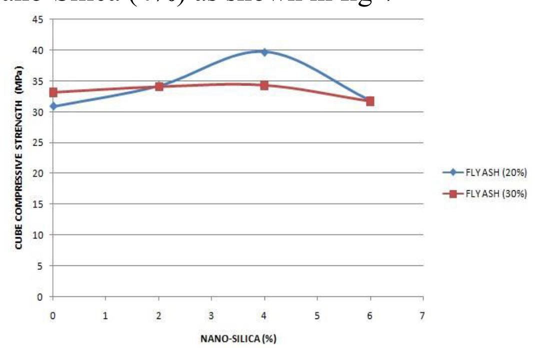
(a) Fly Ash (20%)



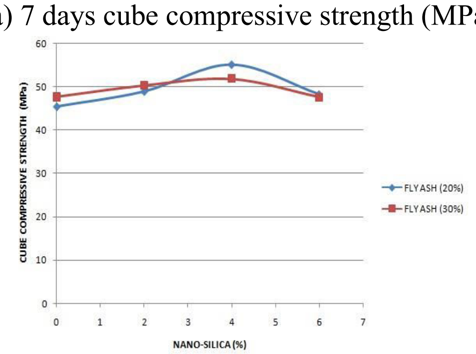
(b) Fly Ash (30%)

Fig: 7 Shows the variation of Compressive strength (MPa) for M35 Grade Concrete at various proportions of Fly Ash and Nano-Silica at different Age (in Days)

From fig-7 it is noticed that, the cube compressive strength increases upto the combination Fly Ash (20%) and Nano-Silica (4%) at 7 days and 28 days as 39.70MPa and 55.13MPa. It is observed that a sudden decrement in cube compressive strength occur when Nano-Silica content is above 4%. When Fly ash (30%) content is changed and Nano-Silica (4%) then the compressive strength is less than the compressive strength of controlled concrete. The cube compressive strength increases upto 11.22% and 12.10% by the combined application of Fly Ash (20%) and Nano-Silica (4%) as shown in fig-7



(a) 7 days cube compressive strength (MPa)



(b) 28 days cube compressive strength (MPa)

Fig: 8 show the variation of cube compressive strength (MPa) at 7days and 28days with Nano-Silica (%) with various proportions of Fly Ash (%).

Differentiating the compressive strength between cube specimen and cylinder specimen at 28days of curing of concrete specimen for various Fly Ash and Nano-Silica proportions is mentioned in table-8. The compressive strength varies between cube and cylinder around a ratio of 0.88.

Table: 10 Shows the Differentiation of compressive strengths of Cube and Cylinder at 28days curing with various Fly Ash and Nano-Silica content

S.No.	Concrete	Cube Compressive Strength (MPa) σ_{Cube}	Cylinder Compressive Strength (MPa) $\sigma_{Cylinder}$	$\sigma_{Cylinder}/\sigma_{Cube}$
1	Control Concrete	43.25	37.25	0.86
2	FA 20 % + NS 0 %	45.42	39.97	0.88
3	FA 20 % + NS 2.0 %	48.92	43.04	0.88
4	FA 20 % + NS 4.0 %	55.13	49.62	0.90
5	FA 20 % + NS 6.0 %	48.25	42.46	0.88
6	FA 30% + NS 0 %	44.19	37.56	0.85
7	FA 30 % + NS 2.0 %	47.25	40.64	0.86
8	FA 30% + NS 4.0%	48.94	43.56	0.89
9	FA 30% + NS 6.0 %	45.32	40.79	0.90

SPLIT TENSILE STRENGTH

For M35 Grade of concrete mix the Split Tensile Test variance is investigated for the concerned proportions of Pozzolanic substituent Fly ash and Nano-Silica and is mentioned in table-9. The investigated Split Tensile Strength for controlled concrete is 4.14 N/mm^2. This strength varies gradually with the increase in Nano-Silica content upto 4% and then a sudden decrement in strength occurs with increase in Nano-Silica as shown in fig-8. It seems that the combined application of Fly ash and Nano-Silica with 20% and 4% gives extreme strength improvements and if the Nano-Silica content changes to 6% with same fly ash obtains the tensile strength as 4.39 N/mm^2.

Table: 11 Shows the percentage variation of split tensile strength for M35 grade concrete mix for various proportions of Fly Ash and Nano-Silica

Concrete Mix	FA (%)	Nano Silica (%)	Split Tensile Strength (N/mm^2) for 28 Days
Control Concrete	0	0	4.14
FA 20 % + NS 0 %	20	0	4.26
FA 20 % + NS 2.0 %	20	2	4.34
FA 20 % + NS 4.0%	20	4	4.70
FA 20 % + NS 6.0%	20	6	4.30
FA 30% + NS 0 %	30	0	4.15
FA 30 % + NS 2.0%	30	2	4.33
FA 30% + NS 4.0%	30	4	4.43
FA 30% + NS 6 .0%	30	6	4.20

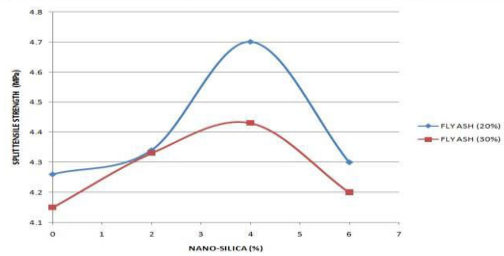


Fig:9 Graphical variation of split tensile strength of M35grade concrete for various mix proportions of Fly ash and Nano-Silica.

FLEXURAL STRENGTH

For M35 Grade of concrete mix the Flexural Strength Test variance is investigated for the concerned proportions of Pozzolanic substituent Fly ash and Nano-Silica is mentioned in table-10. The investigated Flexural Strength for controlled concrete is 6.58N/mm^2. It seems that the combined application of Fly ash and Nano-Silica with 20% and 4% gives extreme strength improvements and if the Nano-Silica content changes to 6% with same fly ash obtains the tensile strength as 7.11 N/mm^2. The improvement of strength by the substitution of Pozzolanic additives of Fly ash (20%) and Nano-Silica (4%) is 7.80 N/mm^2 as shown in fig-9

Table: 12 Shows the percentage variation of Flexural strength for M35 grade concrete mix for various proportions of Fly Ash and Nano-Silica.

Concrete Mix	FA (%)	Nano Silica (%)	Flexural Strength (MPa) for 28 Days
Control Concrete	0	0	6.58
FA 20 % + NS 0 %	20	0	6.81
FA 20 % + NS 2.0 %	20	2.0	7.18
FA 20 % + NS 4.0 %	20	4.0	7.80
FA 20 % + NS 6.0 %	20	6.0	7.11
FA 30% + NS 0 %	30	0	6.68
FA 30 % + NS 2.0%	30	.0	7.01
FA 30% + NS 4.0%	30	4.0	7.18
FA 30% + NS 6.0 %	30	6.0	6.03

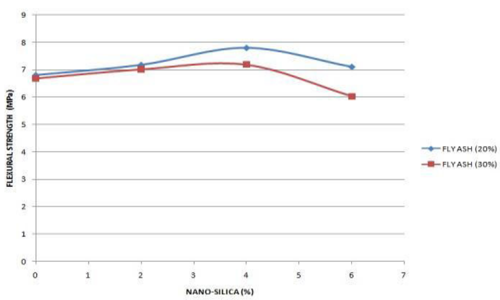


Fig: 10 Graphical variation of Flexural strength of M35grade concrete for various mix proportions of Fly ash and Nano-Silica.

VI. CONCLUSION

This research has shown how adding fly ash and nanosilica to concrete as partial cement substitutes improves the material's strength properties. The findings support the idea that using these two components in concert improves concrete's mechanical performance more than using them alone. While nanosilica speeds up early hydration and increases microstructural density, leading to increased early-age strength, fly ash's pozzolanic activity helps to increase strength over the long term.

Across all curing ages, concrete mixes with the ideal ratios of fly ash and nanosilica showed significant increases in compressive, split tensile, and flexural strength. Additionally, the combined usage resulted in a more refined pore structure and decreased porosity, which improved long-term performance and durability. By reducing cement usage and encouraging the use of industrial byproducts, these improvements not only increase structural integrity but also promote sustainability.

To sum up, the combination of fly ash with nanosilica provides a practical and effective method for creating high-performance, eco-friendly concrete. Further mix percentage optimisation, investigation of durability features including resistance to chemical attack and freeze-thaw cycles, and assessment of the scalability and cost-effectiveness of such blended concrete in large-scale building applications might be the main areas of future study.

REFERENCES

1. Belkowitz,J. and Armentrout, D. L. (2009). The Investigation of Nano Silica in the Cement Hydration Process. ACI Special Publication 267(8): 87-100
2. Thomas et al.,(1999), “Reported that fly ash reduced concrete strength at early ages, but significantly enhanced strength at later ages”. Cement and Concrete Research, Vol 29(4), pp.487-495.
3. Sanchez. F., and Sobolev, K. (2010). “Nano-Technology in Concrete – A Review”, Construction and Building Materials. 24, 2060-2071.
4. Gengying Li.,(2004). “Properties of High-Volume Fly Ash Concrete incorporating Nano-SiO2”, Cement and Concrete Research, pp. 1043-1049.
5. Jagadesh.Sunku (2006),“had studied the advantages of use of fly ash as Supplementary Cementing Materials in Fibre cement sheets. International Inorganic Bonded Fibre Composites Conference, pp.25-32.
6. G.Quercia and H.I.H. Browwers, (2010). ‘Applications of Nano Silica in Concrete Mixtures’, 8th Ph.D. Symposium in Kgs Lyngby, Denmark, June 20-23,
7. C Freeda Christy and D Tensing, (2010). “Effect of Class F Fly Ash as Partial

Replacement with cement" IJEMS, Vol 17 pp 140 – 144

8. D.P. Bentz et al, (2010),"studied the evaluation of sustainable high volume fly ash concretes,Cement and Concrete Composites, Vol 33, pp 39-45.
9. G.Carette et.al. (2010)," studied on the early age strength development of concrete incorporating fly ash".Materials, Vol 90(6),pp.535-544.
10. Kazim Turk et.al.(2012)," studied the effect of fly ash and silica fume on Compressive Strength". Construction and Building Materials, Vol 37, pp.326-334.
11. IS: 10262-2009. Concrete Mix Proportioning – Guidelines (First Revision). Bureau of Indian Standards, New Delhi.
12. IS 516:1959. "Methods of Tests for Strength of Concrete". Bureau of Indian Standards, New Delhi, India.
13. IS: 8112:1989. "43 Grade Ordinary Portland Cement – Specifications". Bureau of Indian Standards, New Delhi.
14. IS: 383:1970 (Reaffirmed 1997) Specification for Coarse and Fine Aggregates from Natural Sources for Concrete. Bureau of Indian Standards, New Delhi.