A Study on The Variation of Strength Properties of Concrete With Partial Replacement of Cement Using Nano-Silica (Ns) And Fly Ash (Fa)

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Abstract- *This paper studies the recent investigations and development of combined application of Pozzolanic additions - Nano-Silica (NS) and Fly Ash (FA) on the strength properties of concrete for sub sequential growth of concrete industry. This investigation not only saves the natural resources but also controls the environmental pollution by usage of wastes. The limited work is done on partial replacement of Fly Ash and Nano-Silica in cement paste, mortar and concrete. In the present study the cement is partially substituted by 20% and 30% of Fly Ash and Nano-Silica 2.0%, 4.0% and 6.0% by weight. To understand the application of Fly Ash and Nano-Silica various literatures have been reviewed and their influence on Compressive Strength, Bending Strength (Flexural Strength), Elastic Modulus or Young's Modulus and Tensile Strength of M35 grade of concrete is investigated.*

The experimental investigation results of concrete are tabulated using the combination of various proportions of Fly Ash and Nano-Silica are collate with that of Controlled Concrete. The mechanical strength development and durability properties of concrete are greatly influenced because of this combined application of Nano-Silica and Fly Ash compared to the Controlled Concrete properties. The sustainable increase in the various strength characteristics of concrete prepared using Nano-Silica and Fly Ash can be accredited to the efficacious packing of colloidal particles and the need of additional binder in the application of Fly-Ash and Nano-Silica.

Keywords- Nano-Silica (NS), Fly Ash (FA), Controlled Concrete, packing of Colloidal particles, Compressive Strength, Flexural Strength, Split Tensile Strength, Partial replacement.

I. INTRODUCTION

1-1 GENERAL

Concrete has been recommended as a construction material in wide range. At present in construction, prior to strength, the durability of concrete also has importance. The minimum cement content to satisfy the strength and durability requirements. The Indian standard code of IS 456:2000 for plain concrete design is used. This results in usage of cement in huge content. The cement production results in evolution of lots of carbon dioxide resulting in environment mortification.

By usage of additive Pozzolanic alternative materials instead of cement upto certain proportion will be another solution for this problem. Earlier studies show that the usage of Fly-Ash (FA), Micro Silica (MS), Ground Granulated Blast Furnace Slag and Kaolinite as replaced materials which results in increases in strength and durability. By introducing Nano sized materials as a partial replacement of cement which improves the performance of cement.

Because of many experimental researches on Nano particles, Nano-Silica is available as replacing material of cement in making concrete. Nano-Silica (NS) is a Nano-sized, highly reactive nebulous silica. Because of Nano-Silica particle is as small as other particles and also having very large surface area as the substitute materials, its usage comparatively intensify the concrete performance upto extensive range. This amalgamation of Nano-Silica and fly ash as a substitute material for cement has to be scrutinized. These particles are very tiny and generally allow forming a group of mass due to its large surface influence, consistent dispersion of these fine particles is a predominant thing to get results upto serviceable or advantageous results.

The substitutes of cement i.e., fly ash and Nano-silica which is highly prospective is to be understandable and used in rightful manner. Until last decade a squander material Nano-Silica is now emerged as an environmental protector with its less toxic nature when compared with cement. Now-a-days the CDM technology or Clean Development Mechanism exceptionally encouraged by both cement industries and also government. Advanced counties like United States and Japan are responsible for 35%-40% of global discharges, besides this India accords upto 3.5% of the Green house emissions (GHS) when compared with normal average of 5.5%.

By the end of every year in India with predominant usage of substitute materials i.e., fly ash and Nano-silica the emission of Carbon dioxide are reduced by 30 million tons, coal powder by 20 million tons and lime powder by 35 million tons. The possible levels of this emission of green house gases are to be controlled upto the mark.

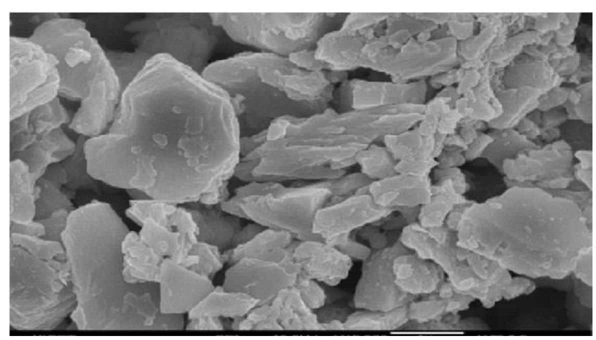
In India prior to usage of cement the Alternative materials are highly used as replaceable materials for partial replacement of cement content in concrete mixture. This Supplementary Cementing materials such as fly ash, Nano-Silica, Blast furnace slag and silica fume are most frequently used. Because of its environmental protective nature and also it's high occurrence the fly ash is taken as a Substitute material for cement. In Thermal power plant due to ignition of coal minerals through pulverization an unintended powdered fly ash is originated. This powdered fly ash is generally inorganic in nature. The ignited ash of the coal accommodated with chemical compositions of iron, silica, calcium and alumina.

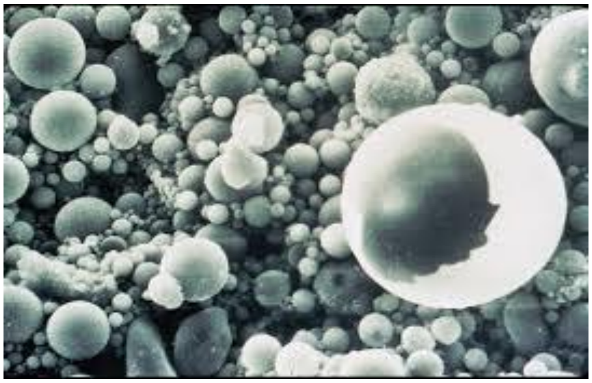
The various stages in Blast furnace ignition of coal, the structure transforms from crystalline nature to non-crystalline nature. The main non-crystalline minerals like mullite ($3Al_2O_3.2H_2O$), Quartz (SiO_2), hematite (Fe_2O_3), wustite (FeO), orthoclase ($K_2O\ Al_2O_3\ 6SiO_2$) and Metallic Iron are formed along with combined silicates which naturally evolves in furnace by ignition of coal. In burnt fly ash 75% -96% of Aluminates and Silicates compositions are predominently occur. On the calcium oxide percentage generally power plants are classified as Class-C (more than 12%) and Class-F (less than 10%). The available fly ash in our country belongs to Class- F. The fly ash that evolved from the ignition of coal furnace generally having crystal or non-crystal nature because of silicate mineral content. This fly ash forms hydrated lime when reacted with H_2O because its calcium content and also elaborate property of Pozzolonic.

Mullite and Quartz which evolved in crystalline stages in fly ash are non-reactive silicate and silica and are generally non-hydraulic. These mineral stages of Mullite and Quartz are the major components. In manufacturing of Fibre Cement Sheets, fly ash is prevailing because of its high pozzolan properties and crystalline structure.

The incombustible property of fly ash is predominant one for its wide usage. In earlier stages when coal is introduced in furnace it is grounded to a fine powder and then flurried into the boiler plant, then the Carbon (C) is swallowed, leaving the liquid materials which are potential in Calcium, Silica and Alumina. Now this liquid particles are very micro sized particles, crystalline and more volatile in nature, so they are to be collected before they tends to escape from the plant and because of this nature it is named as Fly ash. The two common types of Class C and Class F fly ash types are classified by ASTM C618 (American Society for Testing and Materials) as Class-C if $50\%<(SiO_2+Al_2O_3+Fe_2O_3)>75\%$ and Class-F if $(SiO_2+Al_2O_3+Fe_2O_3)>75\%$. The Class-C and Class-F fly ashes reacts with $Ca(OH)_2$ which is emitted from the reaction of cement with H_2O and forms cement like fine powder called Calcium Silicate Hydrate.

In most of the construction projects Class-F fly ash is used. Due to ordinary temperature conditions heat produces while curing of concrete which results in a unique Cementitious material in the mixes of High Strength and Mass Concrete also. So, the Class-F fly ash is a best suitable and recommendable Cementitious material in summer conditions. For the past 7 decades the investigations on the performance of fly ash has been carried out and by its application results itself shows its implementation as substitute. At preliminary phase, Pozzolonic procedure is predominant. Most of Researchers involved for the development of the potential performance of fly ash and the hydration process of substitute materials with cement. Depending on the fly ash properties and their cognition it is seen that the particles Class-F fly ash includes morphology which is quite varying them from normal Pozzolonic particles as shown in Figure 1.





(a) Portland Cement
(b) Fly Ash
Figure1 SEM micrographs (8,000×)

Fly ash has the ideal character of reducing water when compared with other substitute Pozzolonic materials. Both structure of hardened cement and Rheological properties are influenced initially by using fly ash.

The Structural and Surface properties are formed in the mixture due to morphology effect because of crystalline nature of the minerals which are in powdered form. The particle size distribution also occurs because of morphological effect. The three important phases like Filling, Lubricating and well distributing are carried in the concrete because of effect of using fly ash in cement as substitute material. These three phases of concrete depends on shape, size etc. This also impact on properties of concrete.

The further advancements lie in the following features,

1) Assimilating the Fly ash in Concrete which is most commonly used design method deliberately enhances the total quantity of binder in concrete mix and eases the compaction.
2) During the process of hydration of cement heat produces and which can be prodigiously decreased by replacing cement with Fly ash upto certain quantity in concrete mix.

1-2 ORIGIN OF FLY ASH:

For the first time United States of America used Fly Ash as a replacing material of cement in the construction of Hoover Dam. Because of it is a bulk volume construction and also it seems to initiation of Exothermic heat due to hydration of Ordinary Portland Cement was predicted as an issue. There will be deleterious effect on Concrete strength because of heat produced in hydration of cement internally. It is proved experimentally that replacing Ordinary Portland Cement Content with fly ash in concrete mix would give same strength results but the internal heat developed due to hydration of cement can be greatly controlled. Hoover Dam takes 150years nearly to face a cool ambient temperature if Portland cement is replaced with fly ash for the preparation of concrete mix by using this assimilation technique.

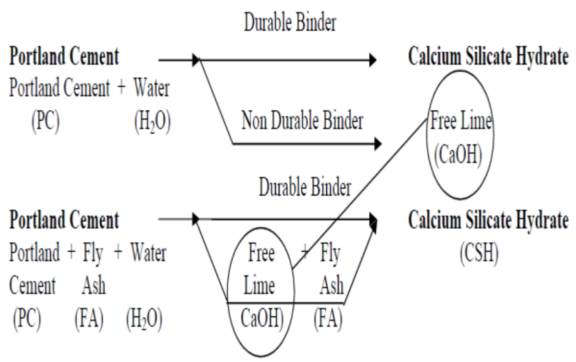
The Detroit Edison Company and Cleveland Electric Illuminating Company carried out using fly ash in the production of concrete mix. In the year 1937 for the first time in the University of California a group of Associates along with Davis carried out preparation of concrete mix using fly ash. Besides a vast investigations carried out to upto 1960s improve usage of fly ash in Construction companies, but a little milestones are achieved in both developed and developing countries. But in India under CBRI-Central Building Research Institute, Roorkee the first study on the using of fly ash in concrete preparation was carried out in the form of Australian and American Research work. While, the using of fly ash in smaller proportion has started in Hydraulic structures and Mass Concreting dams.

Cement is highly Energy intensive one in concrete rather than fly ash. By partial substitution of Portland cement with fly ash can vary the unit cost of concrete exceptionally and this can be done by implementing various admixtures like fly ash. As we know that the fly ash is a waste product of Thermal power plant and also one of the major pollutants of environment, it is unpreferable to dump fly ash which tends to severe environment devastation. To attain required strength and enhances durability the utilisation of fly ash besides dumping it is an advanced idea because of its beneficial features like low water requirement, high workability, appropriate reduction of bleeding and segregation effects.

In Civil Engineering Constructions besides of using many admixtures Portland cement concrete will remain as a major constituent in production of concrete mix. Cement Manufacturing requires huge amounts of calories of energy i.e., about 7.36×10^6 kJ per tonne of cement proportion and also about 1 tonne of CO_2 is emitted and liberated into the Atmosphere during manufacturing of a cement quantity of 1 tonne. Hence, the emission of CO_2 can be significantly controlled by partial substitute of Portland Cement with By-products of mineral industries such as Fly ash, Slag and Silica Fume. To attain technical, ecological and economical aspects fly ash is introduced in concrete production. Fly ash is generally used as siliceous material in concrete to reduce water consumption and produces fine mix of concrete with low hydration.

As per ASTM(American Society for Testing and Materials) C125, is a Siliceous material and Aluminous material which is a non-Cementitious or a partial Cementitious valued one with a finely divided formed and also combines with $Ca(OH)_2$ in the presence of moisture to form a Cementitious compound at ambient temperature. Fly ash is basically used to improves the Strength and Workability and contribute to strength development and hence considered to be an effective ingredient of concrete. It also has been widely used as replacement of cement in both High Strength and normal concrete mix. The preliminary aim of using fly ash is due to its high fineness, which decreases the air gaps (pores) in the concrete mix and improves the compressive strength.

The following equation shows the difference in reaction when fly ash is introduced.



The unstable state of Al_2O_3 and SiO_2 in fly ash are made active using the product $Ca(OH)_2$ which liberated from the hydration of cement due to Pozzolanic effect of fly ash results in the formation of hydrated gel. The air gaps or pores present in the concrete are to be filled by this hydrated gel produced which results in the predominant increase in strength of concrete and also often leads to the generation of long-term strength to concrete. Dumping the waste mineral products of Thermal power plant to the environment can cause severe effects, so that the usage of waste material has been given special importance. The waste By-products are to be utilised to produce new products or used effectively as the natural admixtures for the environmental protection.

For concrete fly ash can be treated as a valuable admixture and it influences fresh and hardened concrete in many properties. The environmental pollution proportion that evolves through the Thermal power plant can be deliberately controlled by using this power plant waste as a substitute material for concrete in construction.

The permeable nature of Concrete is drastically declined by using Fly Ash because of the formation of hydrated gel (Calcium Silicate Hydrate) C-S-H. A partial replacement upto 20%-30% of fly ash to Ordinary Portland Cement would give preferably fair results in fresh state of concrete. Because of its fine, Spherical and smooth shape of fly ash particles the workability property improves in fresh state of concrete.

The spherical surfaces of fly ash balls tend to ease flow of concrete. To attain greater Compressive Strength the water-cement is lowered by its improved workability nature. Meanwhile, in hardened state the strength and durability of concrete increases gradually this is completely based on increase in the setting time of concrete. The harder C-S-H hydrated gel is formed during the chemical reaction because of the Pozzolanic reaction separate the excess $Ca(OH)_2$.

1-3 Fly Ash effects in concrete

Besides of some merits the Class-F fly ash usage have some effect when they are used in roller compacted concrete method:

1. The High Fly Ash Roller Compacted Concrete (HFRCC) has low strength at initial stages of compaction of concrete and deceases with raise in Fly ash content because of its Pozzolanic reaction.
2. The consistent development in the strength of Fly Ash Roller Compacted Concrete (HFRCC) are attained by activating more quantities of fly ash Following the curing age, greater amounts of FA.
3. By Super-Substitution method and by imparting Fly ash more content makes Fly Ash Roller Compacted Concrete (HFRCC) quick to compact, and then the crystalline state of Ca $(OH)_2$ and also permeable property reduction.
4. Fly Ash Roller Compacted Concrete (HFRCC) are homogeneous and normally very dense compounds. The flexural strength of the inner structure increases rapidly because of this very dense nature which is more important than the compressive strength to concrete.

1-4 NANO SILICA

In the present days the micro-level does not provide enough insight into the building materials. Therefore, all around the world, the research is being diverted into the nano level, which is claimed to have tremendous potential for the future. The fundamental processes that govern the properties of concrete are affected by the performance of the material on a nano scale. The main hydration product of cement-based materials, the C-S-H gel, is a natural nano-structured material.

For the creation of huge materials a technology based on the usage of minute particles which are nano sized are used by manipulating them. It is important to check whether the particle size usually in the order of ≤100nm because the particle size i.e., nano (10^{-9}) may affects the properties of materials. The technology of using nano sized particles is not a present-day technology, as we know it exists few decades ago by the continuation of technologies along with science which are rapidly developing on analysis of nano sized, micro sized and other smaller particles as shown below,

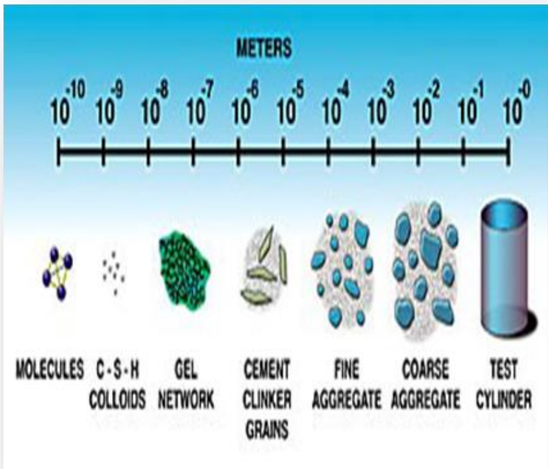


Fig.2 Particle Size variation

1-4-1 HISTORICAL BACKGROUND OF NANO SILICA

Early in the 19^{th} Century Richard Feynman confronts with the idea of using Nano-Silica and later in 1980s Dr.Eric Drexler, who had very deep investigation on Nano-Silica promotions in Civil Engineering through speeches and in books also.

For huge extent, the creation of massive structures within a limit of 100nm are enable through this technology, which includes wire fabrications having enormous advancements in Semi conductors, electronic beam, Lithography, Imprint Lithography, Atomic Layer Depletion and as well as Molecular Depletions which tends to the advance techniques which are developed by using nano sized particles in creating huge structures and also by rapid advancements occurs in scientific researchers are also concluded this nano-technique as a unique purpose for new era development.

1-4-2 Application of Nano Technology in concrete

The inclusion of Nano Technology in concrete preparation is to implement the Nano sized particles in the form of Fibres or in silicates form. Due to addition of these Nano-sized particles exhibits some quality results in the properties of concrete. The rate of hydration of cement in Concrete is rapidly advances through the application of Nano-Silica. By the formation of C-S-H gel the Calcium Hydroxide in the cement hydration product are reduced and formation of C-S-H gel simultaneously increments the strength properties of Concrete specimens.

The air gaps or porosity in the concrete specimen is rapidly declined with the application of Nano-Silica and which results in the partial cement replacement also because of the Micro crystalline structure formation. The concrete failure properties of Bleeding and Segregation of concrete specimen are eradicated with the formation of cohesive bonds between the particles of Nano-Silicates and C-S-H gel in concrete. The casting specimen curing period, higher workability of concrete with more than $100N/mm^2$ and also Bleeding conditions are controlled with the appliance of Nano-Silica in Concrete as cement replacement.

To control environmental devastation conditions with the enormous cement usage and also to control the wastes or by-products resulting from the Thermal industries such as Fly Ash and Furnace Slag are initiated as a replacing materials of cement in concrete preparation. The problem of decreasing Compressive Strengths of concrete and also late curing periods or higher setting time can be controlled by using Nano-Silica which in return improves the durability and workability of concrete.

1-4-3 Nano Silica (NS) Extraction

Drastically huge products are manufacturing from the Silica products for industrial usage now-a-days. For concrete thickness, reinforcement and also for levelling flat specimens these Silicates are enormously used. By the year 1999 the world witnessed that the products of Silica are about 1105 Kilo Tones. The very distinct techniques are adopted to produce the Amorphous natured Silicates. The order of 10^{-9} is for Nano particles are in the one dimensional manner despite we know that the order of DNA is about 2 Nano meters and also for the human hair it is 10^{-4} Meters.

Nano-Silica (NS) is produced by two distinct methods. One of the best methods for this Nano-Silica (NS) production is using SOL-GEL process which is an organic solvent at optimum temperature. By using this method the initiative constituents like Sodium Sulphates and Metallic-organics like Tetra-Ethoxysilicane [TEOS] and Methoxy-Tetra Silicane [MTOS] are dissolved in the organic solvent and then the pH of the dissolved one is a change from its original nature to a gel which is of the silica natured. And now XERO gel is formed by thorough mixing of this silica gel.

By further burning and drying of this XERO gel with Nitrogen, Potassium and Ammonia (Stabilized form) to require concentration will be advisable for usage in concrete.

Precipitation, Biological and Thermal furnace methods are the remaining process to extract Nano-Silica (NS). A $1500\text{-}2000^0$c vapourization method is also suitable method for Nano-Silica (NS) production.

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

Because of its nature the Nano-Silica (NS) tends to accelerate the Hydration process of cement. Cement replacement with Nano-Silica will improve the strength properties also. The spherical shape of Nano-Silica (NS) fills the air gaps in the concrete specimen which results in the improved structure of concrete specimen with more durability and non-permeable nature. Because of the gaps filled with Nano-Silica (NS) the density of concrete specimen is increased and also the Compressive Strength of concrete improves. The two failures conditions of Segregation and Bleeding are controlled with increase in workability of concrete with usage of Nano-Silica (NS). The Early stage cracking occurs in concrete due to low workability is also lowered with the Nano-Silica application in Pavement Design.

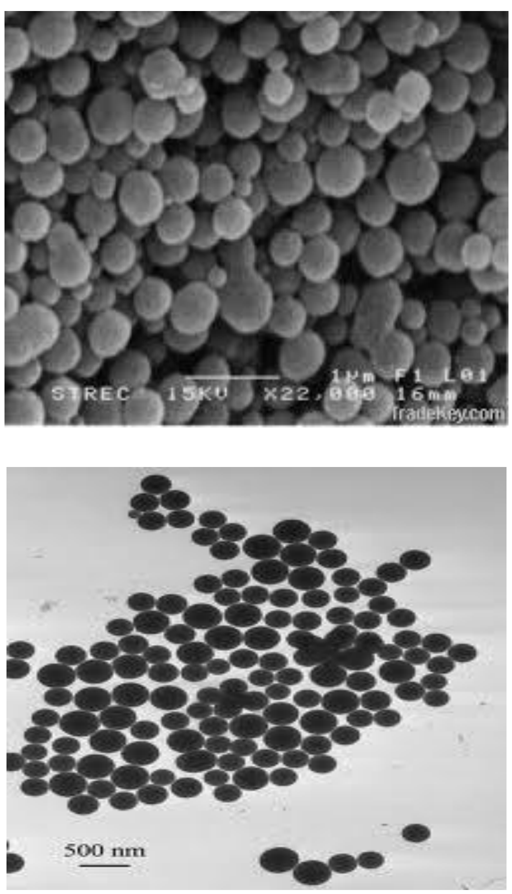


Fig: 1.3 Nano-Silica (NS) with Spherical Shape

1-5 Objectives of the Study

The present study of Cement replacement using Fly Ash and Nano-Silica (NS) has the following objectives:

- The variation in the strength properties of concrete like Flexural Strength, Tensile Strength, Compressive Strength and Modulus of Elasticity are carried out with Fly Ash (FA) application only.

1-6 Scope of the Research Work

The Scope of the present study is

1. To carry out the preliminary tests on Cement, Fine Aggregates and Coarse Aggregates.
2. Mix design of M35 Grade concrete is done and proportioning of ingredients to concrete.
3. Binder formation (Cement +Fly Ash (FS)) ratio was considered as 0.45 water content.
4. The size cubes of 150 mm× 150 mm × 150 mm were casted and underwent curing for the determination of the strength properties of concretes at 7, 28 and 56 Days of curing.
5. Fly Ash content of 20% and 30 % are used as the total Cementitious content.
6. Nano Silica dosages used are 2.0 %, 4.0%& 6.0% of the total Cementitious content.

1-7 Thesis Organization

This study consists of following chapters:

1. Chapter1: Mainly presents a brief introduction of the research work, Objectives and scope of the present study.
2. Chapter2: Presents a inclusion literature review on cement replacement and also strength development of concrete with using Nano-Silica (NS) and Fly Ash (FS) are reviewed. Partial information gathered on the effect of Nano-Silica (NS) is reviewed.
3. Chapter3: Presents the Properties of constituent materials and substitute materials used for concrete specimen.
4. Chapter4: The Mix Design of M35 Grade of concrete as per IS codal provisions.
5. Chapter5: Detailed presentation of Concrete specimen preparing, curing and testing is mentioned.
6. Chapter6: This chapter mainly deals with the experimental investigation reports on various strength properties of concrete.
7. Finally, Chapter 7 encapsulates conclusions drawn based on the investigations.

II. LITERATURE REVIEW

2-1 GENERAL

Now-a-days the Substitute Pozzolonic materials are widely used by the researchers and common users to attain greater strength at curing stages. By using the By-products of Thermal industries and also by some other advanced technologies of using waste products are encouraged vastly. The industrial By-products like Nano-Silica (NS) and Fly Ash (FA) are used for the development of strength properties and also to improve the durability of concrete. One of the investigation techniques to reduce the cement quantity in concrete preparation is by using Fly Ash (FA) and Nano-Silica (NS).

The experimental investigations carried by various researchers on replacement of cement using Nano-Silica (NS) and Fly Ash (FA) are presented in the following literature review.

2-2 REVIEW OF LITERATURE

"THOMAS ET AL. [1999]" - The first ever researcher to reported that the Concrete strength decrement at early stages, but slight increases at curing periods. And also he used Silica-Fume a waste By-product as a replacing material to improve strength properties and given the report that the using Silica-Fume the results are better at earlier stages and with further increment in content of replacing material may gives same results without replacing materials especially at later stages. Hence, he suggested that the replacement of cement with Fly Ash (FA) and Silica-Fume (SF) is an improved technique for strength development.

"BENTZ. D ET.AL [2010]" – Reported about the Fly Ash usage in high volumes in concrete. These experimental tests are compared with the Controlled Concrete and Fly Ash replaced contents of 15-70% and are attained a target slump test value of 200mm ± 5mm. He used super plasticizers to control the water content upto optimum level and attain a reduced water contents to 18% for water cement ratios of 0.45, 0.5, 0.6 and 0.65. The Fly Ash replaced content, Setting periods and strength results are compared for both Controlled concrete with the replaced concrete at 7, 28 and 56 days of curing.

"JAGADESH S [2006]" - Reported the merits of using Fly Ash as Supplementary Cementing Material (SCM) in Fibre cement sheets. Fly ash containing fibre cement sheets exhibits low early strength even at an optimal dosage of 12-25%. Various procedures that is suitable to increase the percentage of Fly Ash by calcium – enrichment and application of calcium on to coal while burning process itself.

"CARETTE.G ET.AL [2010]" – For the research regarding early ages strength development he used a combination of Silica Fume and Fly Ash in condensed state. The present investigation carried has given the results that on early stages of concrete with 30% of Fly Ash may develops strength with low amounts of Silica Fume addition. The quantities of Silica-Fume added are ranging from 0-20% by the weight of the cement and Fly Ash.

"QUERCIA GEORGE ET.AL [2012]" – He studied the behaviour of Self Compacting Concrete with inclusion of Amorphous Nano-Silica (NS) on durability and mechanical properties. The permeable pores in the concrete specimen have been reduced and also a greater strength increment in Compression is observed with the addition of Nano-Silica (NS) because of the formation of C-S-H gel which inhibits the hydration process. This Nano-Silica (NS) application in Concrete is investigated at Fresh state of concrete for workability and later i.e., hardened state for workability. The air gaps between the concrete particles are filled by the spherical Nano particles which results in the increment in density of concrete. By this study he concluded that by the application of Nano-Silica in Self Compacting Concrete (SCC) may greatly improves the strength and durability properties.

"**LANGAN ET.AL [2012]" –** He carried his study on the hydration of cement by using Fly Ash and Silica-Fume as replacing substituents. After successful completion of research he tabulated the results from the Calorimeter tests on cement. At high water-cement ratio the Silica-Fume accelerates the hydration process and at low water-cement ration it retards the hydration process. But it is observed that Fly Ash retards the hydration process at high Water-cement ratio and accelerates at low water-cement ratio. But when both combined application of Silica-Fume and Fly Ash will retards the hydration process at water-cement ratios of 0.4, 0.45, 0.5 and 0.6.

"KAZIM T ET.AL [2012]" – For Self Compacting Concrete (SCC) by the application of both Fly Ash and Silica-Fume the variations in the Sorpitivity, Carbonation and strength properties are investigated in this research. By the proportions of 20%, 25%, 35%, 40% of Fly Ash (Class-F) and 5%, 10%, 15% and 20% of Silica-Fume which may affects the permeability of concrete. By this investigation he given the report that the Self Compacting Concrete specimen with Silica-Fume content with 15% may attains the higher strength in Compression with 78.90 N/mm^2 at 150 days.

III. MATERIAL PROPERTIES

3-1 GENERAL ASPECTS

In general concrete is widely used construction material which comprises of cement, Fine aggregates, coarse aggregates and water. Due to hydration of cement the stronger mass is formed with cement and water paste. The voids in the cement and water paste is filled by the both coarse and fine aggregates.

We know that the plastic nature of cement tends it to mould in any form easily. So, the moulded cement can be smoothened using a trowel. Major precautionary steps are to be followed to control the rapid loss in water content and also to avoid pores in concrete which results in decrement in strength. The two affects of Segregation and bleeding are controlled in concrete. The cement and water paste only defines the quality of the concrete specimen. The proportions which we use in mix design are also plays an important role in determining the characteristics of concrete. An air gaps retarding agent is to be mixed with this so that the pores in the concrete can be eradicated which results in density increment.

3-3 FINE AGGREGATES

Available sand from Local River confirming to IS: 383-1970 was used as fine aggregates in concrete preparation. The fine aggregates passing through 4.75mm IS sieve is utilised as shown in table-2 and sieve analysis is shown in table-3,

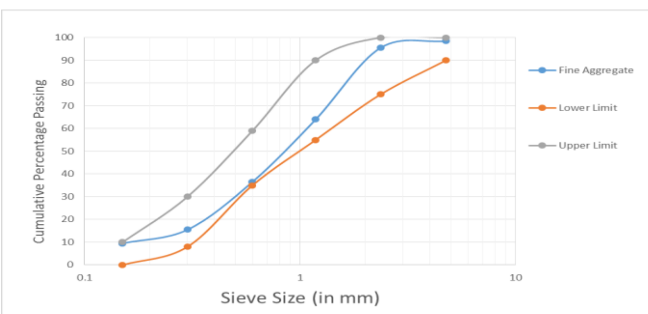


Figure 4 Particle-Size distribution of Fine Aggregate (Zone-II)

3-4 COARSE AGGREGATES

Coarse aggregates of nominal sizes 20mm and 10mm locally accessible demolished stone acquired from the quarries confirming to IS383-1970 was utilized in the proportion of 1.5:1.0 as shown in table-4

3-5 WATER

Water used for casting and curing of concrete specimens should be free from all types of contaminants like alkalis, salts, acids, organic matter, oils and other pollutants. The water with impurities can adversely influence the strength properties of concrete.

3-6 FLY ASH

For the present investigation Fly Ash of "Class-F" obtained from the Thermal Power plant is used. The Fly Ash proportions of 20% and 30% by weight of cement are used. The Physical properties of Fly Ash are as shown in table-5

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

Nano-Silica utilised in this investigation is a Pozzolanic colloidal silica emulsion. It is a better Pozzolanic material because of its high content of Amorphous Silica (>99%) and also their reduced spherical size of order 15 nano meters-50 nano meters.

In our present investigation we used the Nano-Silica contents as 2%, 4% and 6%. The properties of Nano-Silica is shown in table-6.

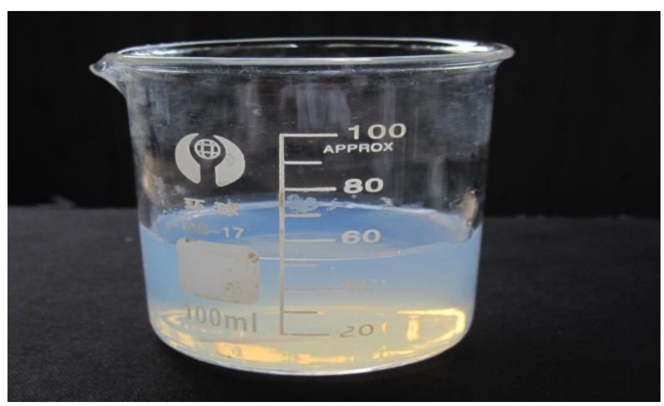


Fig 6 Nano-silica sample

IV. MIX DESIGN

4-1 GENERAL ASPECTS

In this study the proportions of various concrete constituents elements required to form a concrete of required durability, strength and workability. It is design economically as high as possible. The two stages of Plastic and Hardened states of concrete with proportions of cement, Fine aggregates, coarse aggregate and water are calculated. At low workability state it is properly vibrated and compacted to optimum workability.

Based on Quality and Quantity of ingredients to form concrete are generally considered from the compressive strength of concrete and the proportions of water, aggregates of Fine [FA] and Coarse aggregates [CA] are attained. The manufactured cost of concrete is based on the material cost, labour force and batching plant. It is preferable to change cost of concrete is done only by reducing the cement content.

The characteristic strength of concrete is related to the cost of concrete specimen. One of the main thing i.e., quality control maintained while mixing also influences the cost of concrete. The major cost of concrete is depends upon the size and shape of the aggregates. the workability is maintained to control cost of concrete mix which also depends on the compaction value.

4-2 MIX DESIGN

Codal provisions and requirements of Mix design

The following are the steps to be followed while selecting the ingredients for mix design are:

a) For structural provision the minimum Compressive Strength is to be considered.
b) For optimum compaction the required workability is attained.
c) To get optimum durability the W/C ration and cement quantity is found.
d) The various factors that affect the concrete are to be identified and rectified.

The various factors affecting the mix design are:

(i) Compressive Strength:

The concrete main property i.e., compressive strength may affects the other factors of Mix design at hardened state. For nominal W/C ration the minimum or mean compressive strength at 28days of curing age is found. The degree of compaction is also of the factor that influences the strength of concrete. But as per Abraham's law of strength and water-cement ratios are inversely proportional.

(ii) Degree of Workability:

Size, Steel reinforcement and compaction techniques are the three factors on which the workability factor depends. The full compaction in case of very narrow sized reinforced section can be attached only to get workability to optimum. For the Embedded mild steel sections are also based on workability only and also depend on the method of compaction.

(iii) Durability of Concrete:

The main property of the concrete i.e., resistant to the aggressive environmental situations are rely on the durability property. Durability in case of low strength concrete is low and in case of High strength concrete of high durability. But in some cases of high strength is not only required but also exposure condition is needed for more durability nature and also based on the W/C used.

(iv) Nominal Size of Aggregates:

The maximum size of aggregates is one of the important aspects on which the workability of concrete depends. It is investigated that the workability of concrete is increases gradually with the size of aggregates for smaller water-cement ratio.

The nominal provisions of aggregates are confirming to the codes of IS 456:2000 and IS 1343:1980 shows that the maximum sizes of aggregates are preferred.

(v) Aggregate grading and type of aggregate:

In some cases the workability and water-cement ratio of particular grading influences. For Lean mix of concrete the coarse aggregates are preferred than very lean mix is not advisable because of its finer material to make a specimen of concrete.

Aggregate selection also plays a vital role in the strength properties, workability and also water-cement ratio. By uniform grading only the mix design can be accurate for different sizes of aggregates.

(vi) Controlled concrete:

The variation in the test results are mainly depends upon the degree of control. Because of the proportions of mix ingredients, batching, curing, testing and mixing which varies the strength properties of concrete. The factor controlling this difference is termed as quality control.

4-3 MIX DESIGN OF M35 GRADE OF CONCRETE

Table 7: Proportioning of M35 grade concrete mix

Type of Cement	Ordinary Portland Cement 43 Grade
Maximum Nominal size of Aggregate	20 mm
Minimum content of Cement	340 kg/m³
Maximum Water Cement ratio	0.45
Specific Gravity of Cement	3.15
Specific Gravity of Fine aggregate	2.70
Specific Gravity of Coarse aggregate	2.65

Target Mean Strength

V. EXPERIMENTAL INVESTIGATION

5-1 GENERAL ASPECTS

Our present study mainly discuss about the various strength properties like Compressive Strength, Tensile Strength, Flexural Strength and Modulus of Elasticity for M35 Grade of Concrete with partial replacement of cement by using Nano-Silica (NS) and Fly Ash (FA). The proportions suggested for the present investigation are Nano-Silica with 2.0%, 4.0% and 6.0% and Fly Ash 20% and 30% for making concrete specimens by weight of cement.

5-2 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.

5-3 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.

5-3 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.

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

5-4-1 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.

5-4-2 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

5-4-3 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

5-4-4 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.

VI. RESULTS AND DISCUSSIONS

6-1 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.

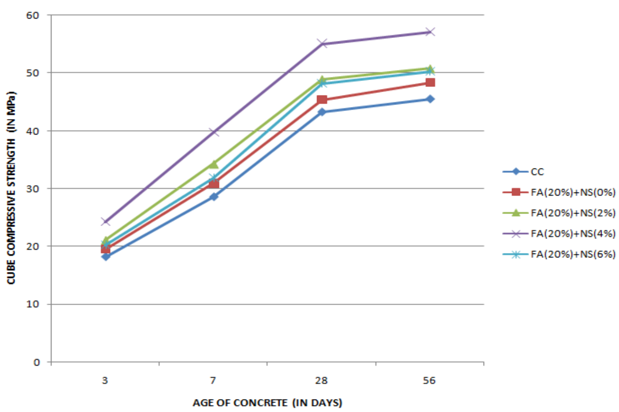
6-2 RESULTS AND DISCUSSION

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:

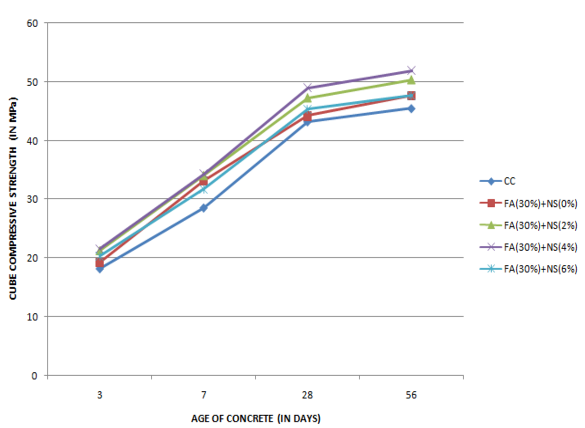
6-2-1 COMPRESSIVE STRENGTH

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



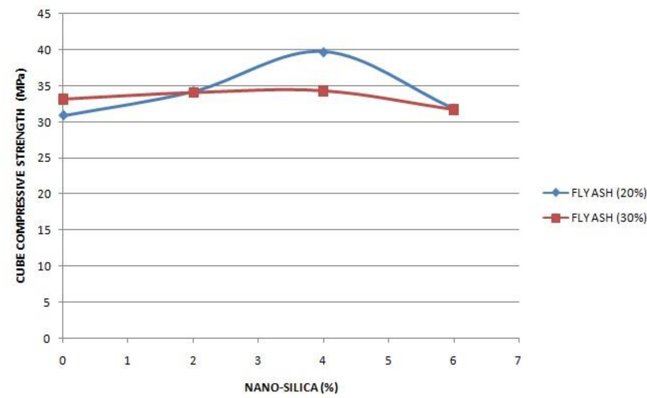
(a) Fly Ash (20%)



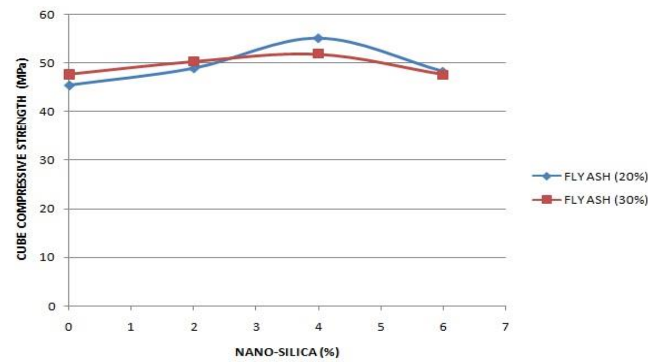
(b) Fly Ash (30%)

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.

6-2-2 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.

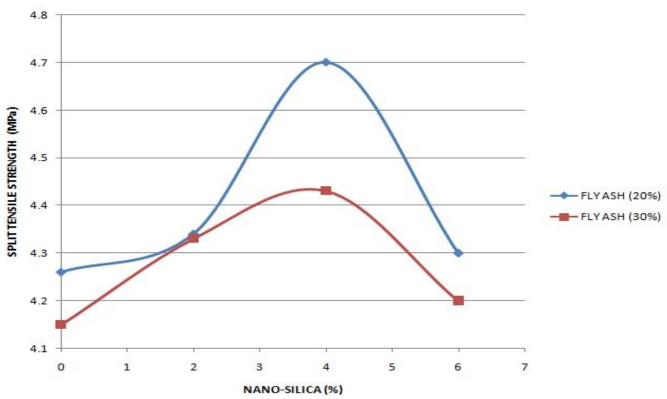


Fig:9 Graphical variation of split tensile strength of M35grade concrete for various mix proportions of Fly ash and Nano-Silica.

6-2-3 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

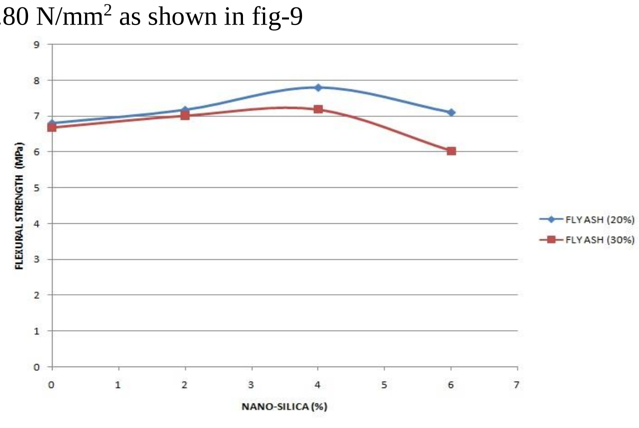


Fig: 10 Graphical variation of Flexural strength of M35grade concrete for various mix proportions of Fly ash and Nano-Silica.

6-2-4 MODULUS OF ELASTICITY

The experimental investigations on the Modulus of Elasticity for M35 grade concrete mix with varying proportions of Fly ash and Nano-Silica are mentioned in the table-11. It is shown that the Modulus of Elasticity for controlled concrete is 32.88GPa.

The increase in the Modulus of Elasticity with Fly Ash (20%) and Nano-Silica (4%) is 4.22GPa and it is the maximum value attained. If this proportion further increases to 6% of Nano-Silica then the Modulus of Elasticity decreased to 34.73MPa as shown in fig-10.

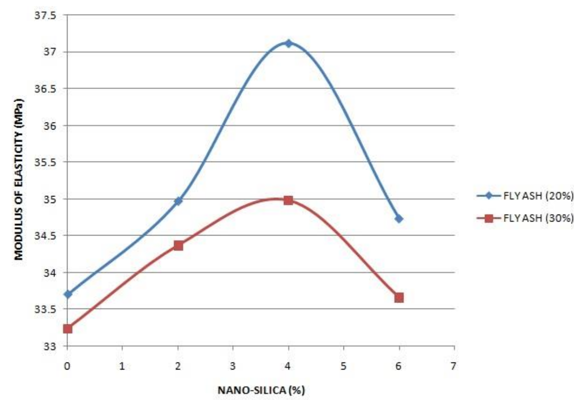


Fig: 11 Graphical variation of Modulus of Elasticity of M35grade concrete for various mix proportions of Fly ash and Nano-Silica.

VII. CONCLUSION

- From the investigation results i.e., a partial replacement of cement with Fly Ash and Nano-Silica it is studied that various strength properties of concrete mix increases upto 4% application of Nano-Silica content and decreases with further increment.
- It is quite enthusiastic observation that the changes occurred in the strength properties like compressive strength, tensile strength and flexural strength with change in cement proportion.
- Due to the presence of additional binder which is formed by the combination of Fly ash and Nano-Silica with Calcium hydroxide substantially increases the strength properties of concrete.
- Because of additional binder formed in concrete due to the Pozzolanic additives tends to form a paste-aggregate bond which leads to increment in the strength properties of concrete.
- The partial replacement of Fly ash and Nano-Silica tends to give maximum increment in strength properties at Fly ash content 20% and Nano-Silica content 4%.

- But the decrement in the strength properties with increase in Nano-Silica content is due to the formation of poor quality binder.

VIII. SCOPE OF FUTURE WORK

The influence of Fly Ash (FA) and Nano-Silica (NS) are investigated on strength properties of concrete and also durability. This study also helps further to investigate the Resistance impact on concrete using Fly Ash (FA) and Nano-Silica (NS).

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