Investigation on Properties of Concrete with Addition of Nano Silica and Partial Replacement of Cement with Fly ash

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Abstract **- Workability is one of the physical parameters of concrete which affects strength and durability as well as cost of labour and appearance of the finished product. It is a vital property of concrete that must be measured correctly to ensure good quality concrete. This research study is directed towards exploring the pullout test as an alternative test for workability of fresh concrete. The study measured the slump, compacting factor, and pullout strength for fresh concrete with water/cement ratios of 0.3, 0.4, 0.5, 0.6, 0.7 and 0.8 representing very low, medium and high workability. Result showed that a pull-out strength of 72 – 94N/mm2 is required for concrete of very low degree of workability while pull-out strength of 62 – 65N/mm2 is required for concrete of high degree of workability in accordance with the requirement of Road Note No. 4. The result was validated by comparing measured and calculated compacting factor. The average ratio of calculated and measured compactive factor was found to be 1.01. The calibration of calculated and measured compacting factor resulted in coefficient of determination R2 of 0.998. These results indicate that pull-out strength is a good predictor of compacting factor and by extension workability of fresh concrete. The simple pull-out test was recommended as an alternative test to compacting factor, slump, and V-B consistometer tests in measuring workability of fresh concrete.**

Index Terms **- Fresh Concrete, Workability, Pull-Out Strength**

I.INTRODUCTION

Concrete can be considered as the most widely used material in the construction industry. In the present-day construction practice, along with the strength equal importance is given to the durability of concrete. The Indian Standard Code of practice for plain and reinforced concrete recommends the minimum cement content to satisfy the strength and durability requirements. Hence, the usage of cement is increased. But the cement production consumes large amount of energy and emits carbon dioxide results in environmental pollution. Hence the best solution to overcome the environmental effect is to reduce the usage of cement and Pozzolona materials for the manufacturing of concrete. Previous studies indicates that the use of Fly-Ash(FA), Micro Silica(MS), Metakaolin (MK) and Ground Granulated Blast Furnace Slag(GGBS) as partial replacement of cement reduces the cement consumption and also increases the strength and durability of concrete. To improve the performance of concrete further, Nano materials are also now being introduced as supplementary materials. The adoption of Nano Technology is basically due to the availability of Nano Silica which is made of supplementary materials in the concrete. Nano silica is a fine amorphous material which is better than the Pozzolanic materials. it is generally available in the form of emulsion of colloidal silica. By using Nano silica, the cement content may be reduced and also it prevents in early cracking of concrete in the pavement structure. Nano silica improves the microstructure and makes concrete more impermeable and more durable. As it produces a dense concrete, compressive strength is increased. In addition, it reduces segregation and bleeding.

Developed countries like US account for 30 % of global emissions, while India contributes about 3 % of the global Green House Gases (GHS) against the global average of 5.2 %. Use of fly ash in various products and partly substituting cement at current annual levels in India reduces the generation of CO_2 by 25 million tons, good quality lime by 35 million tons and coal by 15 million tons per year. Fly ash and silica fume falls under the category of supplementary cementing materials which are highly used in India as the partial replacement of cement and as well as admixture. Selection of fly ash as SCM for the cement is due to its availability and to protect environment from pollution.

Silica fume has been deemed on of a generation of construction materials. Structures ranging from the Tjorn Bridge in Sweden to the Kinzua dam in the U.S. have been built or repaired using these materials. Silica fume concrete plays an important and vital role in civil engineering profession. The first test of silica fume in concrete was held at the laboratories of the Norwegian institute of technology in 1950 which was reported by Sellevold and Nilsen, 1987.In 1952 silica fume was used in the field for the Blindtarmen concrete tunnel in Oslo. This tunnel was exposed to acidic and high sulphate water in the Oslo alum-shale region (Sellevold and Nilsen in1987, Buck and Burkes in 1981)

The first documented use of silica fume in structural concrete took place in Norway in 1971 (Sellevold and Nilsen,1987).With the start of large scale use of filters in the mid of 1970's for environmental regulation and protection purpose ,the use of silica fume in concrete spread to other countries such as Denmark, Sweden and Iceland. Reports of its use appeared in the United States and Canada in the late 1970s and early 1980s (Sellevold and Nilsen, 1987: Mehta and Gjorv, 1982: Malhotra and caratte, 1983: Sheetz etc. al., 1981).By then in Canada, silica fume is used in all commercial applications as a ready mixed concrete

Silica fume is a mineral admixture composed mainly of very fine amorphous silicon dioxide (SiO_2), which is present as individual spheres with a number of agglomerates. Most of the silica fume particles are smaller than 1 micron in diameter, and the majority range in size from 0.01 to 0.3 micron with an average diameter of 0.1 micron. Silica fume particles are 50 to 100 times smaller than cement or fly ash particles. Surface areas range from 1700 m2/kg to 2500 m2/kg, although 2000 m2/kg seems to be the most common figure associated with silica fume used in concrete. The surface area of silica fume is much larger than that of plain Portland cement and fly ash (typically 300-600 m2/kg).The specific gravity of silica fume is usually 2.2, lower than Portland cement (3.10-3.23) and fly ash (2.4-2.7).

In general, silica fume tends to increase the strength of concrete due to the modification of transition zone between cement paste and coarse aggregate by a more homogenous and dense paste comprising amorphous calcium silicate hydrate(C-S-H).Since water helps to form the strength giving the turbulent gel, the quality and quantity of water are to be observed during the process. As water universally naturally available solvent, that can contain a large number of impurities ranging from less to high concentrations.

Fly ash is one of the most extensively used by-product materials in the construction field resembling Portland cement (Pfeifer, 1969). It is an inorganic noncombustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace (Halstead, 1986).

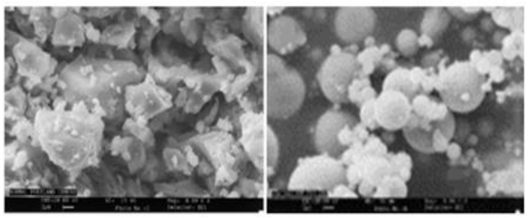
Many class C ashes when exposed to water will hydrate and harden in less than 45 minutes. In concrete, class Fly ash is often used at dosages of 15% to 25% by mass of cementations material and class C fly ash is used at dosages of 15% to 40% (Halstead, 1986). Dosage varies with the reactivity of the ash and the desired effects on the concrete Because of their spherical morphology, when using fly ash admixtures as replacement for cement, workability and long-term strengths are achieved in concretes. In such cases, they act like small balls to reduce inter particle friction.

Fly ashes are also used in concrete mixes in order to reduce the heat of hydration, permeability, and bleeding. The durability is improved by providing a better sulfate resistance, control of the alkali-silica reduction, decreased chloride diffusion and reduction in calcium hydroxide (which is most of the hydration products) and changes in pore structure. However, there are some disadvantages related to the use of fly ash regarding the reduced air entraining ability and early strength due to the influence of residual carbon from the ash (Gebler and Krieger, 1986)

Generally, there are two kinds of fly ash i.e, class F and class C. in India production of class F fly ash is highly manufactured. According to ASTM C618, fly ash belongs to Class F if ($SiO_2+Al_2O_3+Fe_2O_3$) > 70% and belongs to Class C if 70% < ($SiO_2+Al_2O_3+Fe_2O_3$) > 50%.By the process of Pozzolonic reaction with lime these two kinds of fly ash will react with cement and water to form calcium silicate.

Class F fly ash was used in the project work. Class F is the solution to a wide range of summer concreting problems because it is considered as an ideal cementations material in which it attains high strength during concrete curing. Many researchers had paid attention in the investigation of fly ash.

With its application, the action mechanism of fly ash has been recognized. During the initial stage, only its Pozzolanic activity is paid attention. Many researchers devoted themselves to the research of the potential activity of fly ash and the hydration process of fly ash cement. With the deepening of the cognition for fly ash properties, it can be observed that the particles of fly ash have the morphology that is different to other Pozzolanic materials as shown in Figure.



(a) Portland Cement (b) Fly Ash

Figure1.1. SEM micrographs

It is the unique particle morphology to make it have the ability reducing water, which other Pozzolanic materials do not have.

The specific improvement lies in the following aspects:

1. Incorporating FA by the method of super-substituting, a widely used design method, effectively increases the total amount of binder in concrete and makes it easier to compact.
2. Substituting Fly Ash for a part of cement in concrete can remarkably decrease the quantity of heat produced by cement hydration.

II. LITERATURE REVIEW

Now a days the concrete researchers and users are taking advantage of secondary cementations materials to give concrete of greater strengths. One of the newest technologies to break into the concrete design area is the use of industry by-products nanoparticles in the concrete matrix. By using industrial by-products nanoparticles, the development of the strength bearing crystals of cement paste can be increased. A method to reduce the cement content in concrete mixes is the use of fly ash and nano-silica.

The investigations carried by various researchers on the use of fly ash and nano-silica are presented here.

JAGADESH.SUNKU (2006) had studied the advantages of use of fly ash as Supplementary Cementing Material (SCM) in Fibre cement sheets. Fly ash is a mixture of fiber cement sheets which exhibits an early strength at an optimum dosage of 10 to 20%. This increase in amount of fly ash is generally done by the process of calcium enrichment. There are two different kinds namely.

1. Calcium is directly introduced during burning of coal.
2. The other method is which it can be used as additive.

Rather the effects of calcium on both the process were investigated. In the investigation, calcium enrichment of fly ash is done by using additives such as hydrated lime and gypsum. A dosage of 30 – 35 % of calcium enriched fly ash can be used as replacement to cement in the production of fibre cement sheets.

D.P. BENTZ et.al (2010) studied the evaluation of sustainable high-volume fly ash concretes. The results were compared with the controlled concrete and mass substitutions of cement by fly Ash between 15% and 75%, and a target slump of 200 mm ± 20 mm. The total water content was minimized through the use of an optimum Super Plasticizer dosage that resulted in water reductions of 18%, 15%and 11% respectively for the reference mixtures of w/b = 0.5, w/b = 0.55, and w/b = 0.6, which tends to the same percentage reductions of cement. Correlations between the fly Ash substitution and slump loss, setting times, compressive strength, and static modulus of elasticity (E) were established and they represent very useful tools for the practical applications of the results. Compressive Strength development up to an age of 56 days are also reported, as well as correlations between the modulus of rupture and Compressive strength or splitting tensile strength at an age of 28 days.

Vanitha Aggarwal et.al (2010) studied the concrete durability through high volume fly ash concrete. The results showed that fly ash in concrete reduces the compressive strength at early ages but there is a drastic increase in the compressive strength at later ages. By increasing the percentage of partial replacement of cement, the strength at early stage is reduced. It is observed that the later age strength of concrete having more than 40% replacement of cement by fly ash suffers adversely though water/ binder ratio is gradually reduced. The compressive strength of concrete at 28 days is higher if the replacement of cement is higher than 40%. By using more than 40% of replacement of cement the strength at 28 days is lesser, meanwhile when the age of concrete is increased the strength is also increases at 90 days.

G. Carette et.al. (2010) studied on the early age strength development of concrete incorporating fly ash and condensed silica fume. Early-age strength development of concrete in which part of the Portland cement has been replaced by low-calcium fly ash tends to be slow, because fly ash acts as a relatively inert component during this period of hydration, though at later ages it contributes significantly to strength development. It was considered that the problem of low early-age strength of Portland cement-fly ash concrete could be overcome by the incorporation of small amounts of condensed silica fume, a very fine and more rapidly reactive Pozzolan. This report presents the results of an investigation on the early-age strength development of concrete incorporating 30% low-calcium fly ash, and to which small amounts of condensed silica fume have been added. The amounts of the fume ranged from 0 to 20% by combined weight of the Portland cement plus fly ash. A total of thirty 0.06-m3 concrete mixtures with water-(cement + fly ash) ratios ranging from 0.40 to 0.80 were made; 240 cylinders were tested in compression and 180 prisms were tested in flexure. A supplementary series of six concrete mixtures was made to deter-mine the effect of silica fume and fly ash on the long-term strength development of concrete. Test data showed that the incorporation of condensed silica fume increased the compressive strength of concrete at all ages as compared with the compressive strength of the control concrete (70% Portland cement + 30% fly ash). At 7 days, the loss of compressive strength due to the partial replacement of cement by fly ash was completely overcome by the addition of 10% condensed silica fume for concretes with water-(cement + fly ash) ratios ranging from 0.40 to 0.60; 15 to 20% was required for concretes with higher water-(cement + fly ash) ratios, At 28 days, regardless of the water-(cement + fly ash) ratio, the effect was generally achieved with less than 5% silica fume addition. The later age strength development of Portland cement-fly ash concrete did not appear to be impaired by the use of condensed silica fume indicating availability of sufficient lime for the fly ash Pozzolanic activity.

III. MATERIAL PROPERTIES

Concrete is a construction material composed of Portland cement, sand, crushed stone, and water. The cement and water form a paste which hardens by chemical reaction into a strong, stone-like mass. No more cement paste should be used than necessary to coat all the aggregate surfaces and to fill all the voids. The concrete paste is plastic and easily moulded into any form or toweled to produce a smooth surface. Harden state begins immediately, but precautions are taken, generally by covering, to avoid rapid loss of moisture since the presence of water is necessary to continue the chemical reaction and increases the strength. More water, however, produces a concrete that is more porous and weaker. The quality of the paste formed by the cement and water largely determines the character of the concrete. Proportioning of the suitable ingredients of concrete is referred to as designing the mixture. Concrete may be produced as a dense mass which is practically artificial rock, and chemicals may be added to make it waterproof, or concrete can be made porous and highly permeable for such use as filter beds. Fine aggregate used in concrete was originally specified as roughly angular, but rounded grains are now preferred. The unit weight of concrete varies with the type and amount of rock and sand. A concrete with trap rock may have a density of 2,483 kg/m3. In compression concrete is stronger than in tension, and steel bar, known as rebar or mesh is embedded in structural members to increase the flexural and tensile Strengths. In addition to the structural uses, concrete is widely used in precast units such as water pipe, sewer, block, tile, and ornamental products.

For this project 43 grade (OPC – Ultra Tech Cement) was used. Cement was tested for its physical properties in accordance with IS specifications. The properties of cement is shown below in Table 3.1.

Table No3.1 Cement Properties

S.NO	Cement properties	Readings
1	Specific Gravity	3.15
2	Normal Consistency	34 %
3	Setting Time i) Initial Setting time ii) Final setting time	 42mins 6hrs 30min

Fine aggregate (FA)

Fine aggregate / sand is an accumulation of grains of mineral matter derived from the disintegration of rocks. Fine aggregate (FA) is distinguished from gravel only by the size of the grains or particles but is distinct from clays which contain organic materials. Fine aggregate that have been sorted out and separated from the organic material by the action of currents of water or by winds across arid lands are generally quite uniform in size of grains. Generally commercial sand is obtained from riverbeds or from sand dunes originally formed by the action of winds. Much of the earth's surface is sandy, and these sands are generally quartz and other siliceous materials. The commercially used silica sand is 98% pure. Sands in beach usually have smooth, spherical to ovaloid particles from the abrasive action of waves and tides and are free of organic matter. The white beach sands are largely silica but may also be of monazite, garnet, and other minerals, and are used for extracting various elements. Fine aggregate is used for making mortar and concrete and for polishing and sand blasting.

The fine aggregate obtained from riverbed, clear from all sorts of organic impurities was used in this experimental program. The sand was passing through 4.75 mm sieve and the grading zone of fine aggregate was zone II as per Indian Standard specifications. The properties of Fine aggregate are shown in Table 3.2,

Table No 3.2 Properties of Fine Aggregate

S. No	Property	Values
1	Specific Gravity	2.62
2	Fineness Modulus	2.8

Fly ash

Fly ash was taken from Rayalaseema Thermal Power plant (RTPP) Muddhanooru, Kadapa dist. Fly ash sample was shown in figure 3.2 was used for concrete preparation and the properties of Fly ash is shown in Table 3.3.

Figure 2 Fly Ash Sample

Table No3.3 Properties of Fly Ash

S.No.	Ingredient	Value
1	Silica (SiO_2)	56.88 %
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	Calcium oxide (Cao)	3.6 %
6	Magnesium oxide (MgO)	0.34 %
7	Sulphate (SO_4)	0.27 %
8	Loss of ignition (LOI)	4.46 %
9	Specific gravity of Fly Ash	2.12

IV. MIX DESIGN

The process of selecting suitable ingredients of concrete and determining their relative amounts with the objective of producing a concrete of the required workability, strength, durability as economically as possible, is termed as the concrete mix design. The proportioning of ingredient of concrete is governed by the required performance of concrete in two states, namely the plastic and the hardened states. Workability plays a vital role in the concrete. The replacement and compaction of concrete in plastic stage is very difficult.

The compressive strength of hardened concrete is mainly depends on many factors like quality, quantity of cement, water and aggregates, placing, compaction, batching, mixing, and curing. The cost of concrete is derived from the cost of materials, plant, and labor. Depending upon the variation of materials and transportation the cost construction may decreases are increases. The actual cost of the concrete is related to the materials available during the construction process. If the quality and quantity of concrete is effectively high, then the cost of construction and durability of structure automatically increases.

The concrete mix of in adequate workability may result in high cost of labor to obtain the degree of compaction. Generally, workability depends on the cost of the labor. The cost of the cement is high when compared to the aggregates used in the construction. The actual cost of the cost depends on the cost of the materials required for manufacturing a minimum mean strength which is commonly known as compressive strength of concrete.

Mix Design for M20 Grade of Concrete

Type of Cement	OPC 43 Grade
Maximum Nominal size of Aggregate	20 mm
Minimum content of Cement	300 kg/m^3
Maximum Water Cement ratio	0.55
Specific Gravity of Cement	3.15
Specific Gravity of Fine aggregate	2.66
Specific Gravity of Coarse aggregate	2.71

V. EXPERIMENTAL INVESTIGATION

Testing

Tests were conducted on hardened concrete specimens to obtain the compressive strength, split tensile strength, flexural strength and modulus of elasticity. Standard procedures were adopted for testing.

The results of the experimental investigations are presented and discussed below.

The experimental program was designed to compare the properties of compressive strength of cubes and cylinders, flexural strength, split tensile strength and modulus of Elasticity of M20 grade concrete and with different replacement levels of Ordinary Portland cement (Ultra Tech cement 43 grade) with fly ash, nano-silica and the combination of fly ash and nano-silica.

COMPRESSIVE STRENGTH

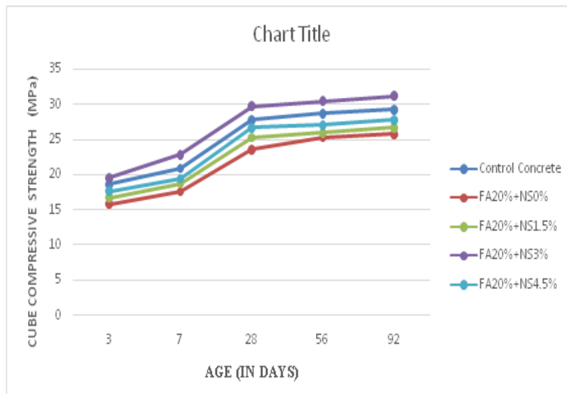
The test results of compressive strength of M20 grade concrete with various proportions of fly ash and nano-silica is shown in Table. The variation of compressive strength of M20 grade concrete with different percentages of fly ash and varying percentages of nano-silica is shown in Figure.

The cube compressive strength indicates the average of three test results. It can be observed that the compressive strength of concrete prepared using fly ash and nano-silica exhibits more strength than the control concrete up to 3% of nano-silica if the percentage of fly ash is 20% and with further increase in nano-silica the compressive strength decreases. But, if the percentage of fly ash is increased to 30% irrespective of the content of nano-silica the compressive strength is less than the control concrete.

The experimental investigation is carried out to obtain the compressive strength, split tensile strength, flexural strength and modulus of elasticity of M20 grade of concrete by partial replacement of cement with nano-silica and fly ash and the combination of fly ash and nano-silica. In the present investigation, Concrete specimens were prepared with various proportions of nano-silica 1.5%, 3% and 4.5% and fly ash 20% and 30% of cement replacement by weight.

Table.Cube Compressive Strengths of M20 Grade Concrete

Concrete Mix	Fly Ash (%)	Colloidal Nano Silica (%)	Compressive Strength (MPa)				
			3 Days	7 Days	28 Days	56 Days	92 days
Control Concrete	0	0	18.64	20.92	27.8	28.62	29.23
FA 20%+NS 0%	20	0	15.82	17.6	23.62	25.34	25.8
FA 20%+NS 1.5%	20	1.5	16.7	18.7	25.3	25.92	26.7
FA 20%+NS 3%	20	3	19.52	22.8	29.72	30.47	31.2
FA 20%+NS 4.5%	20	4.5	17.63	19.4	26.7	27.1	27.82
FA 30%+NS 0%	30	0	14.4	16.7	22.1	23.6	24.1
FA 30%+NS 1.5%	30	1.5	15.6	17.7	24.5	24.9	25.2
FA 30%+NS 3%	30	3	16.8	19.5	26	27.4	28.1
FA 30%+NS 4.5%	30	4.5	16.2	18.32	24.6	25.85	26.1



30% of Fly Ash

5.1 Workability

Workability of concrete is measured in accordance with the code IS 1199-1959 by slump and compaction factor tests.

CONCRETE MIX PREPARATION

Design of concrete mix requires complete knowledge of various properties of the constituent materials. Initially the ingredients such as cement and fly ash are mixed, to which the fine aggregate and coarse aggregate are added and thoroughly mixed. Water and nano-silica are measured exactly. Then it is added to the dry mix and it is thoroughly mixed until a mixture of uniform color and consistency is achieved which is then ready for casting. Prior to casting of specimens, workability is measured in accordance with the code IS 1199-1959 by slump and compaction factor tests.

5.2 CASTING OF TEST SPECIMENS

After the completion of workability tests, the concrete has been placed in the standard metallic moulds in three layers and compacted each time by tamping rod. Before placing the concrete inner faces of the mould are coated with the machines oil for easy removal of test specimens. The concrete in the moulds has been vibrated for 30sec using the Table vibrator and the surface of the specimens have been finished smoothly.

5.3 CURING PROCEDURE

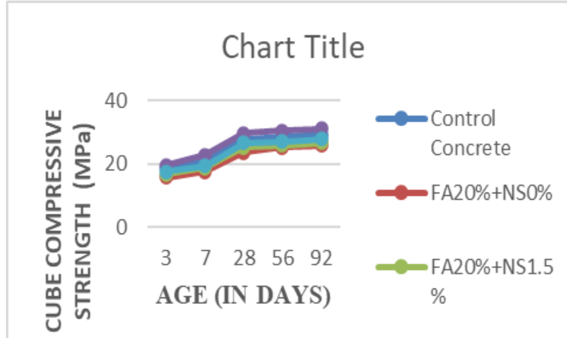
After the casting of cubes, cylinders, and prisms the specimens are kept at room temperature for one day and the specimens are removed from the moulds after 24hours of casting of concrete specimens. Marking has been done on the specimens for identification. To maintain the constant moisture on the surface of the specimens, they are placed in water tank for curing. Concrete specimens are cured for 3, 7, 28 ,56 and 92 days. All the models have been cured for respective ages such as 3, 7, 28 ,56 and 92 days.

5.4 TESTS ON NANO-SILICA AND FLY ASH CONCRETE

5.4.1 COMPRESSION STRENGTH TEST

Compression test is the most common test conducted on hardened concrete because it is an easy test to perform, and most of the properties of concrete are qualitatively related to its compressive strength. Compression test is carried out on specimen of cubical or cylindrical in shape. Compression test is done confirming to IS: 516-1959. All the concrete specimens that are tested in a capacity of the compression-testing machine. Concrete cubes of size 150mm × 150mm × 150mm were tested for Compressive Strength. Compressive Strength of concrete is determined by applying load at the rate of 140kg/cm2/minute till the specimens failed. The Compressive Strengths were tested at the age of 3, 7, 28 ,56 and 92 days.

Tests were conducted on hardened concrete specimens to obtain the compressive strength, split tensile strength, flexural strength, and modulus of elasticity. Standard procedures were adopted for testing.



20% Fly ash

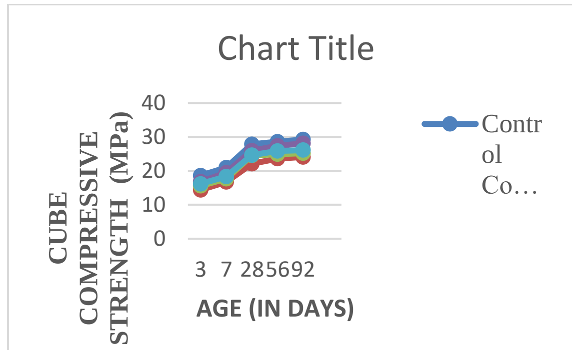
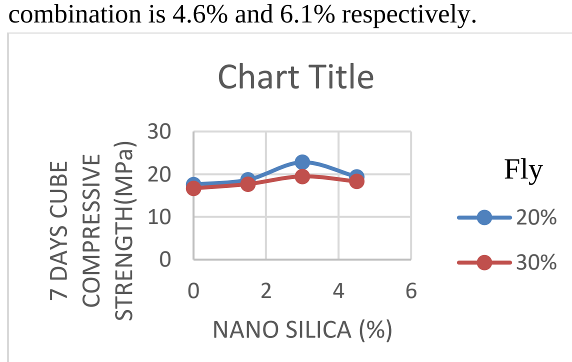


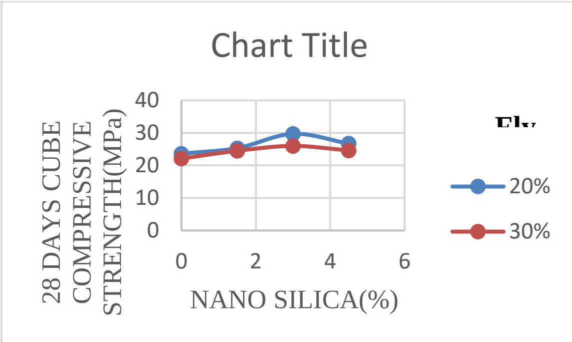
Fig. 5.1. Variation of Cube Compressive Strength of M20 Grade Concrete with Age for Different Percentages of Fly Ash and Nano-Silica.

Variation of 7 days and 28 days cube compressive strength: -

The variation of 7 days and 28 days cube compressive strength of M20 grade of concrete with different proportions of nano-silica and fly ash is shown in Fig 6.2. The compressive strength of concrete initially increases up to 3% nano-silica and then the strength decreases with further increase in nano-silica for 20% and 30% of fly ash content. The 7 days and 28 days cube compressive strength of control concrete is 22.37 MPa and 32.12 MPa respectively. The increase in 7 days and 28 days cube compressive strength of concrete with 3% nano-silica and 20% fly ash combination is 4.6% and 6.1% respectively.



7 days Cube Compressive Strength



28 days Cube Compressive Strength

Fig 5.2. Variation of Cube Compressive Strength of M20 Grade of Concrete with Nano-Silica for various percentages of Fly Ash.

VI. CONCLUSION

The results of the experimental investigation indicate that the combination of fly ash and nano-silica can be used as Ordinary Portland cement replacement for concrete preparation.

1. Using the test results, it can be concluded that with the increase in the percentage of nano-silica for different percentages of fly ash, the various strength properties of concrete are increased up to 3% of nano silica and with further increase in the nano-silica the properties of concrete are decreased.
2. It is very interesting to note that the variation of compressive strength, split tensile strength, flexural strength, and modulus of elasticity of M20 grade fly ash concrete with various percentages of nano-silica indicates the similar trend.
3. The increase in various strength properties of concrete containing fly ash with increase in the nano-silica content can be due to the availability of additional binder in the presence of nano-silica. The nano silica and fly ash react with the calcium CaOH to form additional binder material. The availability of additional binder leads to increase in the paste-aggregate bond, results in improved strength properties of the concrete prepared with nano-silica and fly ash combination.
4. The decrease in the strength characteristics of concrete with increase in the nano-silica content beyond 3% is due to the poor quality of binder formed in the presence of high content of nano-silica and fly ash.
5. The various strength characteristics of concrete can be improved by the combined application of 3% nano-silica and 20% fly ash content. It can also be concluded that the cement content can be reduced without compromising the strength of concrete by the use of fly ash and nano-silica combination.

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