Evaluation of Strength Characteristics of Concrete with Addition of Fly Ash and Nano-Silica Gel

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Abstract- *Concrete is the most common used material for construction and their design consumes almost the total cement production in the world. The use of large quantities of cement produces increasing CO_2 emissions and as a consequence the greenhouse effect. A method to reduce the cement content in concrete mixes is the use of Flyash and silica fines. One of the silica fines with high potential as cement replacement and as concrete additive is nano-silica (NS). This would save not only the natural resources and energy but also protect the environment with the reduction of waste material.*

The present work deals with addition of Fly-ash and Nano-silica to concrete as partial replacement to cement in 10%, 20% & 30% and dosages of 1%, 1.5% and 2% respectively by weight of cement. Based on early research M20 grade concrete has been chosen for this work. The mix design was prepared using IS: 10262-2009 Guidelines for concrete mix design proportioning. In the present work 117 numbers of specimens were casted (78 numbers of cube moulds and 39 numbers of cylinder moulds) with addition of Flyash and Nano-silica in different proportions which are tested for compressive strength and split tensile strength. Addition of Nano-silica to normal cement concrete show increase in compressive strength and decrease in splitting tensile strength. SEM (Scanning Electron Microscope) analysis evidence the direct involvement of Fly-ash and Nano-silica in region of specimen.

Keywords- Cement, Concrete, FlyAsh, Nano-silica, Slump Test, Compressive strength

I. INTRODUCTION

Concrete is the most common material used in the construction. Concrete is a composite material made up of cement, sand, water and sometimes admixtures. Cement is the most active component of concrete usually has the greatest unit cost, its selection and proper use are important in obtaining economical concrete and also concrete of desired properties. The use of large quantities of cement results in increasing CO^2 emissions and as a consequence of the greenhouse effect. One of the methods to reduce the cement content in concrete mixes is the use of nano materials. The properties of concrete in hardened state such as strength is affected by the mix proportions and grading which results in particle packing.Concrete can be considered as the most widely used in the construction industry. The Indian Standard Code of practice for plain and reinforced concrete recommends the minimum cement content to satisfy the strength. Hence, the utilization of cement is increased. But, the cement production consumes large amount of energy and emits carbon dioxide results in environmental pollution. Hence, one of the solutions to these problems is to reduce the consumption of cement and utilize Pozzolana materials for the preparation of concrete. Previous studies indicate that the use of Fly Ash, Micro Silica, Matakaoline, Ground Granulated Blast Furnace Slag as partial replacement of cement, reduces the cement consumption and also increases the strength. To improve the performance of concrete further, Nano materials are now being introduced as supplementary materials. Recent developments in Nano-technology and the availability of nano-silica made the use of such materials in concrete. Nano-Silica (NS) is a Nano-sized, highly reactive amorphous silica. Due to the smaller particles size and high surface areas compared to the other pozzolanic materials, the use of nano-silica possibly enhances the performance of concrete more effectively. As the nano silica particles are very fine and they tend to agglomerate due to high surface interaction, uniform dispersion of nano-silica is an important issue to get its beneficial effects. The influence of combined application of fly ash and nano-silica is to be investigated

Concrete and Sustainability

Concrete is probably unique in construction, it is the only material exclusive to the business and therefore is the beneficiary of a fair proportion of the research and development money from industry. Concrete is a composite construction material composed primarily of aggregate, cement, and water, which is a nanostructured, complex, multi-phase material that ages over time. Sustainability is defined by the World Commission on Environment and Development as the development that meets the needs of the present, without compromising the ability of the future generations to meet their own needs. It is basically an idea for concern for the well being of planet Earth ollwith continued growth and human development. The current construction practices are based on the consumption of enormous quantities of building materials and drinking water, resulting in the scarcity of these resources after a long turn. The mortar properties in fresh state such as workability are governed by the particle size distribution and the properties in hardened state, such as strength and durability, are affected by the mix grading and resulting particle packing. Rheological properties of a fresh cement paste play an important role in determining the workability of concrete. The water requirement for flow, hydration behavior, and properties of the hardened state largely depends upon the degree of dispersion of cement in water. Factors such as water content, early hydration, water reducing admixtures and mineral admixtures like nano-silica determine the degree of flocculation in a cement paste.

Fly ash in Concrete

Flyash is used as a supplementary cementitious material (SCM) in the production of Portland cement concrete. A supplementary cementitious material, when used in conjunction with Portland cement, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both. As such, SCM's include both pozzolans and hydraulic materials. A pozzolan is defined as a siliceous or siliceous and aluminous material that in itself possesses little or no cementitious value, but that will, in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperatures to form compounds having cementitious properties. Pozzolans that are commonly used in concrete include fly ash, silica fume and a variety of natural pozzolans such as calcined clay and shale, and volcanic ash. SCM's that are hydraulic in behavior include ground granulated blast furnace slag and fly ashes with high calcium contents (such fly ashes display both pozzolanic and hydraulic behavior).

Nanotechnology in Concrete

Nanotechnology is rapidly becoming the Industrial Revolution of 21st century. It will affect almost every aspect of one's life. In comparison to other technologies, nanotechnology is much less well defined and well-structured. It is known that 'Nano' is a Greek word and means'dwarf'.

It does not mean dealing with dwarfs but it became a common word for everything which is smaller than 1 Micron or 1 million of a millimeter. 1 Micron is 1000 Nanometer. The nanoscience and nano-engineering (nano-modification) of concrete are terms that have come into common usage and describe two main approaches of applications of nanotechnology in concrete (Scrivener and Kirkpatrick, 2008; Scrivener, 2009). Until today, concrete has primarily been seen as a structural material. Nanotechnology is helping to make it a multipurpose ''smart'' functional material. Concrete can be nano-engineered by the incorporation of nano-sized building blocks or objects e.g., nanoparticles, nano admixtures and nanotubes) to control material behavior and add trailblazing properties, or by the grafting of molecules onto the cement particles, cement phases, aggregates, and additives (including nano-sized additives) to provide the surface functionality adjusted to promote the specific interfacial interactions of the molecules. Recently, nanotechnology is being used in many applications and it has received increasing attention also in building materials, with potential advantages and drawbacks being underlined.

Objective of the present work

The objective of the present work is to find the influence of the application of Flyash and Nano-Silica on various strength properties of M20 grade of concrete. 10%, 20% and 30% of Flyash and 1%, 1.5% and 2% of Nano-Silica gel are adopted as cement replacement by weight. Specific objectives are

- To find the workability aspect of the Nano-Silica for M20 grade concrete using Fly ash.
- To know the strength characteristics of the concrete using Fly ash and Nano-Silica.

II. LITERATURE REVIEW

Fly ash

Alvin Harison et.al (2014) The following conclusions were made based on the findings of the study: Compressive strength of fly ash concrete up to 30% replacement level is more or equal to referral concrete at 28 and 56 days. Optimum replacement level of fly ash is 20%. It was observed that at 28 and 56 days in 20% replacement of PPC by fly ash, the strength marginally increased from 1.9% to 3.28%. It was also observed that up to 30% replacement of PPC by fly ash, the strength is almost equal to referral concrete at 56 days. PPC gains strength after the 56 days curing because of slow hydration process.

C. Marthong et.al (2010) Normal consistency increases with increase in the grade of cement and fly ash content. Setting time and soundness decreases with the increase in grade of cement. Use of fly ash improves the workability of concrete and workability increases with the decreases in the grade of cement. Bleeding in fly ash concrete is significantly reduced and other properties like cohesiveness, pumping characteristics and surface finish are improved. Compressive strength of concrete increases with grade of cement. As the fly ash contents increases in all grades of OPC there is reduction in the strength of concrete. This is expected, as the secondary hydration due to pozzolanic action is slower at initial stage for fly ash concrete. The reduction is more at earlier ages as compared to later ages. The rate of strength gain of concrete with age is almost similar in all the three grades OPC. Concrete with 20% fly ash content closer to that of ordinary concrete at the age of 90 days. In all grades OPC, fly ash concrete is more durable as compared to OPC concrete and fly ash upto 40% replacement increase with grade of cement.

Nano-Silica

M. Nazeer et.al (2013) Silica fume added mixes shows higher strength values compared to their high volume fly ash counterparts at later ages (after 28 days). A linear logarithmic relation was developed for co-relating the compressive strength with age and silica fume content in various mixes. Using this correlation equation compressive strength values for various mixes are calculated and compared with the experimental results obtained. The addition of supplementary cementitious materials improves the resistance of concrete to chloride penetration. Mathematical models for predicting the diffusion coefficient, total charge passed in 6 hours and carbonation depth by knowing the oxide composition of the binder material for various mixes were developed and compared with the experimental values. The models gave satisfactory results. Equation for predicting the total charge passed in 6 hours knowing the initial current during the beginning of RCPT is formulated to overcome the disadvantage of longer test duration.

G.Quercia et.al (1986-1991) A new nano-silica (NS) can be produced in high quantities and for low prices that allows for a mass application in concrete. It may replace cement in the mix, which is the most costly and environmentally unfriendly component in concrete. The use of nS makes concrete financially more attractive and reduces the CO2 footprint of the produced concrete products. The NS will also increase the product properties of the concrete: the workability and the properties in hardened state, enabling the development of high performance concretes for extreme constructions.

Flyash and Nano-Silica :

Dr. D. V. PrasadaRao et.al (2014) The results of the experimental investigation indicate that the fly ash and nano-silica can be adopted as Ordinary Portland cement replacement for concrete preparation. Using the test results, it can be concluded that with the increase in the percentage of nano-silica the various strength characteristics of concrete increased up to 3%, with further increase in the nano-silica the strength characteristics of concrete are decreased for the given percentages of fly ash. It is very interesting to note that the variation of compressive strength of M25 grade fly ash concrete with nano-silica indicates the similar trend .The increase in various strength characteristics 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. Nano silica has high amorphous silicon dioxide content. The Portland cement in concrete releases calcium hydroxide during the hydration process. The nano silica and fly ash reacts with the calcium hydroxide to form additional binder material. The availability of additional binder leads to increase in the paste-aggregate bond, results improved strength properties of the concrete prepared with nano-silica and fly ash combination. 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. The various strength characteristics of concrete can be improved by the addition of 3% nano-silica and 20% fly ash content. It can 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 at an appropriate proportion.

Abdul Wahab et.al (2014) 2% nano silica appears to be the optimum in the high strength concrete mixes like M60 and M80 without any admixtures. The highest compressive strength with 2% nano silica and 10% CSF appears to be the optimum in the present triple blended concrete mixes.In the case of split tensile strength 2% nano silica gives the highest value without any admixture. The highest strength with 2% nano silica and 10% CSF appears to be the optimum in present conditions for split tensile strength. In the case of fly ash, nano silica, concrete mixes, the presence fly ash does not contribute towards any strength increased. In these mixes, 1.5 percent nano silica is giving the optimum strength without fly ash. However, replacement of cement by an admixture like fly ash would leave other beneficial properties besides economy.
S. Yuvaraj et.al (2012) Nano concrete could control the carbon dioxide emission from the earth which is shown by using fly ash concrete products instead of cement concrete. Thus the Nano particles which is in the form of silica can easily react with cement particles which are normally in Nano scale initiate the CSH reaction and hence its tend to accelerate the compressive strength of concrete.Nano-silica consumes calcium hydroxide crystals, reduces the size of the crystals at the interface zone and transmute the calcium hydroxide feeble

crystals to the C-S-H crystals, and improves the interface zone and cement paste structures. Compressive strength of the concrete increases with adding the Nano-silica, especially at early ages. However the early strength of the concrete decreases slightly with adding the fly ash, but decreases at later ages. These results indicate that the Nano silica may adopt for higher strength green concrete technologies. Corrosion resistance property of the NS added concrete is comparatively higher than ordinary fly ash concrete. The corrosion resistance of optimum percentage replacement of fly ash is higher in nano concrete than the ordinary fly ash concrete. The average increases in compressive strength up to 7% than the compressive strength ordinary partially replaced fly ash concrete on 7 days cured concrete But in the fourteen days cured cubes the increase in compressive strength is incrementally up by 13% percentages compared to the ordinary partially replace fly ash concrete.

III. METHODOLOGY

General

The present method deals with evolution of Mechanical Properties of Concrete Compressive Strength and Split-Tensile Strength. The program involves Casting and Testing of specimens where the standard size of the cube (150mm x 150mm x150mm) and standard size of cylinder (150mm x 300mm).Cement is partially replaced with Flyash (10%,20% and 30%) and Nano-Silica Gel of dosages (1%,1.5% and 2%) in Standard Grade of M20 according to IS: 10262-2009.

Procurement of Materials

The Materials used for the study are:

- Cement
- Fine Aggregate
- Coarse Aggregate
- Fly ash
- Nano Silica gel

Cement

Cement is a material that has cohesive and adhesive properties in the presence of water. such cements are called hydraulic cements. these consist primarily of silicates and aluminates of lime obtained from lime stone and clay.

Fly ash

In the present experimental investigation ‘Class F’ Fly ash obtained from a Thermal Power Plant is used. Cement is replaced by 10%, 20% and 30% of fly ash by weight of cement.

Nano-Silica Gel

Nano-silica is a new pozzolanic material commercially available in the form of water emulsion of colloidal silica. It is potentially better than the other pozzolanic materials because of high content of amorphous silica (>99%) and the reduced size of its spherical particles of order 5-10nm. In this experimental investigation cement is replaced by of nano-silica 1%, 1.5% and 3% by weight

Concrete

Mixing concrete is simply defined as the "complete blending of the materials which are required for the production of a homogeneous concrete". Batching is the "process of weighing or volumetrically measuring and introducing into the mixer the ingredients for a batch of concrete". Initially we have weighed coarse aggregate, fine aggregate and cement according to the mix design and water according to the w/c ratio. Then we weighed the desired quantities of admixtures. First we added coarse aggregate in the concrete mixer followed by fine aggregate, cement and admixtures.

IV. RESULTS AND DISCUSSION

Workability is one of the physical parameters of concrete which affects the strength as well as the cost of labor and appearance of the finished product. Concrete is said to be workable when it is easily placed and compacted homogeneously i.e without bleeding or Segregation. Unworkable concrete needs more work or effort to be compacted in place, also honeycombs &/or pockets may also be visible in finished concrete.

The influence of different combinations of Flyash (10%, 20%, and 30% by weight) and Nano-Silica Gel (1%, 1.5%, 2% by weight) with normal concrete at a constant w/c ratio of 0.5 has shown a trend of vary in workability (slump).The observed values are tabulated below:

Table: 1. Slump Values

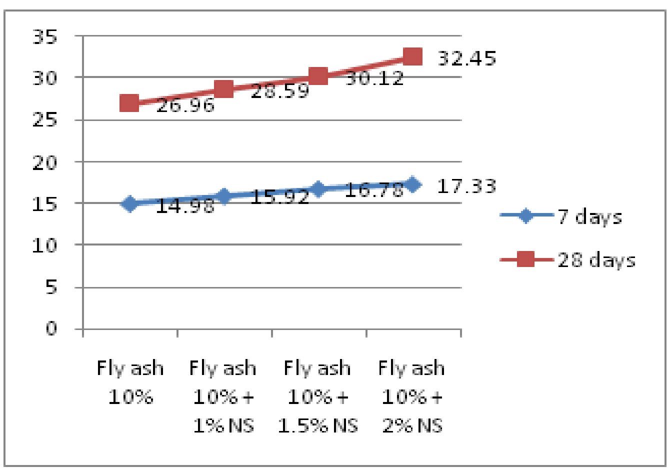
S.No	Description	Slump Value
1	Control Concrete	75mm
2	CF 10%	83mm
3	CF 10% + 1% NS	81mm
4	CF 10% + 1.5% NS	80mm
5	CF 10% + 2% NS	78mm
6	CF 20%	88mm
7	CF 20% + 1% NS	85mm
8	CF 20% + 1.5% NS	82mm
9	CF 20% + 2% NS	79mm
10	CF 30%	96mm
11	CF 30% + 1% NS	93mm
12	CF 30% + 1.5% NS	90mm
13	CF 30% + 2% NS	87mm

Compressive Strength

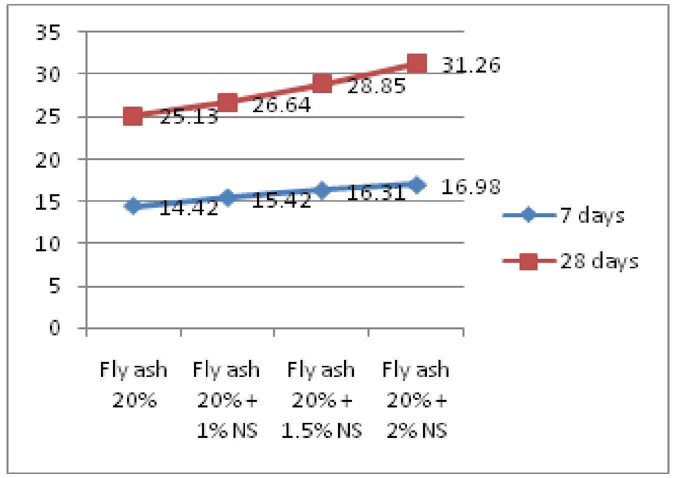
The Compressive Strengths of the casted specimens were determined by the axial compressive strength test and are tabulated as follows:

Table: 2. Compressive Strength of Cubes

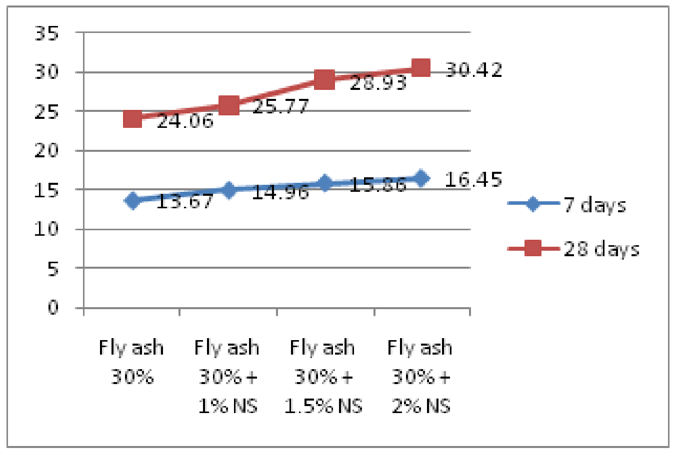
S.No	Specimen Description	Compressive Strength (N/mm^2)	
		7 Days	28 Days
1	Control Concrete	17.51	34.32
2	CF 10%	14.98	26.96
3	CF 10% + 1% NS	15.92	28.59
4	CF 10% + 1.5% NS	16.78	30.12
5	CF 10% + 2% NS	17.33	32.45
6	CF 20%	14.42	25.13
7	CF 20% + 1% NS	15.42	26.64
8	CF 20% + 1.5% NS	16.31	28.85
9	CF 20% + 2% NS	16.98	31.26
10	CF 30%	13.67	24.06
1	CF 30% + 1% NS	14.96	25.77
12	CF 30% + 1.5% NS	15.86	28.93
13	CF 30% + 2% NS	16.45	30.42



Graph.1: Compressive Strength details with % variation of Nano-Silica Gel with 10% fly ash



Graph.2: Compressive Strength details with % variation of Nano-Silica Gel with 20% fly ash



Graph.3: Compressive Strength details with % variation of Nano-Silica Gel with 30% fly ash

V. CONCLUSION

- We observed that when Flyash is added to Concrete, the Workability has increased and when Nano-Silica Gel is added to Flyash Concrete, the Workability has decreased.
- When compared with Control Concrete, Concrete partially replaced with 10% Flyash has a decrease in 7 daysCompressive Strength by 14.48%. When Nano-Silica gel is added to CF10 in dosages of 1%, 1.5% and 2% the Compressive Strength is increased by 6.27%, 12.01% and 15.68% respectively.
- When compared with Control Concrete, Concrete partially replaced with 20% Flyash has a decrease in 7 days Compressive Strength by 17.64%. When Nano-Silica gel is added to CF20 in dosages of 1%, 1.5% and 2% the Compressive Strength is increased by 6.93%, 13.1% and 17.75% respectively.
- When compared with Control Concrete, Concrete partially replaced with 30% Flyash has a decrease in 7

days Compressive Strength by 21.93%. When Nano-Silica gel is added to CF30 in dosages of 1%, 1.5% and 2% the Compressive Strength is increased by 9.43%, 16.02% and 20.33% respectively.

- When compared with Control Concrete, Concrete partially replaced with 10% Flyash has a decrease in 28days Compressive Strength by 21.44%. When Nano-Silica gel is added to CF10 in dosages of 1%, 1.5% and 2% the Compressive Strength is increased by 6.04%, 12.05% and 20.36% respectively.
- When compared with Control Concrete, Concrete partially replaced with 20% Flyash has a decrease in 28days Compressive Strength by 26.77%. When Nano-Silica gel is added to CF20 in dosages of 1%, 1.5% and 2% the Compressive Strength is increased by 6.0%, 14.8% and 24.39% respectively.
- When compared with Control Concrete, Concrete partially replaced with 30% Flyash has a decrease in 28days Compressive Strength by 29.89%. When Nano-Silica gel is added to CF30 in dosages of 1%, 1.5% and 2% the Compressive Strength is increased by 7.1%, 20.24% and 26.4% respectively
- Due to decrease in the quantity of cement, the concrete becomes economical and eco-friendly.
- By adding Flyash CO_2 emission is decreased and in presence of NS the compressive strength has been increased.

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