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A Study on the Variation of Properties of Concrete with Partial Replacement of Cement Using Nano-Silica (Ns) and Fly Ash (Fs)

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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 1.0%,2.0%,3.0%, 4.0%,5.0% 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 abd RCPT of M20 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 mix in the application of Fly-Ash and Nano-Silica

Keywords:- Nano silica, fly ash, cement, concrete, aggregates, compressive strengthen Etc..

I. INTRODUCTION

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. After the collapse of Roman Empire in the mid-18th century, the technology was re-pioneered as the usage of concrete has become rare. Today, the 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

II. MATERILAS

2.1.1 Cement

In this experimental study, Ordinary Portland Cement 53 grade, conforming to IS: 8112-1989 was used. The different laboratory tests were conducted on cement to determine the physical and mechanical properties of the cement used are shown in

TABLE1

Properties	Values
water absorption	**0.2 to 0.4 %**
Fineness modulus	**3.43**
Specific gravity	**4.05**
bulk density (gm/cc)	**2.20**

2.1.2 Aggregates

Locally available natural sand with 4.75 mm

maximum size confirming to class II- IS 383 was used as fine aggregate, having specific gravity, fineness modulus and unit weight as given in Table 3 and crushed stone with 16mm maximum size having specific gravity, fineness modulus and unit weight as given in Table 3 was used as coarse aggregate. Table 2 gives the physical properties of the coarse and fine aggregates

Table 2: Physical Properties of coarse aggregate and fine aggregate

property	Fine aggregate	Coarse aggregate
Specific gravity	2.66	2.95
Fineness modulus	3.1	7.96
Surface texture	Smooth	--
Practical shape	rounded	Angular

Table 3 Physical properties of Coarse Aggregate

Physical properties	Results
Fineness	8%
Normal consistency	31.5%
Vicat initial setting time(minutes)	43mins
Vicat final setting time (minutes)	256min
Specific gravity	3.15
7-days compressive Strength	39.65
28-days compressive Strength	54.86

2.1.3 Water

Ordinary potable water available in the laboratory has been used.

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 physical properties of the cement are listed in Table – 1

Objectives of the NANO SILICA

- 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.
- The variation in the strength properties of concrete like Flexural Strength, Tensile Strength, Compressive Strength and Modulus of Elasticity are carried out with combined application of Fly Ash (FA) and Nano-Silica (NS).
- The comparision of Controlled concrete and concrete with replaced cement with Fly Ash (FA) and Nano-Silica (NS) are represented graphically

is required to be used in the concrete and it should have pH value ranges between 6 to 9.

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 fig5

Figure 5 Fly Ash Sample

Table 6: 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

III. MIX DESIGN FOR M20 GRADE CONCRETE

Table 7: Content of materials as per mix design per one cube and one cylinder:

CUBE	CYLINDER
Volume = 0.15x0.15x0.15 = 0.00338m³	Volume = Π/4 x0.15² x0.3 =0.00530m³
Cement = 1.292kg	Cement = 2.029kg
F.A = 1.845kg	F.A = 2.893kg
C.A = 4.015kg 60% 20mm =2.409kg 40% 12mm=1.606kg	C.A = 6.296kg 60% 20mm =3.777kg 40% 12mm=2.518kg
Water =0.647lit	Water = 1.015lit

3.1 MOULDS USED FOR CASTING:

Standard cube moulds of 150 x 150 x 150mm made of cast iron used for the cement mortar and concrete specimens for testing of compressive strength.

Cylindrical moulds of 150 mm in diameter and 300 mm height is made for concrete specimens for testing of Split tensile strength.

Fig 3.1: Samples of cube and cylindrical moulds

3.2 CASTING:

The standards moulds were fitted such that there are no gaps between the plates of the moulds. If there is any gap, they were filled with plaster of Paris. The moulds were then oiled and kept ready for casting. Concrete mixes are prepared according to required proportions for the specimens by hand mixing; it is properly placed in the moulds in 3 layers. Each layer is compacted 25 blows with 16 mm diameter bar. After the completion of the casting, the specimens were vibrated on the table vibrator for 2 minutes. At the end of vibration the top surface was made plane using trowel. After 24 hours of a casting the moulds were removed and kept for wet curing for the required number of days before testing.

3.3 CURING:

Cement	Fine aggregate	Coarse aggregate	Water
383 Kg/m³	546 Kg/m³	1188 Kg/m³	191.6Kg/m³
1	1.425	3.10	0.50

The test specimens are stored in place free from vibration; specimens are removed from moulds after 24 ± half an hour time of addition of water to dry ingredients. After this period, the specimens are marked and removed from the moulds and unless required for test within 24 hours immediately submerged in clean fresh water and kept there until taken out just prior to test. The water in which the specimens are submerged, are renewed every seven days and are maintained at temperature of 27°±2°C.The specimens are not allowed to become dry at any time until they have been testing. The specimens were put under curing for 28 days.

IV. TESTS CONDUCTED

- Workability
- Compressive strength
- Split tensile strength
- Bending strength
- **Rapid Chloride Permeability Test(Test Procedure (ASTM C 1202)**

4.1 WORKABILITY:

Workability is one of the physical parameters of concrete which affects the strength and durability 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.

In this study, the slump-cone test is carried out to determine the workability of concrete.

Table 9: Results of workability

S.no	% of replacement	w/c ratio	Slump(mm)
1	0%	0.50	27
2	10%	0.50	42
3	20%	0.50	76
4	30%	0.50	105
5	40%	0.50	137

4.2 COMPRESSIVE STRENGTH:

A total of 20 cubes of size 150 x 150 x 150mm were casted and tested for 7 days and 28 days testing each specimen after conducting the workability tests. The results are tabulated below

Fig 4.1: Compression testing of Cube Specimen

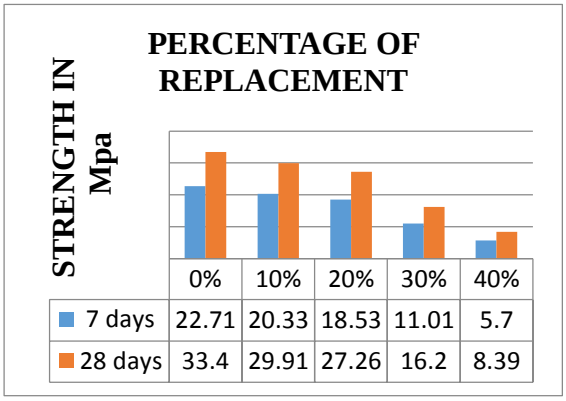

Fig 4.2. Comparison of Compressive strength of M20 at 7 and 28 days

Table 10: Compressive strength results of M20 grade of concrete for 7 and 28 days

%of replacement of nano silica	% of replacement Fly ash	For 7 days	For 28 days
5%	0%	22.71 Mpa	33.40 Mpa
5%	10%	20.33 Mpa	29.91 Mpa
5%	20%	18.53 Mpa	27.26 Mpa
5%	30%	11.01 Mpa	16.20 Mpa
5%	40%	5.70 Mpa	8.39 Mpa

4.3 SPLIT TENSILE STRENGTH:

The split tensile strength obtained by testing the cylindrical specimen for M20 grade of concrete to all the mixes designed for various replacements are given below:

Table 11: Split tensile strength results for M20 grade of concrete

% of replacement nano silica +fly ash	For 7 days	For 28 days
5%+0%	9.94 Mpa	11.98 Mpa
5%+10%	8.40 Mpa	9.08 Mpa
5%+20%	8.50 Mpa	14.17 Mpa
5%+30%	6.82 Mpa	7.57 Mpa
5%+40%	2.35Mpa	2.60 Mpa

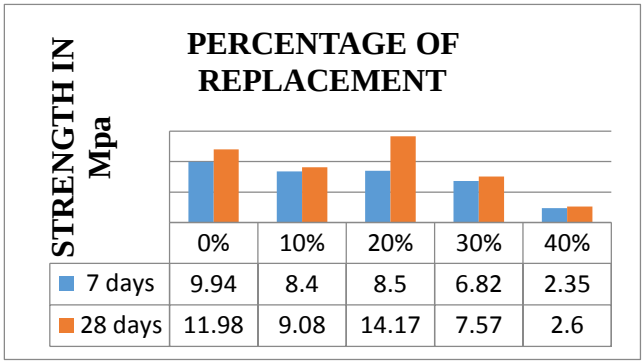

Fig 4.4: Split tensile strength for M20 at 7 and 28 days

4.4 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.

Experimental Setup for Flexure Test

4.5 RapidChloridePermeability Test(Test Procedure (ASTM C 1202)

Introduction

Reinforced concrete structures are exposed to harsh environments yet is often expected to last with little or no repair or maintenance for long periods of time (often 100 years or more). To do this, a durable structure needs to be produced. For reinforced concrete bridges, one of the major forms of environmental attack is chloride ingress, which leads to corrosion of the reinforcing steel and a subsequent reduction in the strength, serviceability and aesthetics of the structure. This may lead to early repair or premature replacement of the structure. A common method of preventing such deterioration is to prevent chlorides from penetrating the structure to the level of the reinforcing steel bar by using relatively impenetrable concrete. The ability of chloride ions to penetrate the concrete must then be known for design as well as quality control purposes. The penetration of the concrete by chloride ions, however, is a slow process. It cannot be determined directly in a time frame that would be useful as a quality control measure. Therefore, in order to assess chloride penetration, a test method that accelerates the process is needed, to allow the determination of diffusion values in a reasonable time.

Test Procedure (ASTM C 1202)

*Rapid chloride permeability test According to ASTM C1202 test, water-saturated, 50 mm thick, 100 mm thick diameter concrete specimen is subjected to applied DC voltage of 60 V for 6 hours.

*In one container 3.0% NaC1 solution and in the other container 0.3 M NaOH solution.

RCPTAPPARATUS

RCPT ratings as per ASTM C1202.

Charge Passing (Coulombs)	Charge Passing (Coulombs)
>4000	High
2000-4000	Moderate
1000-2000	Low
100-1000	Very Low
<100	Negligible

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.

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