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EXPERIMENTAL INVESTIGATION ON STRENGTH OF CONCRETE BY USING FLY ASH AND NANO-SILICA AS PARTIAL REPLACEMENT TO THE CEMENT

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Abstract

The cement consumption is directly related to the country infrastructure sector and thus its growth is paramount in determining development of the country. With a current production capacity of around 366 million tonnes (MT), India is the second largest producer of cement in the world. Therefore efforts being practiced to partial replace cement with new supplements and industrial by products. The aim of the present experimental investigation is to find the influence of combined application of Nano-Silica (NS) and Fly Ash (FA) on the strength properties of concrete. Fly Ash and Nano-Silica are used as partial replacement of cement. Thus the cement is partially replaced by 20% and 30% of Fly Ash and Nano-Silica 1.5%, 3% and 4.5% by weight. The effect of combined application of Fly Ash and Nano-Silica on compressive strength, split tensile strength, flexural strength and modulus of elasticity of M25 grade of concrete is investigated. The test results of concrete prepared using the combination of different proportions of Fly Ash and Nano-Silica are compared with that of controlled concrete. The variation of different test results of concrete prepared with various proportions of Fly Ash and Nano-Silica indicates the same trend. Based on the test results, it can be observed that concrete prepared with 20% Fly Ash and 3% Nano-Silica combination possesses improved strength properties compared to the controlled concrete. The increase in the various strength characteristics of concrete prepared using Fly Ash and Nano-Silica can be attributed to the effective particle packing and the also the availability of additional binder in the presence of Fly-Ash and Nano-Silica.

Keywords: Fly-Ash, Nano-Silica, Partial Replacement, Particle Packing and Strength of Concrete.

INTRODUCTION

Concrete can be considered as the most widely used product in the construction industry. The mechanical and durability properties of concrete have a similar meaning in the modern construction experience. Cement is the most commonly found product in concrete. Therefore, the consumption of cement increases. This absorbs a significant amount of energy in the manufacture of cement, which produces carbon dioxide and emission of hazardous gases into the atmosphere. Consequently, the solution to this problem is to reduce the use of cement and use Pozzolanic products for the preparation of concrete. Previous studies indicates that the use of Fly-Ash (FA), Micro Silica (MS) and Ground Granulated Blast Furnace Slag (GGBS) as partial replacement of cement that reduces the consumption of cement and also increases the strength and durability of concrete. For further improvement of concrete properties Nano materials are currently used as supplementary materials. Recent advances in nanotechnology and the use of Nano silica have allowed the use of concrete materials. Any type of mineral admixtures in concrete can be used with combination of Nano silica.

EXPERIMENTAL PROGRAMME

Materials:

The materials used to design the M60 grade of concrete mix are Cement, Sand, Coarse aggregate, Water, Super Plasticizer and Nano Silica. The properties of these materials are presented below.

Cement

Cement used in this study was 53 grade Ordinary port land cement conforming to IS 12269:1987. The Physical and Chemical properties are shown in table 3.1 and 3.2.

Table 3.1: Properties of Cement

PROPERTIES	TEST VALUE
Specific gravity	3.14
Initial Setting time	45mins
Final Setting time	230 min
Consistency	30%
Fineness modulus	6.5%

Table 3.2: Chemical Composition of Cement

CHEMICAL COMPOSITION	TEST VALUE (%)
Silicon dioxide	21.1
Calcium oxide	62.4
Ferric oxide	2.49
Aluminium oxide	4.50
Loss on ignition	2.40

Aggregates

The sand collected conforming to IS: 383-2016. For coarse aggregate, the parent rock is crushed through mini jaw crusher. During the crushing, we tried to maintain the maximum size of the aggregate. Aggregate with grain sizes above 4.75mm is termed as coarse aggregate and below 4.75mm is called as fine aggregate. The physical properties of the fine aggregate and the coarse aggregate are evaluated according to IS: 2386 (Part III)-1963.

Table 3.3: Properties of Fine Aggregate

PROPERTIES	TEST VALUES
Specific gravity	2.61
Water absorption	0.43%
Fineness modulus	2.72
Size of fine aggregate	Passing through 4.75mm

Table 3.4: Properties of Coarse Aggregate

PROPERTIES	TEST VALUES
Specific gravity	2.69
Water absorption	1%
Max Size of aggregate	12.5 mm

Fly Ash

Fly ash, the by product and fine particulate which is the product of the pulverized coal-based thermal power station, is an environmental pollutant, it has the potential to be a resource material. The class F fly ash was used in this project to replace cement in concrete and it is acquired from thermal power station near Vijayawada

Table 3.5: Chemical Composition of Fly Ash

CHEMICAL COMPOSITION	VALUE (%)
SiO_2	49.45
MgO	1.3
Al_2O_3	29.61
Fe_2O_3	10.72
Cao	3.47
K_2O	0.54

Table 3.6: Properties of Fly Ash

S. No.	PHYSICAL PROPERTY	TEST VALUES
1	colour	Grey
2	Specific Gravity	2.4

Nano Silica

The Nano silica used in this investigation is in Colloidal form. It is acquired form beechems pvt.Ltd, Kanpur.

Table 3.7: Properties of Nano Silica

PHYSICAL PROPERTIES	RESULT
Physical state	Micronized powder
Appearance	White colour powder

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Colour	White
Appearance Form	Powder
pH at 5% solution	5
Specific gravity	1.40
Particle size	40nm
Purity	99.5%

Super plasticizer

Glenium SKY 8233 is a new generation admixture based on modified polycarboxylic ether. The product was developed mainly for high performance concrete applications whereas maximum durability and performance is required. Glenium SKY 8233 does not contain chlorides and low alkali. It is well-suited with all types of cement.

Table 3.10: Properties of Super Plasticizer

PHYSICAL PROPERTIES	RESULT
Specific gravity	1.08
pH	≥6
Relative Density	±0.02 @25°C
Chloride ion content	≤ 0.2%
Colour	Reddish brown liquid

RESULTS AND DISCUSSIONS

Table.6.1 Cube Compressive Strengths of M20 and M30 Grade Concrete

Concrete Mix	Fly Ash (%)	Colloidal Nano Silica (%)	Compressive Strength (MPa)			
			3 Days	7 Days	28 Days	56 Days
Control Concrete	0	0	18.76	20.96	27.83	28.72
FA 20 % + NS 0 %	20	0	15.92	17.55	23.67	25.14
FA 20 % + NS 1.5 %	20	1.5	16.46	18.97	25.46	26.18
FA 20 % + NS 3 %	20	3	19.43	22.68	29.81	30.57
FA 20 % + NS 4.5 %	20	4.5	17.54	19.45	26.60	27.20
FA 30% + NS 0 %	30	0	14.51	16.65	22.03	23.47
FA 30 % + NS 1.5 %	30	1.5	15.58	17.67	24.44	24.97
FA 30 % + NS 3 %	30	3	16.97	19.40	26.06	27.54
FA 30 % + NS 4.5 %	30	4.5	16.29	18.44	24.71	25.88

Table 6.2. Comparison of 28 days Compressive Strength of Cube and Cylinder with Fly Ash (FA) and Nano-Silica (NS).

S.N	Concrete	Cube Compressive Strength (MPa) 'σ' Cube	Cylinder Compressive Strength (MPa) σ Cylinder	σ Cylinder/ σ Cube
1	Control Concrete	27.83	23.65	0.86
2	FA 20 % + NS 0 %	23.67	20.82	0.88
3	FA 20 % + NS 1.5 %	25.46	20.40	0.88
4	FA 20 % + NS 3 %	29.81	27.12	0.91
5	FA 20 % + NS 4.5 %	26.60	23.67	0.89
6	FA 30% + NS 0 %	22.03	18.97	0.86
7	FA 30 % + NS 1.5 %	24.44	21.26	0.87
8	FA 30% + NS 3%	26.06	22.67	0.89
9	FA 30% + NS 4.5 %	24.71	21.74	0.88

SPLIT TENSILE STRENGTH:

Table No 6.3 Split Tensile Strengths of M20 Grade of Concrete

Concrete Mix	FA (%)	Colloidal Nano Silica (%)	Split Tensile Strength (MPa) for 28 Days
Control Concrete	0	0	3.30
FA 20 % + NS 0 %	20	0	2.84
FA 20 % + NS 1.5 %	20	1.5	3.05
FA 20 % + NS 3 %	20	3	3.57
FA 20 % + NS 4.5 %	20	4.5	3.19
FA 30% + NS 0 %	30	0	2.64
FA 30 % + NS 1.5 %	30	1.5	2.93

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FA 30% + NS 3%	30	3	3.12
FA 30% + NS 4.5 %	30	4.5	2.96

Table No.6.4Flexural Strengths of M20 Grade of Concrete

Concrete Mix	FA (%)	Colloidal Nano Silica (%)	Flexural Strength (MPa) for 28 Days
Control Concrete	0	0	4.45
FA 20 % + NS 0 %	20	0	3.78
FA 20 % + NS 1.5 %	20	1.5	4.07
FA 20 % + NS 3 %	20	3	4.76
FA 20 % + NS 4.5 %	20	4.5	4.25
FA 30% + NS 0 %	30	0	3.52
FA 30 % + NS 1.5 %	30	1.5	3.91
FA 30% + NS 3%	30	3	4.16
FA 30% + NS 4.5 %	30	4.5	3.95

Table 6.5 Modulus of Elasticity of M20 Grade of Concrete

Concrete Mix	FA (%)	Colloidal Nano Silica (%)	Modulus of Elasticity (GPa) for 28 Days
Control Concrete	0	0	21.42
FA 20 % + NS 0 %	20	0	19.64
FA 20 % + NS 1.5 %	20	1.5	20.81
FA 20 % + NS 3 %	20	3	22.65
FA 20 % + NS 4.5 %	20	4.5	20.74
FA 30% + NS 0 %	30	0	18.94
FA 30 % + NS 1.5 %	30	1.5	20.4
FA 30% + NS 3%	30	3	21.5
FA 30% + NS 4.5 %	30	4.5	20.56

CONCLUSIONS

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 reacts with the calcium hydroxide 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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