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Effect of Nano- Flyash on Strength of Concrete

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ABSTRACT

The use of nano-particles in developing materials with desired properties has gained popularity and is being applied in many fields. More specifically, such particles can lead to improvements in the nanostructure of building materials such as cement and concrete. Concrete technology is a multidisciplinary area of research where nanotechnology potentially offers the opportunity to improve the properties of concrete to suit the specific requirements. Recent research has shown that addition of nanoparticles and nanotubes depends in the properties of concrete by modifying the structure of cement hydrates. It is also reported that addition of nano materials to concrete can lead to significant improvements in the strength and life of concrete. The grain size of the nano particles will be in the order of 10^{-9} m (1-100nm) [(1)]. An attempt has been made to carry out an experimental investigation on concrete with nano-fly ash. Class F fly ash was grinded in the ball grinding mill to produce nano-fly ash[(5)]. Different grades of concrete viz., M20, M30. M40 and M50 were cast with nano-fly ash. For each grade of concrete, 10%, 20% and 30% of coarse aggregate was replaced with nano-fly ash. The workability and compressive strength of concrete with nano-fly ash were determined and the results were compared with that of Normal Cement Concrete (NCC). Concrete with nano-fly ash was found to be stronger than NCC and the percentage increase in strength of concrete with nano-fly ash with respect to NCC was found to be in the range 17% to 50 % for various grades of concrete. The workability of concrete with nano-fly ash was found to be significantly more than that of NCC.

Key words: Nano particles, Nano -fly ash, Normal Cement Concrete, Ball Grinding mill

1. Introduction

Nanotechnology is not a new science and it is not a new technology. It is rather an extension of the sciences and technologies that have already been in development for many years and it is the logical progression of the work that has been done to examine the nature of our world at an ever smaller scale. Virtually every aspect of the construction process will be touched by the foregoing innovations of nano-scale technologies . The nano scale-size of particles can result in dramatically improved properties from conventional grain-size materials of the same chemical composition. Perumalsamy Balaguru and Ken Chong [(5)] highlighted that the nano-materials show unique physical and chemical properties that can lead to the development of more effective materials than the ones which are currently available. The extremely fine size of nano-particles yields favorable characteristics. Moreover, the rapid development of the field of materials science on the nano-scale has offered the civil engineers a new window of understanding into traditional construction materials, such as cementitious materials or steel, allowing us to enhance their properties, extend their lifetime bringing cost-savings and reduction in energy consumption.

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Fly ash not only improves the durability and strength but also reduces the requirement of cement. However, V.M.Malhotra(2003) and R.N.Swamy(1983) found out that the hydration process of concrete is slowed down by the addition of fly ash and the early stage strength is low in comparison to normal concrete. Gengying Li(2004) reported that fly ash reduces the amount of non-durable calcium hydroxide (lime) and converts it into calcium silicate hydrate (C-S-H), which is the strongest and most durable component of the paste in concrete. Fly ash also makes substantial contributions to workability and chemical resistance . In India, about 75% of energy supply is coal based and shall be so for the next few decades. Approximately 110 million tons of fly ash is produced per annum in the Country. Nearly 38% of the fly ash waste is utilized in the Country at present, in various fields including landfills, cement making and for the production of concrete .

The unique properties of fly ash such as fineness, specific surface area, particle shape, hardness, freeze-thaw resistance, etc. have paved way for its use in Construction and polymer industry. In construction industry fly ash has been used as a partial replacement of cement in order to achieve strength, durability and economical concrete. In polymer industry fly ash is utilized in making polymeric composites where fly ash is being used as inorganic particulate filler without much breakthrough. The utilization of fly ash is determined based on their properties. During the past decade numerous research have been carried out towards the effective utilization of fly ash and with understanding of potential environmental and health impacts associated with its disposal by land filling.

In this paper, an attempt has been made to modify the particle size fly ash by transforming the micro sized fly ash into nanostructured fly ash using high energy ball mill. The surface properties can be modified by ball grinding. The smooth, glassy and inert surface of the fly ash shown in figure.1 can be altered to a rough and more reactive product by this technique. Nano-fly ash is used for the partial replacement of coarse aggregate.

2. Experimental programme

The experimental programme consisted of making normal cement concrete (NCC) and concrete with nano- fly ash and comparing the performance of both. slump cone apparatus and compaction factor apparatus were used to carry the workability test on fresh concrete. Concrete cubes of size 150mm x 150mm x 150mm were cast and tested using the compression testing machine of capacity 2000kN. The tests were carried at a uniform rate of $14N/mm^2/min$ after the specimen had been centered in the testing machine. Scanning Electron Microscope (SEM) was used to study the morphology of the nano fly ash. [13]

3. Material

The materials used are the ordinary Portland cement, fine aggregate of specific gravity 2.67 belonging to zone II, coarse aggregate of specific gravity 2.8 and nano-fly ash. M20, M30 and M40 and M50 grade normal cement concrete (NCC) were cast. For making concrete with nano-fly ash, class F fly ash was scaled down to nano level and was used for the partial replacement of coarse aggregate in the production of nano-fly ash concrete[10]. The nano-fly ash is produced in high intensity ball milling. High impact collisions are used to reduce microcrystalline materials down to nano-crystalline structure without chemical change.[11] The Scanning Electron Microscope (SEM) was used to determine the particle size of nano-fly ash. Figure.2 shows the SEM picture of nano-fly ash. Nano-concrete was made by replacing

10%, 20%, and 30% of coarse aggregate with nano-fly ash for M20, M30, M40 and M50 grades.

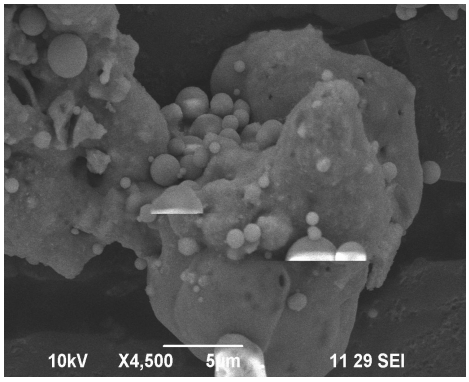

Figure 1: SEM picture of fly ash

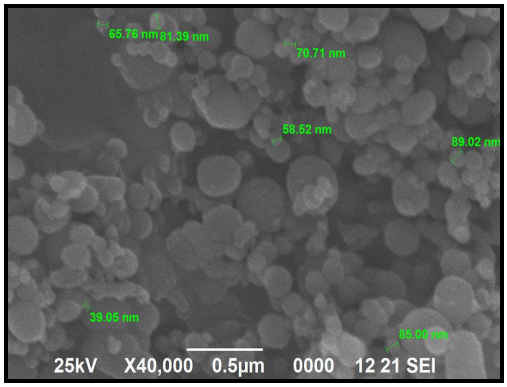

Figure 2: SEM picture of nano fly ash

4. Results and discussion

4.1 Compressive strength

The variation of the 28th day and 35th day cube compressive strength with respect to the percentage replacement of coarse aggregate with nano-fly ash are shown in Figure.3.

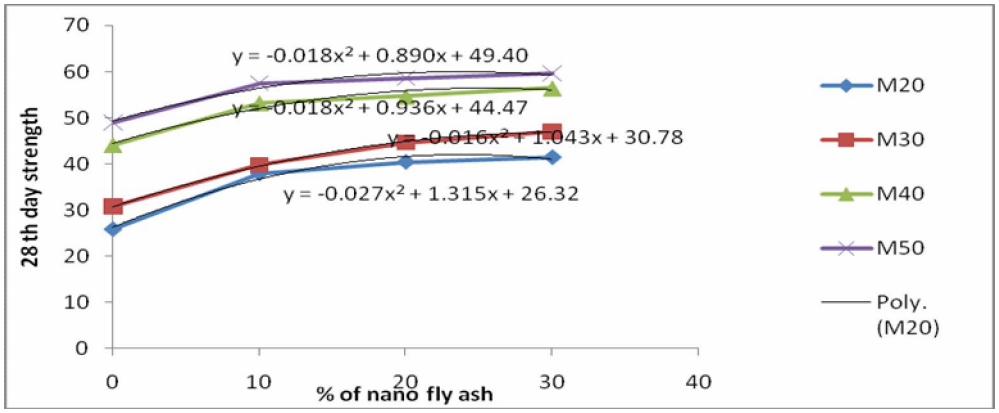

Figure 3: Cube Compressive Strength of Different Grades of Concrete with Nano-Flyash

The values of the 28th day and 35th day compressive strength and the workability values for different grades of the NCC are given in Table 1.

Table 1: Test results of Fresh and Hardened NCC

Grade	28-Day Compressive Strength of Cube (N/mm^2)	35-Day Compressive Strength of Cube (N/mm^2)	Slump Test (mm)	Type of Slump	Compaction Factor
M20	25.92	30.26	25	True	0.85
M30	30.70	33.51	28	True	0.88
M40	44.07	47.33	30	True	0.89
M50	49.03	50.40	34	True	0.92

The cube compressive strength and workability values of concrete with 10% of nano-fly ash are given in Table.2.

Table 2: Test results of fresh and hardened concrete with 10% of coarse aggregate replaced with nano-fly ash

Grade	28-Day Compressive Strength of Cube (N/mm^2)	35-Day Compressive Strength of Cube (N/mm^2)	Slump Test (mm)	Type of Slump	Compaction Factor
M20	37.93	40	48	True	0.94
M30	39.78	42.53	52	True	0.94
M40	53.21	55.98	56	True	0.96
M50	57.55	58.22	58	True	0.96

The cube compressive strength and workability values of concrete with 20% of nano-fly ash are given in Table.3.

Table 3: Test results of fresh and hardened concrete with 20% of coarse aggregate replaced with nano-fly ash

Grade	28-Day Compressive Strength of Cube (N/mm^2)	35-Day Compressive Strength of Cube (N/mm^2)	Slump Test (mm)	Type of Slump	Compaction Factor
M20	40.43	42.21	51	True	0.95
M30	44.67	47.89	58	True	0.95
M40	54.65	55.21	64	True	0.97
M50	58.62	59.26	72	True	0.97

The cube compressive strength and workability values of concrete with 30% of nano-fly ash are given in Table.4.

Table 4: Test results of fresh and hardened concrete with 30% of coarse aggregate replaced with nano-fly ash

Grade	28-Day Compressive Strength of Cube (N/mm^2)	35-Day Compressive Strength of Cube (N/mm^2)	Slump Test (mm)	Type of Slump	Compaction Factor
M20	41.44	43.56	58	True	0.96
M30	47.02	49.77	66	True	0.96
M40	56.45	58.67	72	True	0.97
M50	59.66	59.83	79	True	0.98

For M20 Grade of Concrete

1. The 28^{th} day and 35^{th} day compressive strength of Concrete with 10% replacement of coarse aggregate with nano- fly ash were found to be 46.33% and 32.18% more than that of the Normal Cement Concrete respectively.

2. The 28th day and 35th day compressive strength of Concrete with 20% replacement of coarse aggregate with nano-fly ash were found to be 56% and 39.49% more than that of the Normal Cement Concrete respectively.
3. The 28th day and 35th day compressive strength of Concrete with 30% replacement of coarse aggregate with nano-fly ash were found to be 59.87% and 43.95% more than that of the Normal Cement Concrete respectively.

For M30 Grade of Concrete

1. The 28th day and 35th day compressive strength of Concrete with 10% replacement of coarse aggregate with nano-fly ash were found to be 25.48% and 26.92% more than that of the Normal Cement Concrete respectively.
2. The 28th day and 35th day compressive strength of Concrete with 20% replacement of coarse aggregate with nano-fly ash were found to be 40.91% and 42.92% more than that of the Normal Cement Concrete respectively.
3. The28th day and 35th day compressive strength of Concrete with 30% replacement of coarse aggregate with nano-fly ash were found to be 48.32% and 48.52% more than that of the Normal Cement Concrete respectively.

For M40 Grade of Concrete

1. The 28th day and 35th day compressive strength of Concrete with 10% replacement of coarse aggregate with nano-fly ash were found to be 20.73% and 18.27% more than that of the Normal Cement Concrete respectively.

2. The 28th day and 35th day compressive strength of Concrete with 20% replacement of coarse aggregate with nano-fly ash were found to be 24% and 16.64% more than that of the Normal Cement Concrete respectively.

3. The 28th day and 35th day compressive strength of Concrete with 30% replacement of coarse aggregate with nano-fly ash were found to be 28.09% and 23.95% more than that of the Normal Cement Concrete respectively.

For M50 Grade of Concrete

1. The 28th day and 35th day compressive strength of Concrete with 10% replacement of coarse aggregate with nano-fly ash were found to be 17.37% and 15.51% more than that of the Normal Cement Concrete respectively.
2. The 28th day and 35th day compressive strength of Concrete with 20% replacement of coarse aggregate with nano-fly ash were found to be 19.55% and 17.57% more than that of the Normal Cement Concrete respectively.
3. The28th day and 35th day compressive strength of Concrete with 30% replacement of coarse aggregate with nano-fly ash were found to be 21.68% and 18.71% more than that of the Normal Cement Concrete respectively.

4.2 Slump test

The comparison between the slump values of NCC with respect to the concrete with nano-fly ash is shown in Figure.4.

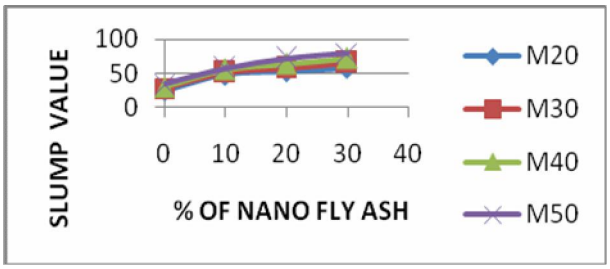

Figure 4: Comparison of Slump values of NCC and concrete with nano-fly ash

For M20 Grade of Concrete

1. The slump value of Concrete with 10% nano-fly ash was found to be 92% more than that of Normal Cement Concrete.
2. The slump value of Concrete with 20% nano-fly ash was found to be 112% more than that of Normal Cement Concrete.
3. The slump value of Concrete with 30% nano-fly ash was found to be 132% more than that of Normal Cement Concrete.

For M30 Grade of Concrete

1. The slump value of Concrete with 10% nano-fly ash was found to be 85.71% more than that of Normal Cement Concrete.
2. The slump value of Concrete with 20% nano-fly ash was found to be 107.14% more than that of Normal Cement Concrete.
3. The slump value of Concrete with 30% nano-fly ash was found to be 135.71% more than that of Normal Cement Concrete.

For M40 Grade of Concrete

1. The slump value of Concrete with 10% nano-fly ash was found to be 86.66% more than that of Normal Cement Concrete.
2. The slump value of Concrete with 20% nano-fly ash was found to be 113.33% more than that of Normal Cement Concrete.
3. The slump value of Concrete with 30% nano-fly ash was found to be 140% more than that of Normal Cement Concrete.

For M50 Grade of Concrete

1. The slump value of Concrete with 10% nano-fly ash was found to be 70.58% more than that of Normal Cement Concrete.
2. The slump value of Concrete with 20% nano-fly ash was found to be 111.76% more than that of Normal Cement Concrete.
3. The slump value of Concrete with 30% nano-fly ash was found to be 132.35% more than that of Normal Cement Concrete.

5. Conclusions

The following conclusions are derived based on the present research.

1. Since the nano sized particles are most active, the strength of concrete with nano-materials was found to be higher than that of Normal Cement Concrete.
2. The 28^{th} day strength of concrete with 10% of nano-fly ash was found to be 17 to 46% higher than that of Normal Cement Concrete. M20 concrete had the highest increase in strength where as M50 concrete had the least increase in strength.
3. The 28^{th} day strength of concrete with 20% of nano- fly ash was found to be 19 to 56% higher than that of Normal Cement Concrete.
4. The 28^{th} day strength of concrete with 30% of nano- fly ash was found to be 21 to 60% higher than that of Normal Cement Concrete.
5. The workability of the concrete with nano- fly ash was found to be 90 to 140% higher than that of Normal Cement Concrete.

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