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INTERNATIONAL JOURNAL OF CURRENT RESEARCH

International Journal of Current Research
Vol. 4, Issue, 12, pp. 382-384, December, 2012

ISSN: 0975-833X

RESEARCH ARTICLE

STUDY Of EFFECT OF Al_2O_3 NANOPARTICLES ON THE COMPRESSIVE STRENGTH AND WORKABILITY OF BLENDED CONCRETE

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ARTICLE INFO

Article History:
Received 09th September, 2012
Received in revised form
12th October, 2012
Accepted 23rd November, 2012
Published online 28th December, 2012

Key words:
Compressive strength ,
Nanophase,
Workability,
Cement,
Plain concrete.

ABSTRACT

The compression test was carried out in accordance with IS 456-2000; on nano Al_2O_3 blended concrete & plain concrete. Al_2O_3 nanoparticles with the average diameter of 15 nm were used with four different contents of 0. 5%, 1.0%, 1.5% and 2.0% by weight. The tests were carried out on M20 grade of plain cement concrete and nano Al_2O_3 Blended concrete. The results revealed that the compressive strength of some of the samples is improved. The workability of fresh concrete was decreased by increasing the content of Al_2O_3 nanoparticles.It is concluded that partial replacement of cement with nanophase Al_2O_3 particles improves the compressive strength of concrete but decreases its workability.

INTRODUCTION

The world of materials is rapidly progressing with new technmologies.Nano technology is among these modern and sophisticated technologies, which is creating waves in modern times. Nano technology is a advanced technology, which deals with the synthesis of nano particles, processing of nano particles and their applications.Normallly, if the particle sizes are in the 1-100 nm ranges, they are generally called as nano particles. More is the fineness, more is the surface area, which increases the reactivity of the material.Portland cement is the essential bonding material in concrete, which is the most widely, used non metallic material of construction in our industrial age. Different oxides present in cement, plays a vital role in deciding the strength of concrete.The change in the composition of oxides of cement may increase the compressive strength of concrete. Microscopic investigation shows that Portland cement essentially consists of the following constitutes: C_3S,C_3A ,C_2S,C4AF,MgO and small quantities of free CaO.It also consist of gypsum ,added during grinding to control the setting time of the cement and traces of TiO_2,Mn_2O_3,Na_2O,K_2O.The compressive strength of concrete plays key role in construction industry. The many efforts were made to optimize the compressive strength of concrete by using materials/additives[11]. The cement having more compressive strength is preferred in the construction Industry. The aim of this study is to compare the compressive strength of the standard M-20 grade cement concrete with Al_2O_3 nano particles Blended concrete. In the present study attempt were made to improve the compressive strength and workability by using Al_2O_3 nano particles.

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Literature Review

The literature review revealed that the change in the composition of oxides in the cement, affects the compressive strength and workability of the concrete**.** Hui et al. (2003)[1] investigated the properties of cement mortars blended with nanoparticles to explore their super mechanical and smart (temperature and strain sensing) potentials. Lu and Young [2] achieved high strengths on compressed samples. Richard and Cheyrezy[3] developed Reactive Power Concretes (RPCs) with high compressive strength and appropriate fracture energy. The development of an ultrahigh strength concrete was made possible by the application of DSP (Densified System containing homogeneously arranged ultra-fine Particles) with super plasticizer and silica fume content [4]. There are several papers on incorporating nanoparticles into concrete specimens to achieve improved physical and mechanical properties, most of which have focused on using SiO_2 nanoparticles[5].

In addition, some of the work has been conducted on utilizing nano-Al_2O_3[6] . Previously, the effects of SiO_2[7], TiO_2[8] and ZnO_2[9] nanoparticles on different properties of self-compacting concrete have been studied. In addition, in a series of works[10] the effects of several types of nanoparticles on properties of concrete specimens which are cured in different curing media have been investigated. It has been shown that utilizing nanoparticles in concrete improves the mechanical properties of the specimens besides the improvement in microstructure and pore structure of the concrete specimens. Nanoparticles can act as heterogeneous nuclei for cement pastes, further accelerating cement hydration because of their high reactivity, as nano-reinforcement, band as nano-filler, densifying the microstructure, thereby, leading to a reduced porosity. The most significant issue for all nanoparticles is effective dispersion. Incorporating of other nanoparticles is rarely reported. Therefore, introducing other nanoparticles which probably could improve the mechanical and physical properties of cementitious composites is interesting. The literature review has motivated us to undertake the present study. The aim of this study is to investigate the effects of Al_2O_3on compressive strength and workability of the concrete.

MATERIALS AND METHODS

Cement: Ordinary Portland cement of 53 grades obtained from ultratech cement confirming IS Code 12269-1987 was used. The composition of cement is shown in table -1

Particulars	SiO_2	Al_2O_3	Fe_2O_3	CaO	MaO	SO_3	Na_2O	K_2O	Loss on ignition
%	18%	4%	3%	61%	2%	1%	0.4%	0.6%	3.21%

Nano Al_2O_3 particles: Nano Al_2O_3 with avg. particles size of 40-50nm was used. The properties of nano Al_2O_3 are shown as below[13].

Diameter(nm)	Surface volume (m^2/gm)	Density (gm/cm^3)	purity %	make
(40-50)	32-40	< 0.1 %	> 99.5%	Alfa Aesar

Sand: locally available natural sand with particles smaller than 0.5mm is used; the properties of sand are shown as below.

Sp. Gravity of Sand (gm/cm^3)	Water absorption of sand
2.065	1.23%

Mixtures

Mixture proportioning

A total of two series of mixtures were prepared in the laboratory trials. Series A mixtures were prepared as control specimens. The control mixtures were made of natural aggregates, cement and water. Series B were prepared with different contents of Nano- Al_2O_3 particles with average particle size of 45 nm. The mixtures were prepared with the cement replacement of 0.5%, 1.0%, 1.5% and 2.0% by weight. The aggregates for the mixtures consisted of a combination of crushed basalt and of fine sand, with the sand percentage of 30% by weight[14].

Preparation of test specimens

Series B mixtures were prepared by mixing the course aggregates, fine aggregates and powder materials (cement and nano- Al2O3 particles) in a laboratory. The powder material in the series A mixtures was only cement. They were mixed in dry condition for two minutes, and for another three minutes after adding the water. Slumps of the fresh concrete were determined immediately to evaluate the workability following the mixing procedure. Cubes of 75 mm edge were cast. Then the specimens were remolded and cured in water at a temperature of 20o C prior to test days. The compressive strengths tests of the concrete samples were determined at 7, 14 and 28 days. The reported results are the average of three trials[15].

Compressive strength of nano-Al2O3 particles blended concrete

Compressive strength of nano-Al2O3 particles blended cement concrete cubes was determined after 7, 28 and 90 days of moisture curing[16].

Workability

Standard slump tests were used to determine the workability of the concrete[10].

RESULTS AND DISCUSSION

The compressive strength results obtained from the experimental investigations are showed in tables and the comparison between the results of workability test is presented in form of bar chart. All the values are the average of the three trails in each case in the testing program of this study. The results are discussed as follows.

Compressive strength

The compressive strength results of series A and B mixtures are shown in Table 1

Table 1. Compressive strength results

Sample designation	nano-Al_2O_3 particle %	Compressive strength (Mpa)		
		7 days	14 days	28 days
A	0	27.3	31.3	36.8
B1	0.5	30.4	35.5	41.1
B2	1.0	31.7	36.9	42.3
B3	1.5	31.9	37.1	42.8
B4	2.0	27.5	32.4	37.7

Comparison of the results from the 7, 28 and 90 days samples shows that the compressive strength increases with nano-Al_2O_3 particles up to 1.0% replacement (B2) and then it decreases, although the results of 2.0% replacement (B4) is still higher than those of the plain cement concrete (A). It was shown that the use of 2.0% nano-Al_2O_3 particles decreases the compressive strength to a value which is near to the control Concrete. This may be due to the fact that the quantity of nano-Al_2O_3 particles present in the mix is higher than the amount required to combine with the liberated lime during the process of hydration thus leading to excess silica leaching out and causing a deficiency in strength as it replaces part of the cementitious material but does not contribute to strength. Also, it may be due to the defects generated in dispersion of nanoparticles that causes weak zones. The high enhancement of compressive strength in the B series blended concrete are due to the rapid consuming of $Ca(OH)_2$ which was formed during hydration of Portland cement specially at early ages related to the high reactivity of nano-Al_2O_3 particles. As a consequence, the hydration of cement is accelerated and larger volumes of reaction products are formed.

Workability

A high-quality concrete is one which has acceptable workability (around 6.5 cm slump height) in the fresh condition and develops sufficient strength. Basically, the bigger the measured height of slump, the better the workability will be, indicating that the concrete flows easily but at the same time is free from segregation. Maximum strength of concrete is related to the workability and can only be obtained if the concrete has adequate degree of workability because of self compacting ability. The workability of A and B series concrete are presented in Figure 1.

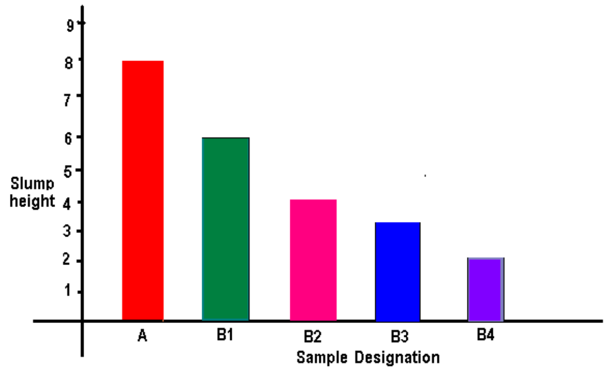

Fig.1

Table 2.Slump cone test results

Sample designation	nano-Al_2O_3 particle %	Slump height(cm)
A	0	8cm
B1	0.5	6cm
B2	1.0	4cm
B3	1.5	3.5cm
B4	2.0	2.0cm

The figure shows the influence of Nano- Al_2O_3 particles content on the workability of mixtures. The results show that unlike the A series, all investigated Nano- Al_2O_3 particles blended mixtures had low slump values. This may be due to the increasing in the surface area of powder after adding nanoparticles that needs more water for wetting the cement particles. With the improvement of novel plasticizers, to obtain high filling rates is possible even for compound molding systems[11]. The fresh characteristics of concrete, strength and durability of mortars can be improved by the addition of inert or pozzolanic material. The selection of the amount and the type of cementitious or inert powders depends on the physical and physico-chemical properties of these powders which are affecting the performance of fresh paste such as particle shape, surface texture, surface porosity and rate of superplasticizer adsorption, surface energy (zeta potential), finest fraction content, Blaine fineness and particle size distribution. There is no universally accepted agreement on the effect of these factors due to the complex influence of the combination of these factors[12]. Usually, increasing the fine particles content in cements changes the rheological properties of pastes and consequently influences the workability of mortars and fresh concrete mixtures. It is usually expected that, if the volume concentration of a solid is held constant, for a specific workability, the replacement of cement with a fine powder will increase the water demand due to the increase in surface area. This is more observed for nanoparticles blended concrete. However, in some cases, the above-mentioned conclusion is not appropriate.

Conclusions

The results show that the nano-Al_2O_3 particles blended concrete had significantly higher compressive strength compare to that of the concrete without nano-Al_2O_3 particles. It is found that the cement could be advantageously replaced with nano- Al_2O_3 particles up to maximum limit of 2.0% with average particle sizes of 45 nm. Although, the optimal level of nano-Al_2O_3 particles content was achieved with 1.0% replacement. Partial replacement of cement by nano-$Al2O_3$ particles decreased workability of fresh concrete; therefore use of super plasticizer is substantial.

Future Scope

Partial replacement of nano Al_2O_3 increases the compressive strength of concrete but decreases the workability. Therefore there is scope for work on how to increase the workability along with the compressive strength of concrete.

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