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Experimental investigation on Nano particles in High Performance Concrete

P. Jaishankar[1] and K. Saravana Raja Mohan[2]

[1]School of Civil Engineering, SASTRA University, Thanjavur, Tamilnadu, 613402, India.

Abstract: The influence of Nano particles on mechanical properties and durability of concrete has been investigated. For this purpose, constant content of Nano-ZrO_2 (NZ), Nano-Fe_3O_4 (NF), Nano TiO_2 (NT) and Nano-SiO_2 (NS) have been added to concrete mixtures. Mechanical properties have been investigated through the compressive and indirect tensile strength and durability has been investigated through chloride penetration test and concrete permeability. Results of this study showed that Nano particles can be very effective in improvement of both mechanical properties and durability of concrete. Results of this study seem to indicate that the Nano-SiO_2 (NS) is most effective nano-particle of examined nano materials in improvement of mechanical properties of high performance concrete.
Keywords: Nano particles, Mechanical, Durability properties.

1. Introduction

Nano technology has attracted considerable scientific interest due to the new potential uses of particles in the order of nanometer (10-9 m) scale. The nano scale-size particles can result in dramatically improved properties from conventional grain-size materials of the same chemical composition. During the recent years, Nano technology is developing with noticeable rate. Due to the new potential uses of Nano particles there is a global interest in investigation of the influence of Nano-particles in construction materials especially in cement mortar and concrete. Many of the available studies have focused on the effect of Nano-SiO_2 on properties of hardened cement paste, cement mortar and/or concrete. Ye Qing et al [3] experimentally investigated the effects of Nano-SiO_2 on properties of hardened cement paste. Byung-Wan Jo et al [2] studied the influence of Nano-SiO_2 on characteristics of cement mortars. The results of these studies showed that Nano-SiO_2 can improve the mechanical properties of hardened cement paste and cement mortar. Hui Li [6] investigated the effects of Nano-SiO_2 and Nano-Fe_2O_3 on mechanical properties of cement mortars. Gengying Li [5] investigated the influence of Nano-SiO_2 on mechanical properties of high volume fly ash concretes. Through the literature survey of the authors there are few published studies on the influence of other Nano-particles on mechanical properties and durability of high performance concrete. In this study the influence of NF, NZ, NS and NT on durability and mechanical properties of high performance concrete is experimentally investigated. For this purpose different contents of nano-particles ranging from 0 to 2% have been added to a concrete mixture. Mechanical properties (compressive strength and indirect tensile strength) of concrete samples as well as durability parameters (chloride penetration and water absorption) have been measured in order to explore the influence of these particles on mechanical properties and durability of concrete.

2. Experimental Program

Cementitious materials used were commercial ordinary Portland cement, Metakaolin and Nano-particles. The content of Metakaolin in each sample was 15% of the cementitious material. The range of Nano-particle sizes were 10 to 25 nanometers. The content of nano-particles in each of the specimens was 1.5% of the weight of cementitious materials. A super plasticizer (SP) used was commercial conplastSP430 solution.

a) Cement: Ordinary Portland cement of 43 grade confirming to IS 8112:1989[9]of locally available RAMCO cement which comprises good quality. The chemical configuration of cement was found using X-ray fluorescence analysis and has the following properties are given in table1.

Table 1: Physical and chemical composition of ordinary Portland cement (OPC)

Description	**Composition**
Physical Properties	
Color	Grey
Specific gravity	3.15
Specific surface area (cm^2/g)	3540
Chemical Composition	
CaO (%)	62.8
SiO_2 (%)	20.3
Al_2O_3 (%)	5.4
Fe_2O_3 (%)	3.9
MgO (%)	2.7
Na_2O (%)	0.14
K_2O (%)	62.8

b) Fine aggregate: For fine aggregates, uncrushed locally available natural river sand of maximum size 2.36 mm with a fineness modulus of 3.35 and specific gravity of 2.65 using IS 2386(Part III):1963[10] was used.

c) Coarse aggregate: The size of the coarse aggregates used ranges between 10 mm to 12 mm of specific gravity 2.74 using IS 2386(Part III):1963. The properties of coarse aggregate are given in Table 2.

Table 2. Properties of coarse aggregate

Aggregate properties	**Values**
Impact value	17.18
Crushing value	21.46
Water absorption	1.56
Abrasion value	24.40

d) Admixtures (Super-plasticizer): CONPLAST SP430 (G) complies with IS: 9103:1999[11] and BS: 5075 (Part 3) and ASTM-C-494[12] type 'F' having a specific gravity of 1.2 was used as a high range water reducing agent. Air entrainment of Approx. 1%. The mix proportions are indicated in table 3.

Table 3: Mix proportion of concrete specimens

Sample	**Cement+ metakaolin (Kg/m^3)**	**SP(%)**	**W/C**	**Nano-ZrO_2**	**Nano-Tio_2**	**Nano-SiO_2**	**Nano-Fe_3O_4**
A*	580	1.5	0.25	-	-	-	-
NZ	580	1.5	0.25	1.5	-	-	-
NT	580	1.5	0.25		1.5	-	-
NS	580	1.5	0.25	-	-	1.5	-
NF	580	1.5	0.25	-	-	-	1.5

* A denotes Control concrete sample (Sample without any Nano-particle)

3. Experimental Procedures

The fresh concrete was cast in 150x150x150 mm cubic and 300x150 mm cylindrical molds. After being demoulded at the age of one day, all specimens were cured in water at 20 ± 1 °C for 28 days. All of the tests were conducted after 28 days curing.

3.1. Compression test

Cubic samples were used for measuring the compressive strength. Three cubes were tested for each mixture by a hydraulic press with 300 KN capacity. The loading rate was set to 0.3 MPa/s.

3.2. Indirect tensile test

Indirect tensile tests were conducted on cylindrical samples. For each mixture three samples were prepared and tested. The results presented herein for indirect tensile tests are average of three samples of each mixture.

3.3. Chloride penetration test

Chloride penetration test were conducted according to ASTM C 1202-97. Three samples of each model were used for chloride penetration tests. The results presented herein are the average of three specimens.

3.4. Water absorption

Water absorption tests were performed on three specimens of each mixture according to ASTM C 642. The average of three specimens was reported as water absorption for each mixture.

4. Results and Discussions

Compressive strengths after 28 days are shown in table 4. As indicated in figure 1, compressive strength was developed in specimens containing nano-particles in every case higher than that of control concrete specimens (without nano-particles). It can be also seen that the influence of NA in improvement of compressive strength of concrete is more than the effect of other nano admixtures.

Table 4: Compressive strength of specimens after 28 days

Sample	Compressive strength (MPa)
A	61
NZ	63
NT	64.5
NS	68
NF	64

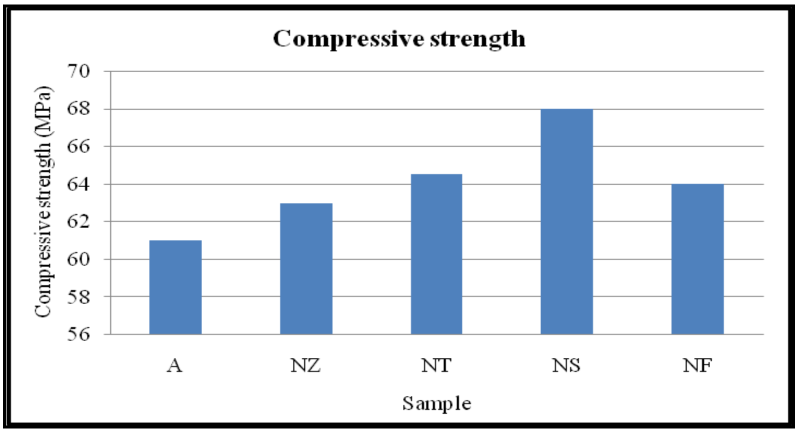

Figure 1: Compressive strength of examined specimens

Results of indirect tensile tests are indicated in Figure 2. It can be seen in the figure that the indirect tensile strength of samples containing nano admixtures were higher than that of control concrete sample. It is also observable that indirect tensile strength in samples with NS and NF is greater compare to other specimens.

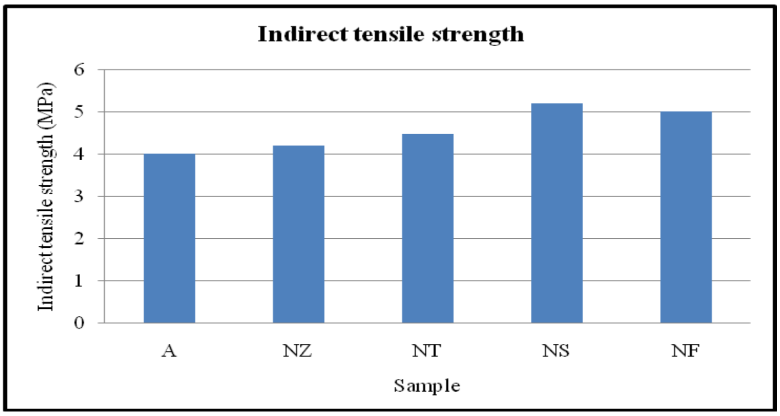

Figure 2: Indirect tensile strength of examined specimens

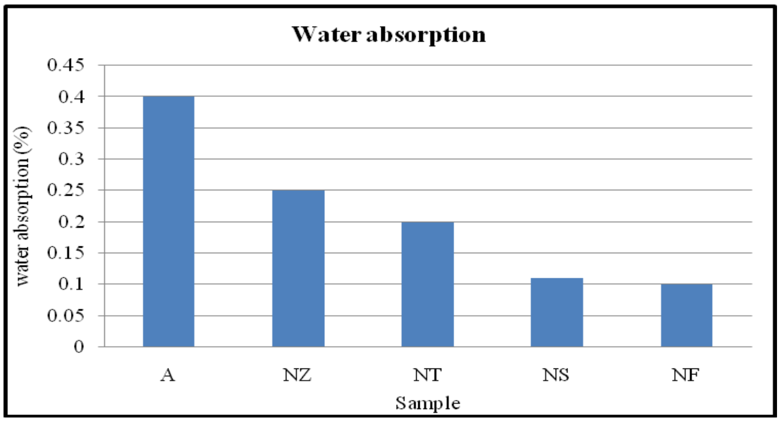

Figure 3: Water absorption of specimens (%)

As indicated in figure 3, Nano particles can reduce the water absorption of concrete samples. The values of the water absorption (in Percent) in all of the concrete samples with nano-particles were less than 0.25 of water absorption of control specimens. The influences of nano-particles on chloride penetration of concrete specimens are shown in figure 4. It can be seen that nano particles have reduced the chloride penetration compare to control specimen. The reduction of chloride penetration in various specimens is 15% to 65%.

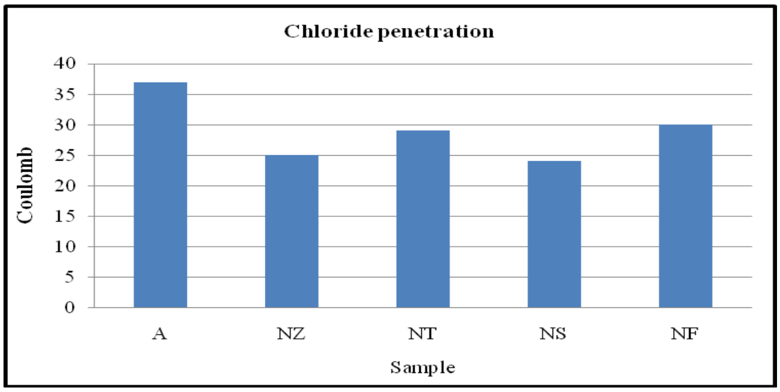

Figure 4: Chloride penetration in examined specimens

5. Conclusions

The influence of Nano-ZrO_2, Nano-Fe_3O_4, Nano-TiO_2 and Nano-SiO_2 on durability and mechanical properties of high performance concrete was experimentally investigated. For this purpose compressive tests and indirect tensile tests were conducted in order to investigate the effects of nano-particles on mechanical properties of high performance concrete. Moreover water absorption and chloride penetration tests were conducted to explore the effect of nano particles on durability of concrete. Results of this study showed that:

a) All of the examined nano-particles can improve durability and mechanical properties of high performance concrete.
b) The contribution of NA on improvement of mechanical properties of high performance concrete was more than the other nano-particles.
c) All of the examined nano-particles had noticeable influence on improvement of durability parameters.

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