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Research Paper

EFFECT OF MICRO AND NANO PARTICLES IN M-SAND CEMENT MORTAR

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Recently, Nano particles have gain more attention in many fields to fabricate new materials with novel functions due to their unique physical and chemical properties. It has been found that physical properties of mortar, particularly strength and permeability significantly depend on its pore structure. Ultra fine particles of Nano composites provide more homogenous distribution of hydrated products of concrete. This effect of micro and nano particles enhances the durability of cement composites as well as the strength. In the present investigation, micro level materials such as Marble Powder (MP) are used to replacement of cement. Fine aggregate are replaced by Manufacturing Sand (M-Sand). In addition, influence of nano particles on different properties of cement mortar was investigated with marble powder and Rice Husk Ash (RHA) as a well known active pozzolana. Nano particles such as Al_2O_3, Fe_2O_3 of different percentage (0.5%, 1%, 1.5% and 2%) by weight of cement were replaced and their influence on mechanical properties, physical properties of the specimens were determined. The experimental results revealed that compressive strength and tensile strength were found to perform better than the control concrete.

Keywords: Manufactured Sand (M-Sand), CSH gel formation, Cement mortar, Marble Powder (MP), Fine Aggregate (FA), Super Plasticizer (SP), Nano Alumina (NA), Nano Ferrous (NF), Rice Husk Ash (RHA)

INTRODUCTION

Concrete durability has attracted a lot of attention from many researchers, because it has critical influence on the service life of concrete structure. Concrete is a porous material with pore sizes ranging from a few Nanometers to a few millimeters. The uses of mineral admixtures such as SF, fly ash, etc., (Hassan *et al*., 2000; Memon *et al*., 2002; Canan Tasdemir, 2003; Tahir Gonen and Salih Yazicioglu, 2007; and Shannag, 2011) are well recognized to enhance the properties of concrete. The majority of recent Nano technology research in construction has

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focused on the structure of cement based materials and their future mechanisms. Integrating Nano particles with cement based building materials results in some outstanding properties. Nano particles can react with calcium hydroxide (Ca $(OH)_2$) a crystal which are arrayed in the Interfacial Transition Zone (ITZ) between hardened cement pastes and aggregate and produces C-S-H gel. The size and amount of calcium hydroxide crystals are significantly decreased, and the early age strength of hardened cement paste is increased (Ye, 2001; Chen and Ye, 2002; Ye *et al*., 2003; and Sobolev and Ferrara, 2005). In the studies performed using NA, it was found that the powder increased compactness of the aggregate-cement paste interface, and also improved the modulus of elasticity and early age compressive strength of mortars up to a certain level (Li *et al*., 2006). Campillo *et al*. (2007) reported that the more environmentally friendly blended cements possessing a lower initial compressive strength had limited usage, but after blending them with colloidal NA and NA powder blended cements also exhibited an enhanced level of initial compressive strength. However, the effect of this powder on compressive strength varies depending on the proportion of powder and the curing conditions (Nazari and Riahi, 2011). Mortars containing NF powder demonstrated improved mechanical properties when the powder was used at proportions not exceeding 10% (Li *et al*., 2004). There is also a researcher (Li *et al*., 2004) who reported that the ability to identify tensions that occurred in NF powder—containing mortars increased with NF content, and therefore, NF-containing materials could be smart materials sensitive to tensions. Li *et al*. (2004) and Quiroga *et al*. 2004) also stated that NF and NS containing mortars displayed increased levels of compressive and flexural strength when compared with mortars containing the same ratio of water/binder but not the additives. The use of RHA as a highly reactive pozzolanic material in concrete production has been researched, especially in developing countries. This RHA contains high silica content in the form of non-crystalline or amorphous silica of up to 95% (Cai *et al*., 2006). The reactivity is attributed to the high content of amorphous silica, and to the very large surface area governed by the porous structure of the particles. Manufactured sands are produced by crushing rock depositions to produce a fine aggregate which is generally more angular and has rougher surface texture than naturally weather sand particles.

Common river sand is expensive due to excessive cost of transportation from natural source. Also large-scale depletion of this source creates environmental problem. Environmental transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry need to be found. The production of M-Sand also generates high percentages of micro fines, particles that pass the 75μ sieve, ranging from 5% to 20%. Generally the micro fines are washed out since the Chinese national standard JTG F 30-2003 limits the amount of micro fines to 5% (Quiroga and Fowler, 2004), and it is not feasible to eliminate a portion of them. The elimination of the micro fines represents a wasted aggregate resource and leads to a disposal problem for producers.

In addition, the elimination of the micro fines often produces a harsh mix that does not finish well, leading to the necessity of adding natural sand for increasing workability (Donza *et al*., 2002). Previous researches have shown that good quality concrete can be made using Nano particles with high amount of micro fines (Donza *et al*., 2002; and Li *et al*., 2009). Generally the compressive strength, flexural strength, and abrasion resistance as well as freezing resistance tend to increase to a certain limit with increasing proportions of micro fines. After the limit is reached, the strength decreases because there is not enough paste to coat the aggregate; impermeability varies without law and shrinkage, while slightly higher, is still within acceptable ranges. Water reducers and mineral admixtures can be used to improve workability, since in many cases the more angular MS results in reduced workability (Wang *et al*., 2003).

EXPERIMENTAL PROCEDURE

Materials Used

Marble Powder

Composition are given in the following Table 1. The average particle size distribution was 80-60 μm.

Cement Used

Ordinary Portland cement (OPC) – 43 Grade as per IS: 8112 Composition of OPC are given in the following Table 2.

Physical Properties

The physical properties of Natural and M-sand are given in the Table 3.

Chemical Properties

The chemical composition of OPC, Marble powder and M-sand are tabulated in Table 4.

The tests are conducted using SEM analysis with Energy Dispersive Analysis X-ray (EDAX) Spectrometer.

Table 1: Properties of Nano Particles

Item	Diameter (nm)	Spe. Surface Area (m^2)	Density (g/cm^3)	Purity (%)
Nano Al_2O_3	20-25	180	3.7	99.8
Nano Fe_2O_3	20-25	20-60	5.24	98

Table 2: Physical Properties of Cement

S. No.	Characteristics	Experimental value
1.	Standard consistency	30 min
2.	Setting time	
	Initial	140 min
	Final	355 min

Table 3: Physical Property of Natural Sand and M-Sand

S. No.	Characteristics	Experimental Value	
		Natural Sand	M-Sand
1.	Specific gravity	2.61	2.70
2.	Bulk density loose(kg/L)	1.48 kg/m^3	1.67 kg/m^3
3.	Fineness modulus	2.60	2.80
4.	Water absorption	0 .65	Nil
5.	Grading zone	Zone-II	Zone-II
6.	PH	8.93	–

Table 4: Chemical Composition of Material

Composition	OPC (%)	Marble Powder (%)	M- Sand (%)
SiO_2	21.0	18.43	67.62
Al_2O_3	5.4	–	15.43
Fe_2O_3	4.6	–	5.58
CaO	63.0	67.79	3.25
MgO	0.7	13.78	–
SO_3	2.9	–	–
Na_2O, K_2O and Others		–	4.01
LOI	2.5	–	3.25

Figures 1 and 2 shows the EDAX results of manufacturing sand and the marble powder.

Figure 3 and 4 shows the SEM analysis results of manufacturing sand and the marble powder.

Experimental Methods

Compression Test

The compressive strength of mortar is one of its most important properties. Mortar specimens of 50 x 50 x 50 mm cubes were cast using 1:3 mortar with W/C ratio of 0.45 with different types of blended cement mortars. After 24 h the specimens were demoulded and subjected to curing for14 days in water. After 14 days of curing, the cubes were then allowed to become dry for a few hours. The cubes were tested in the compression-testing machine (60 T capacity). The load was applied at the rate of 140 kN/min. The ultimate load at which the cube fails was taken.

EDAX Results

Figure 1: Manufacturing Sand

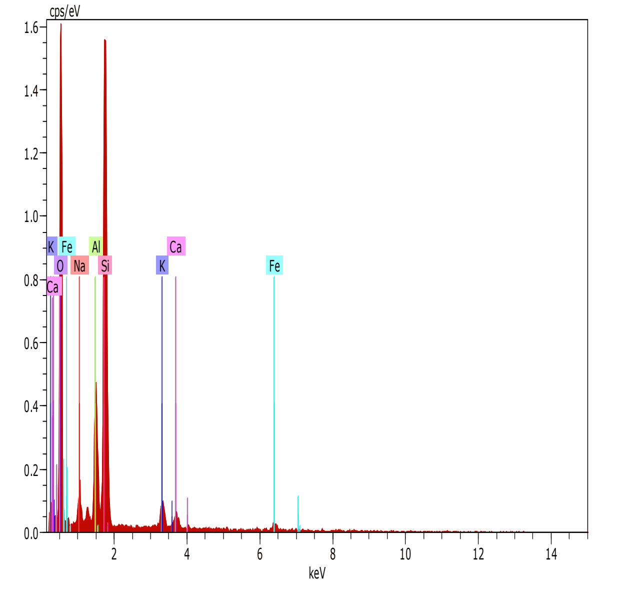
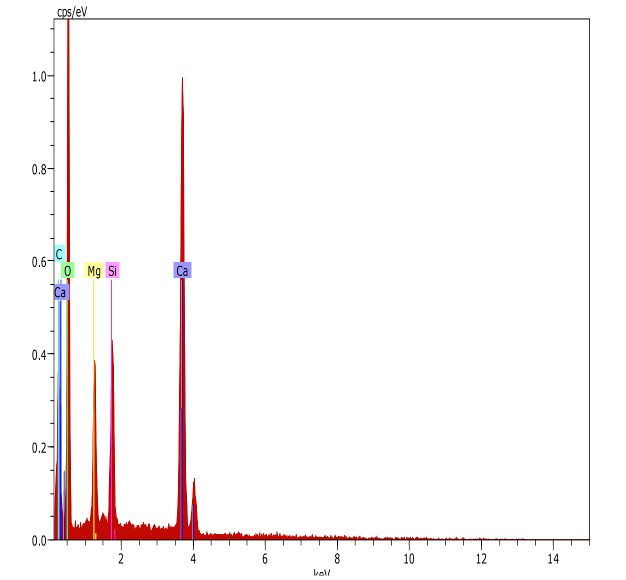


Figure 2: Marble powder



SEM Results

Figure 3: Manufacturing Sand

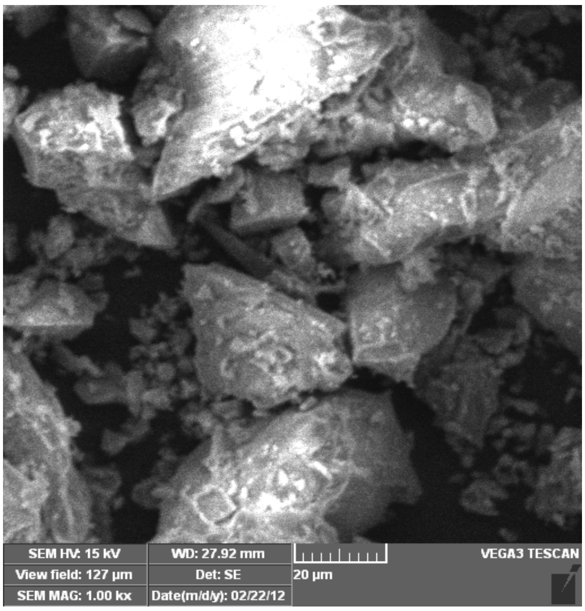
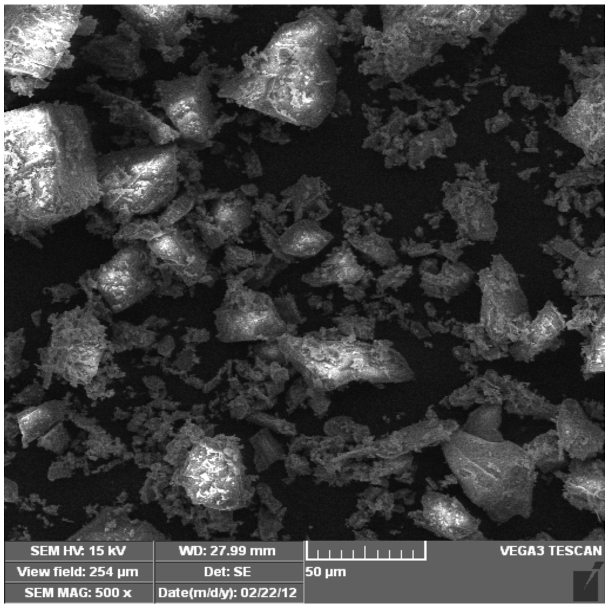


Figure 4: Marble powder



Split Tensile Test

Split tensile test was carried out as per ASTM C496-90. Concrete cylinders of size 60 mm diameters and 100 mm height were cast using 1:3 mortar with W/C ratio of 0.45. During casting, the cylinders were mechanically vibrated using a table vibrator. After 24 h, the specimens were removed from the mould and subjected to water curing for 28 days. After the specified curing period was over, the concrete cylinders were subjected to split tensile test by using the universal testing machine.

Tables 5, 6 and 7 shows the results of preliminary tests to find the optimum values of M-Sand, Nano Al_2O_3 and Nano Fe_2O_3 respectively.

Table 5 and Figure 5: Optimum Value for M-Sand

% of Replacement of M-Sand	Comp. Strength (N/mm^2)
0	11.88
25	18.16
50	19.4
75	24.48
100	11

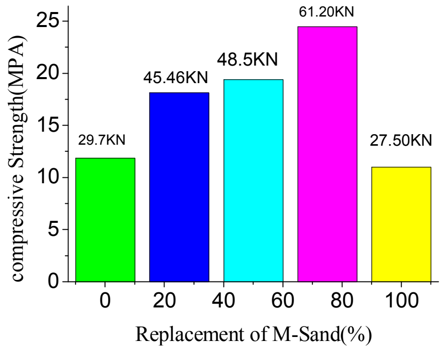


Table 6 and Figure 6: Optimum Value for Nano Al_2O_3

% of Replacement of Cement	Comp. Strength (N/mm^2)
0	43.196
0.5	47.28
1	49.99
1.5	32.11
2	27.664

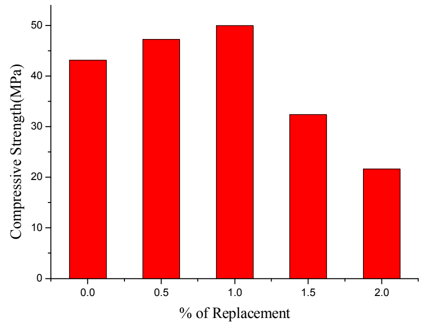


Table 7 and Figure 7: Optimum Value for Nano Fe_2O_3

% of Replacement of Cement	Comp. Strength (N/mm^2)
0	43.196
0.5	47
1	50.944
1.5	30.72
2	29.33

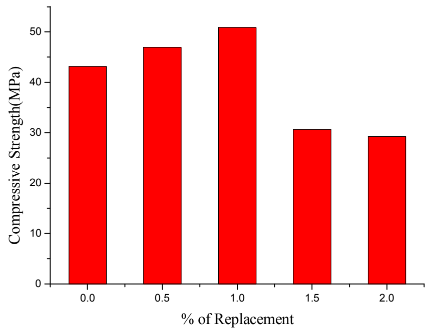


Table 8 to 13 shows the results of compressive and split tensile strength of Mortar cubes with Nano materials.

RESULTS AND DISCUSSION

Mechanical Properties

Compressive Strength Test

The compressive strength obtained for OPC (control) mortar was 43.196 N/mm² and the strength was increased about 6 and 2.4 times more than the control at 1% Nano Al_2O_3 and Fe_2O_3 respectively. The reactive silica present in particles favored the formation of Calcium Silicate Hydrate (CSH) gel and enhanced the compressive strength 1% level. From the Tables 5 and 6 it was found that the 1% NA and NF added mortars showed the optimum value.

Table 8 and Figure 8: Compressive Strength for Micro Particle

System	7-Days	14-Days	28-Days
OPC	12	20.128	43.196
OPC + MP	13.8	21.192	43.28
OPC + RHA	14.48	21.3	44.34

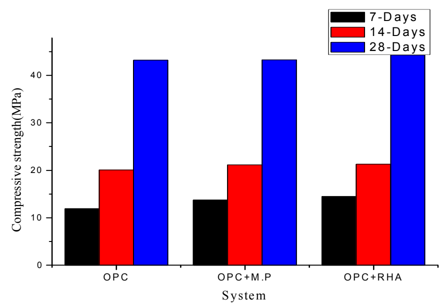


Table 9 and Figure 9: Compressive Strength for Micro and Nano Al_2O_3 Particle

System	7-Days	14-Days	28-Days
OPC + 1% NA	23	29.64	49.99
OPC + MP + 1% NA	27.16	29.76	54.56
OPC + RHA + 1% NA	27.22	30.52	55.84

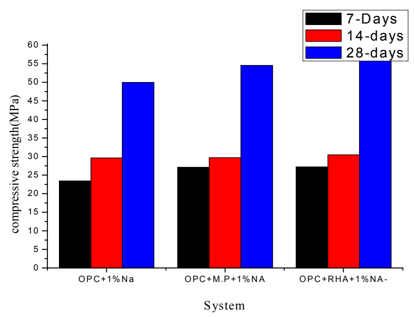


Table 10 and Figure 10: Compressive Strength for Micro and Nano Fe_2O_3 Particle

System	7-Days	14-Days	28-Days
OPC + 1% NF	22.72	32.32	50.944
OPC + MP + 1% NF	23.24	32.4	52.8
OPC + RHA + 1% NF	24.76	34	56

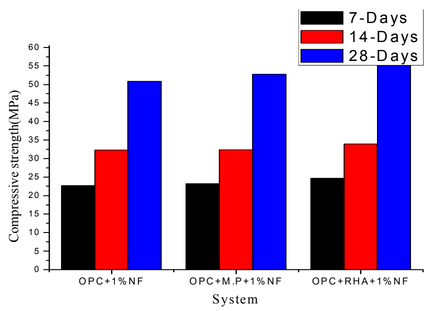


Table 11 and Figure 11: Tensile Strength for Micro Particle

System	7-Days	14-Days	28-Days
OPC	7.710	8.771	9.322
OPC + MP	7.958	9.054	10.298
OPC + RHA	8.028	9.516	10.610

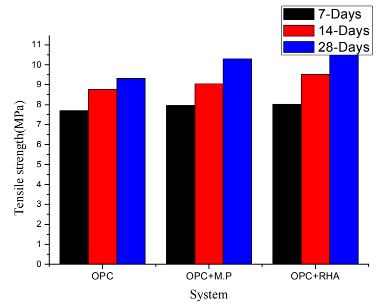


Table 12 and Figure 12: Tensile strength for Micro and Nano Al_2O_3 particle

System	7-Days	14-Days	28-Days
OPC + NA	9.054	10.575	11.14
OPC + MP + 1% NA	9.516	10.716	11.88
OPC + RHA + 1% NA	9.833	10.753	13.362

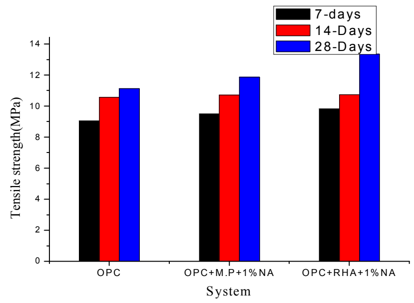
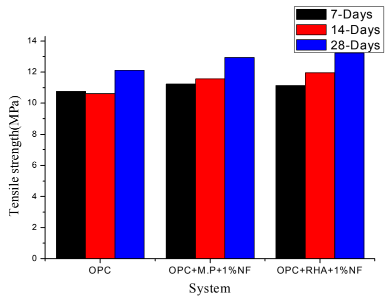


Table 13 and Figure 13: Tensile Strength for Micro and Nano Fe_2O_3 Particle

System	7-Days	14-Days	28-Days
OPC + NF	10.762	10.616	12.13
OPC + MP + 1% NF	11.24	11,565	12.904
OPC + RHA + 1% NF	11.14	11.958	13.228



Split Tensile Strength of Mortars

From Tables 11 and 12 it was found that OPC mortar showed split tensile strength of 9.32N/mm^2 at 28 days. The addition of NA in 1% level showed a maximum split tensile strength of 11.88 N/mm^2. Below 1% level, the tensile strength decreased. As observed in compressive strength values NA and NF at 1% level showed the highest tensile strength values indicating the tolerable limit of replacements 1%. From the compressive and tensile strength results it is confirmed that the tolerable limit of NA and NF addition is found to be 1%. Below 1% NA and NF addition, there is a reduction in strength observed due to the delayed formation of CSH.

CONCLUSION

The specimen cast by marble powder and Nano particles which is a replacement of cement sand. Combination of M-sand, marble powder and RHA increases the compressive strength as compared to control. Considerable results is obtained from the specimen which contains 1% of Nano particles exhibits more strength than the 0.5%, 1.5% of Nano particles. These results proved that strength of the specimen is increased up to 20% as compared to the control mix.

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