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STUDY OF ADDING NANOPARTICLES ON THE MECHANICAL PROPERTIES AND WATER ABSORPTION OF CEMENT MORTAR

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ABSTRACT

Effect of ZnO nanoparticles on the mechanical properties and permeability of cement mortar was studied. The apparatus made by ELE Company; England was used for performing the mechanical tests. Compressive tests were carried out according to the ASTM C109 (6) and tensile tests were carried out according to the ASTM C190 (7). Flexural tests were carried out according to ASTM C348 (8). The microstructure of the specimens was studied by the scanning electron microscopy (SEM) Hitachi S-4160. A Philips PW-1800 unit was used for XRD analysis. The test results show that when the cement is replaced with ZnO nanoparticles, improved strength and permeability of cement mortar. Studied by scanning electron microscopy (SEM) and X-ray diffraction (XRD) analysis of the mechanism for this effect is applied. Studies show that ZnO nanoparticles fill voids amount and size of crystals Ca (OH) 2 has been compressed to reduce the hydration products.

INTRODUCTION

With the development of nanotechnology, nanoparticles are widely used for the construction of the new materials. Many reports on the effects of nanoparticles on cementitious materials there. Nanoparticles in Mqayshh with other mineral additives perform better. Much research on the addition of nanoparticles on cementitious materials have shown that. Add nanoparticles in fresh state, to improve the rheological properties of cement (11) Hard Mode improves the mechanical properties (8). Nano-scale studies show that nanoparticles are the core of the cement paste and the nuclei with higher specific surface area can be more sites to provide products hydrate and accelerates the rate of chemical reactions (13).

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Reports on the effects of nanoparticles on cementitious materials there. The effect of nano particles such as SiO2 and TiO2 than it looked. SiO2 nanoparticles have a significant impact on the performance of cementitious materials Qing et al Showed that the addition of nanoparticles to the hardened cement paste and the crystal size decreases CH And the dense structure of hydrated products and bond strength at the interface between the batter and the compressive strength increases Danh. Also (8) because of the increased compressive strength and flexural strength of cement paste with colleagues Stefanidou nanoparticles were investigated by TEM and the results were similar.

Meng et al showed that TiO2 nanoparticles to improve the mechanical properties of cement mortar. They claimed the most important reason for improving strength, core function is to modify the arrangement of CH crystals not increase the amount of hydrated products. Our previous studies suggest that other nanoparticles such as Fe2O3, Al2O3 also go to work repairing the micro-structure and mechanical properties of cement mortar to improve. Rincon et al. Long-term behavior of ZnO as a Hlvgyry of corrosion were investigated. The results show that ZnO porous concrete and reinforcement reduces the amount of chloride in surface and thus reduces the corrosion of reinforcement. If ZnO can reduce corrosion of reinforcement because the nanoparticles have a higher energy level meter and the number of atoms on the surface increases, leading to increased levels of chemical reactions (17). Certainly, this property using nanoscale ZnO escalate. The report on the effect on the mechanical properties of ZnO there reformer cement.

The purpose of this study is to explore the possibility of adding ZnO nanoparticles to improve the mechanical properties and permeability of cementitious materials. For this purpose, the compressive strength and tensile strength of cement mortar containing ZnO nanoparticles have been investigated.

MATERIAL AND METHODS

Materials and mixture proportions

ASTM C 150 (4) Type II portland cement was used. The chemical and physical properties of the cement are shown in Table 1. The ZnO nanoparticles with average particles size of 10-30 nm which were purchased from... Inc were used.

Table 1. Chemical and physical properties of Portland cement (wt %).

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	K_2O	L.O.I	I.R
Cement	20.92	4.61	4.16	62.10	2.75	2.02	0.30	0.59	1.40	0.40

The characteristics of the ZnO nanoparticles were shown in Table 2. The superplasticizer (a commercial sulphonated melamine formaldehyde polymer) with relative density of 1.15 was employed to achieve good workability. In this study in order to prevent self-desiccation by increasing the added nanoparticles, the amount of super plastizer is increased too, which is consistent with literature (10,11). Also, the distilled water was used for preparing all mixtures. The fine aggregate was crushed silica sand with a fineness modulus of 2.4, the apparent density of 3.33 gr/cm^3. The sand was graded according to ASTM C33 (5) standard. The largest diameter of these aggregate particles was 4.75mm.

Table 2. Characteristics of nano- ZnO particles

Average particle size	Specific surface area (m^2/g)	True density (g/cm^2)	Purity (%)
10-30nm	20-60	5.606	99.9%

The proportions of the mixtures were presented in table 3. The ratio of the water to binder (the cement and ZnO nanoparticles) was chosen 0.42. In this study the mixtures were prepared with the cement replacement of 1%, 3% and 5% by weight of binder.

Table 3. Mix proportion of specimens

Specimens designation	Water	Cement	Sand	Nano-ZnO	*SP
*PC	150	360	1800	-	-
1ZA	150	356.4	1800	3.6	3.68
3ZA	150	349.2	1800	10.8	4.29
5ZA	150	342	1800	18	4.9

**PC: plain cement mortar*
**SP: superplasticizer*

Specimens' preparation

The behavior of such materials is mainly influenced by chemical reactions at the interface, and by the fact that they easily form agglomerates. such agglomeration affects the rheological properties of mixtures containing nanoparticles, whose dispersion is more difficult (11). Hence in this study ZnO nano powder was mixed with the distilled water and stirred for 6-10 hours by rotational speed of 250-300 rpm. At first, the suspension of the ZnO nanoparticles and the superplasticizer were mixed in the mixer for 30 second, where the cement was added to this mixture simultaneously. Thereafter, the sand, from finest to coarsest, was added gradually to the mixture, and the mixing continued until the complete homogenization of the mixture. Then, the mortar was poured into the standard mold. For tensile test, the briquette specimens with 75×25×25 mm dimension were utilized. The mortar was poured in two layers, both of them compressed by 4 impacts of a steel rod. In order to prepare the specimens of the compressive tests, the mortar was poured into molds to form cubes of size 50×50×50 mm in three layers alternatively, which all layers compressed by 10 impacts of a steel rod. For the flexural test, the mortar was poured into the molds with dimensions of 40×40×160 mm in two layers. Each layer was compacted by 15 impacts of a steel rod. The molded specimens were covered with a plastic layer for 24 hours and then were cured in water at the room temperature up test day. Six specimens were prepared for each test and the average result was reported.

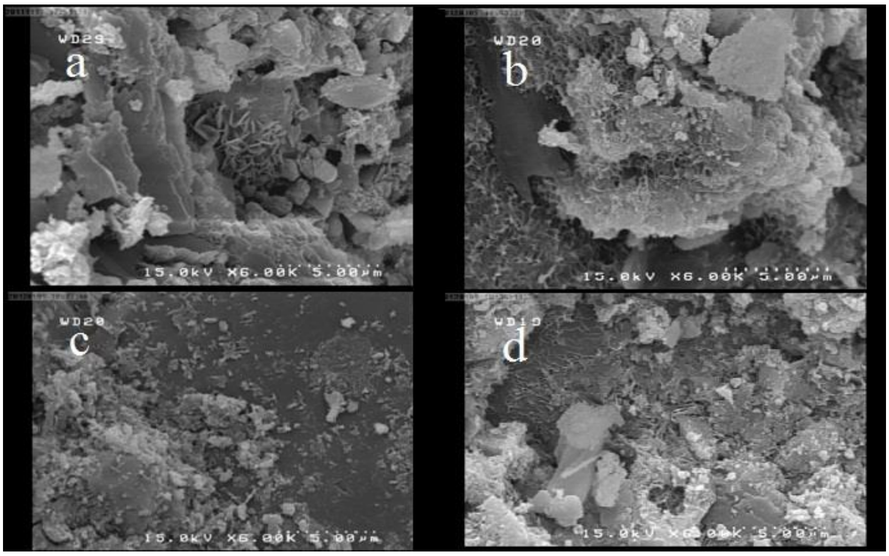
Test methods

The apparatus made by ELE Company; England was used for performing the mechanical tests. Compressive tests were carried out according to the ASTM C109 (6) and tensile tests were carried out according to the ASTM C190 (7). Flexural tests were carried out according to ASTM C348 (8). The microstructure of the specimens was studied by the scanning electron microscopy (SEM) Hitachi S-4160. A Philips PW-1800 unit was used for XRD analysis.

RESULTS AND DISCUSSION

Microstructure of the samples

Figure 1 shows micrographs of cement with different content of nano-particles in the twenty-eighth day of the show. As can be seen in the form of micro-crystal structure typical of large samples of mortar Ca (OH) 2 are the edge of the crystal-clear C-S-H gel and isolated by Jude Law and hydrate crystals large needles and Ca (OH) 2 is connected to encapsulation. Micro structure, cement, and completely non-compact spaces where it can be seen. Micro-structure of the sample containing 1% of nanoparticles is similar to a conventional mortar sample of both crystalline Ca (OH) 2 is observed, the difference is that the reduced size of the crystal edge (CH) were pulverized and reduced spaces. With increasing content of nanoparticles to 3% improved micro-structure and dense products are fully hydrated And crystals of Ca (OH) 2 has been dramatically reduced and dense and homogeneous structure is obtained. As shown in Figure 1 d is the sample containing 5% of nanoparticle agglomeration of nanoparticles formed voids.



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SEM micrographs of specimens a) PC, b) 1NZ, c)3NZ, d)5NZ

XRD analysis

Figure 2. XRD curves of different samples in the twenty-eighth day of the show. Use crystals Ca (OH) 2 due to reaction with ZnO nanoparticles in the CH peak intensity changes on 2ϴ =18.07 is proven. The severity of this side of the sample 3 NZ, 5NZ and 10NZ compared with Ordinary mortar samples (PC) were 17.35%, 28.92% and 34.71% decrease. Reduce the intensity of the peak Ca (OH) 2 crystals reduces Ca (OH) 2, and as shown in Figure 1. SEM images, This improves the micro-structure of cement mortar.

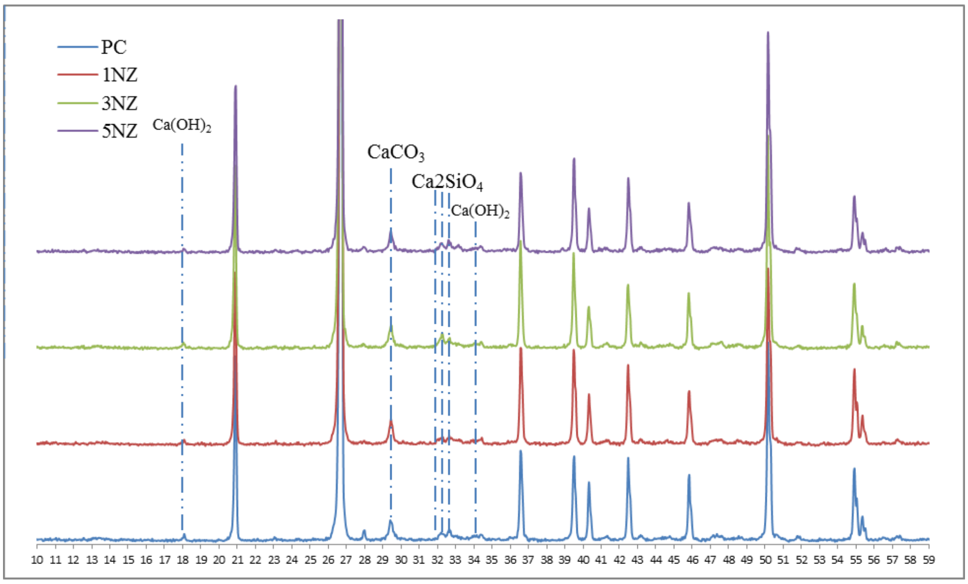


Fig 2. XRD results of specimens PC, 1NZ, 3NZ, 5NZ

Mechanical Properties

Table 4 and Figure 3 shows the results of compressive strength, tensile and flexural strength after 7 and 28 Rvznshan data. From Table 4, we find that the addition of nanoparticles to 3% of the compressive strength and tensile strength increased and then decreased. This may be because the nanoparticles tend to agglomerate due to their high surface energy being. When nanoparticles are added to excess mortar can be evenly distributed in cement mortar and creation of agglomeration areas are poor in cement mortar. While a small amount of nanoparticles, even if not playing very good resistance increase That is the reason A small amount of agglomeration of nanoparticles weak areas (weak zone) will not be.

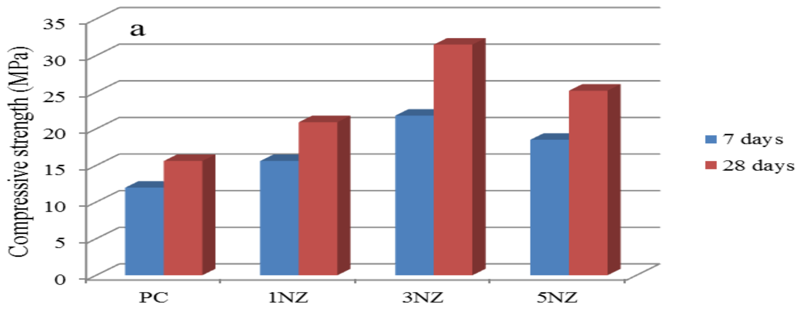
ZnO nanoparticles mechanism that increases the resistance of cement to be this way we can justify that, as Figure 2 shows the XRD curve Nanoparticles of ZnO due to the special surface to their high-rise intake crystals Ca (OH) 2 in the process of hydration of cement shaped and open spaces, the gel C-S-H fills the resulting hydrated product into denser and denser more. In other words, when the nanoparticles are dispersed uniformly in cement mortar. Each particle consists of a cube model has an adjustable distance between the nanoparticles. After the cement hydration process starts nanoparticles due to their high activity of cement hydration develop Speed and enhances the production of nanoparticles as a core surrounded by a hydrate. If the distance between the particles is appropriate. Nanoparticles of growing crystals of Ca (OH) 2 prevent (4). But with excessive content of nanoparticles in the sample 5NZ, nanoparticles dropped away as Figure 2 shows the XRD curve Crystal Ca (OH) 2 due to limited space can not grow enough. By reducing excessive crystals Ca (OH) 2 in the sample 5NZ fine crystals suitable for Ca (OH) 2 which role they are also reduced. This along with the agglomeration of nanoparticles has declined, although the volume resistivity 5NZ 3NZ compared to the resistance of the samples is higher 1NZ and PC (Figure 3). The results show that the addition of ZnO nanoparticles increases the tensile strength and flexural strength than that. This can be justified due to the form With increasing content of nano-particles in the sample 5NZ have increased surface area and therefore reduces the efficiency Leading to an increase in the number of micro-cracks and weak areas in cement mortar. The impact of micro-cracks on the flexural tensile strength and compressive strength is greater than (1).

From Table 4, we can increase the resistance by adding nanoparticles to increase the strength of more than 28 days in 3 days. That this was not the case in other nanoparticles.

Table 4. Mechanical properties of specimens

Mixture type	Compressive strength		Tensile strength		Flexural strength	
	7 days	28 days	7 days	28 days	7 days	28 days
PC	11.96	15.6	1.51	1.9	2.2	2.8
1NZ	15.6 (30.43)*	20.9 (33.97)	1.9 (25.82)	2.5 (31.57)	2.7 (22.72)	3.6 (28.57)
3NZ	21.8 (82.27)	31.5 (101.9)	2.6 (72.18)	3.8 (100)	3.9 (77.27)	5.8 (107.14)
5NZ	18.5 (54.68)	25.2 (61.53)	2.2 (45.69)	3.2 (68.42)	3.2 (45.45)	4.4 (42.85)

**Enhanced extent*



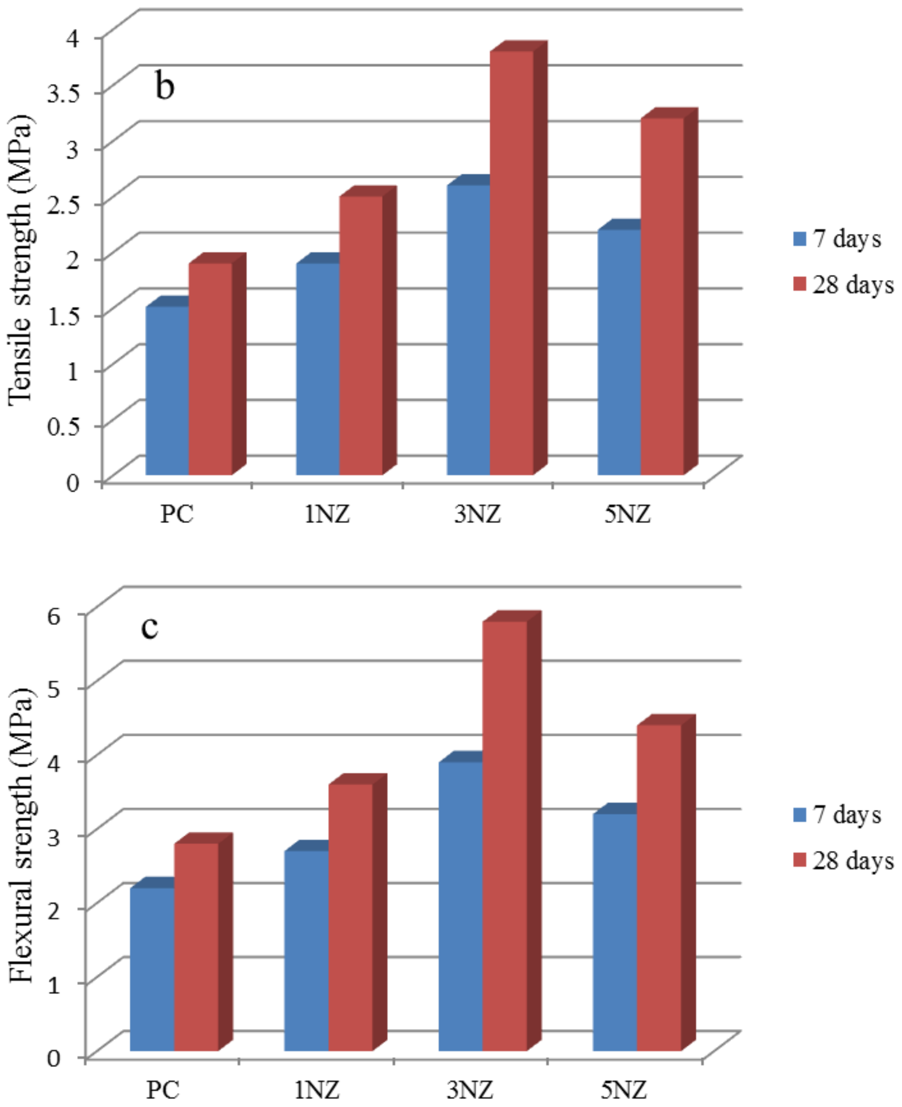


Fig 3. Compressive strength (a), Tensile strength (b) and flexural strength (c)

Water permeability

Water permeability tests are performed with several methods such as coefficient of water absorption, percentage of water absorption and rate of water absorption. In this study water permeability tests were performed by percentage of water absorption. After demolding the cement mortar, the specimens were cured in water for 5 days, and dried at the ambient atmosphere for 2 days. Then, the specimens were weighed (W_{dry}); thereafter, they were merged into water for other 24 hours, and then weighed again (W_{wet}). The percentage of the water absorption (permeability) was calculated using the following formula:

$$P\% = \frac{W_{wet} - W_{dry}}{W_{dry}} \times 100$$

There are two mechanisms by adding nanoparticles. Nanoparticles from one party to act as a filler and permeable pores and reduces On the other hand, due to their specific surface, wet surface will increase and thus increase the amount of water absorption. The results are presented in Figure 4. As you can see the maximum absorption for ordinary cement mortar And minimum absorption of the sample is 3NZ SEM images also confirmed these results (Figure 1), the best example is the maximum density of the sample 3NZ.

With increasing content of nanoparticles to 5% of the sample 5NZ, agglomeration of nanoparticles creates a weak areas This factor, along with increased levels of moisture and water absorption of more 3NZ example, although still lower than normal mortar specimens.

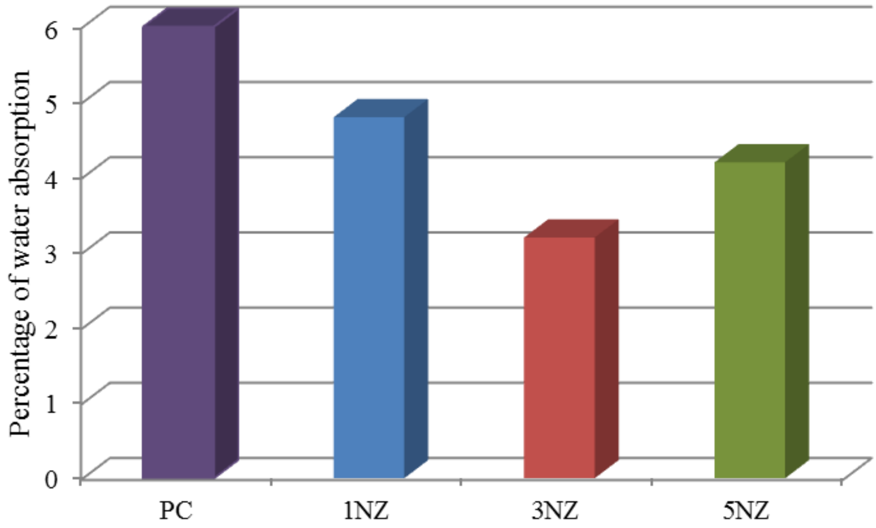


Fig 4. Percentage of water absorption of specimens

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