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THE EFFECTS OF ADDING NANO ZrO_2 ON THE PHYSICAL AND SOME MECHANICAL PROPERTIES OF CEMENT PASTE

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Abstract: The aims of this work are study the effects of adding nano zirconia ZrO_2 particles (NZ) on the physical and some mechanical properties of cement paste like: porosity, dry density, water absorption and compressive strength, where different cement replacement weight percentages of NZ particles, 0%, 0.75%, 1.5%, 2.25%, and 3 % by weight of cement, had used in cement paste. Physical properties of the prepared specimens had been tested and evaluated after various curing times, 7, 14, 21, and 28 days, while compressive tests had been performed after 28 days. The results showed direct decreasing in porosity, water adsorption and increasing in density and compressive strength with increasing weight fractions of NZ. The maximum increasing in density and compressive strength were 13% and 21% respectively of that of plain cement paste, while porosity and water adsorbtion decreasing were about 43.5 % and 43.7 % respectively of that of plain cement paste, when using 2.25 wt. % NZ cement replacement, after curing for 28 days

Keywords: *Nano ZrO,, cement paste, physical properties, compressive strength*

1. Introduction

The development in nanotechnology supports the efforts of boosting concrete performance like homogeneousness, workability, durability, strength, and stability [1]. Nano-size materials can offer dramatic properties' enhancement comparing with traditional materials, which have similar chemical component. Thus, might lead to reengineering many current products and to innovation new others, which have capacity to serve at more uncommon levels conditions [2]. Different forms of nano-size materials had been used on purpose of boosting concrete strength in many previous researches, like nano cellulose fibers, carbon nanotube CNTs, nano-SiO2, nano-TiO2, nano-Fe2O3...etc. [3 ,4]. Zirconia-based ceramics characterized by a unique combination of high strength, toughness and chemical resistance, which allow their use in harsh environment under severe loading conditions [5]. Several researches studied the performance of nano-ZrO2 (NZ) as toughening materials. Kaykha1 et al. [6] studied the effects of NZ into porosity and flexural strength of concrete after treated for various periods, the results show possibility of increasing flexural and splitting strength, about (31.8) % & (83.3) % respectively, by adding (1) % of NZ to concrete mixture. Nazari et al. [7] studied the effects of NZ into Portland cement paste, after treated by limewater, the results show that

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compressive strength of cement past could increase till specific percent before stepping down with extra increasing of NZ. Han et al. [8], investigated the effects of NZ into reactive powder concrete, the results indicated that NZ obviously improved mechanical strength, and decreasing electoral conductivity of concrete comparing with plain reactive powder concrete [8]. Based into the previous researches, this work aims to investigate effects of using NZ as cement replacement into physical properties and compressive strength of cement paste after various periods of water treating.

Nano Zirconia powder (NZ) has white color with high surface area, particles with typical dimensions (5-100 nm) range has specific surface area (25-50 m2/g) range. NZ based ceramic show superior properties like, hardness, durability, flexibility, chemical inertness, good thermal insulation, and at elevated temperatures its exhibit good strength and toughness [9, 10].

Generally, the effects of adding nano-size particles to cement mortar are:

1. Good dispersion of nano-size particles could increase the liquid phase viscosity, helping to suspend aggregate and cement grains, so increase resistance to segregation, and improve system workability.
2. Nano-size particles could fill the voids between the grains of cement, causing immobilization of free-water.
3. When nano-size particles had been distributed uniformly within matrix and after hydration process begins, hydrate products diffuse and surround nano particles as kernel. In case the distances between nano-particles are uniform and appropriate, controlled crystallization will occur as restricted of Ca(OH)2 crystals' growth by nano-particles and that make cement matrix more homogenous and strength while, in case of high amount addition of nano-particles the available distances between nano-particles within matrix is reduced, consequently Ca(OH)2 crystals haven't enough space to grow up and that lead to small crystal to CSH gel ratio, which make cement microstructure loose and low strength
4. Nano-size particles improve contact zone of aggregates, leading to better bonding between cement paste and aggregates.
5. Nano-size particles could detention cracks and interlocking between the slip planes, which increase toughness, flexural, shear, and tensile strength of cement-based materials.
6. Nano-size particles may contribute in the pozzolanic reactions, causing acceleration of Ca(OH)2 consumption and creation of an additional (C-S-H) [11-13]

2. Experimental Work

The experimental work includes combining of cement paste with different cement replacement weight fractions of NZ. Four specimens groups with different NZ weight fractions, 0.75%, 1.5%, 2.25% and 3% by weight of cement, beside to plain cement paste specimens, had been prepared and treated for different curing times, 7, 14, 21, and 28 days.

2.1. Preparation of Cement Paste Specimens

Ordinary Portland cement, tap water, NZ particles was used to prepare the specimens with (5 x 5 x 5 cm) dimensions. The water to binder ratio was fixed at 0.5 for all mixtures. Preparing processes include, firstly dispersed of nano-particles in water at an ambient temperature by using ultrasonic mixer, (750 watt) power for (30 min.), before adding water and NZ to cement to prepare mixture. Then, the mixtures poured inside lubricated wooden molds in order to shape specimens, where leaved for 24 hours with wet burlap cover to prevent losing of moisture before, releasing from modes. The specimens had cured in tap water at temperature of about (28-30) °C for different periods of, 7, 14, 21, and 28 days, before performing tests.

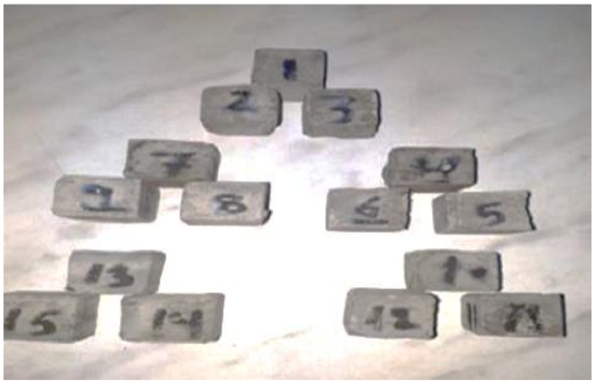

Figure 1. the prepared cement paste specimens

2.2. Physical Tests procedure

The physical properties tests include; dry density, porosity, and total water adsorption tests, where the tests had determined accordance to ASTM C642 [14]. The testing procedure includes following steps: measuring dry weight W_1 after drying the specimens, measuring submerged weight W_2 after immersed the specimens in water for (24 h.), finally, measuring wet weight of specimens W_3 by weight the specimens after removing further water by cloth piece. All tests were conducted after variant curing periods of, 7, 14, 21, and 28 days. The dry density, porosity, and water adsorption, had been calculated by the following equations:

$$dry\ denisity = \frac{W_1}{W_1 - W_3} * \rho_w \qquad (1)$$

$$porosity\ \% = \frac{W_2 - w_1}{W_2 - W_3} * 100 \qquad (2)$$

$$water\ adsorbtion\ \% = \frac{W_2 - w_1}{W_1} * 100 \qquad (3)$$

Where: W_1 is the dry weight of specimen (g), W_2 is the suspending weight of sample (g), W_3 is the saturated weight of the specimen (g), and ρ_w is the density of water which is equivalent to (1 g/cm^3).

2.3 Compressive strength tests

Cubic specimens with (5 x 5 x 5 cm) dimensions were prepared and used to perform compressive tests according to ASTM C (780-002) standard after (28 days) curing time. Computerize universal testing machine (WDW-50, 50KN, LARYEE), was used to perform the tests [15]

3. Results and discussion

3.1. Dry densities

The effects of NZ particles in cement paste dry density at variant curing times can be discussed depend to the results shown in Figure (2).

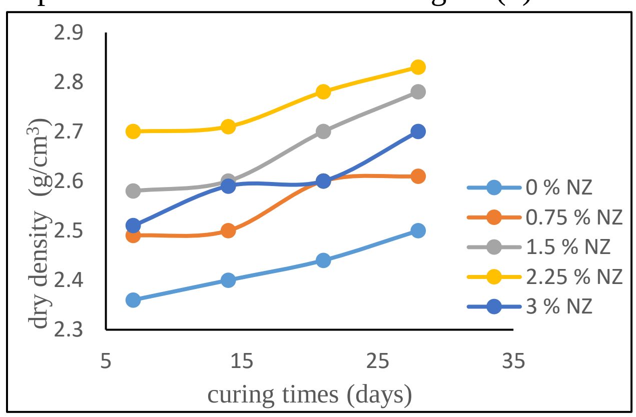

Figure 2. Dry densities versus curing times at different NZ content.

It can be notice that the densities of all mixed specimens are higher than density of plain cement paste specimen at all treatment times, and density has directly proportional with NZ weight fraction. This increasing in density may reflect the development in microstructure of cement paste due to nano particles effects, where nano particles help decreasing the capillary porous percentage and voids between cement particles, nano particles could fill these voids and cut capillary porosities, leading to better packing and increasing density. Furthermore nano particles has effective role in regulating microstructure of pozzolanic reactions products, as previously mention. Maximum density occur when using 2.25 wt.% of NZ, while adding high weight fractions of nano particles could lead to negative effects in density due to possibility of creation agglomeration sites of nano particles inside the matrix, as difficulties of distributing high percentage additive uniformly within matrix without creation of these sites. However, these results agree with similar work used carbon nano tube [13].

3.2. Porosity

The effects of NZ particles in cement paste porosity after variant curing times can be discussed depending to the results shown in Figure (3).

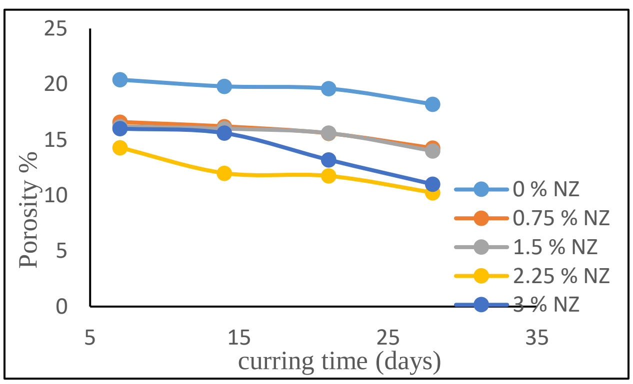

Figure 3. Porosity versus curing times at different NZ content

It can be notice that porosity of mixed specimens are less than porosity of plain cement paste specimen at all ratios and after all treatment times. The reduction in porosity percentages may be related to possibility of filled these porosities by extremely small NZ particles. Minimum porosity percentage was at 2.25 wt. % of NZ. On the other hand, adding higher weight fractions of nano particles have less efficiency of porosity reduction, this may because of possibility of agglomerations and nonhomogeneous structure effects. However, this results confirm the results of densities tests, where porosity inversely proportional with density until 3 wt. % of nano particles.

3.3. Water adsorption

The effects of NZ in cement paste water adsorption after variant curing times can be discussed depending on the results shown in Figure (4).

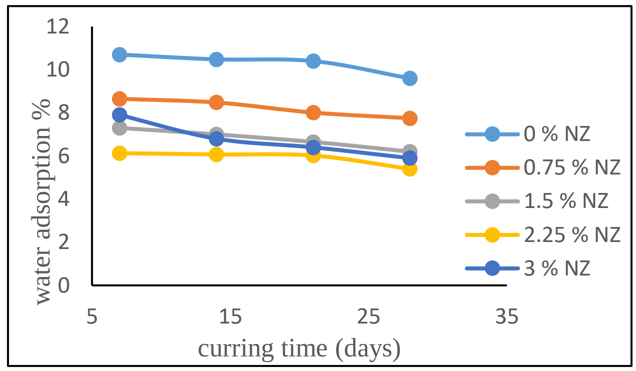

Figure 4. Water adsorption versus curing times at different NZ content

It can be noticed that water adsorption percentage in all mixed specimens are less than that of plain cement paste specimens. Basically, water adsorption is highly related to porosity and voids. Decreasing voids and capillary porous with increasing nano particles, lead to reduce the ability of cement to adsorption and maintaining water inside the specimens. Minimum water adsorption was at 2.25 % wt. NZ. On other hand, adding high weight fractions of nano particles could relatively increase water adsorption due to non-homogenously mixture that may create when using high percentages nano particles, but it still lower than that of plain cement paste specimens.

3.4. Compressive Strength

The effects of NZ particles in cement paste compressive strength, after 28 days of curing, can be discussed according to the results shown in Figure (5).

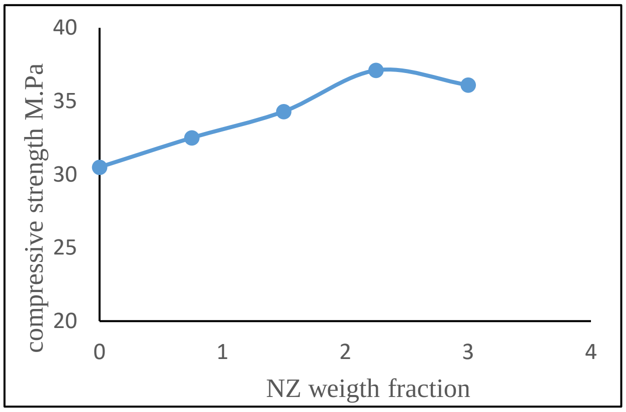

Figure 5. Compressive strength versus NZ content after treating for 28 days

It can be notice increasing compressive strength with increasing NZ weight fraction. Indeed, this modification in compressive strength related to development microstructure of cement, where cement structure become denser and less porosity when adding NZ as previously mention, the best result was when added 2.25 wt. %. Beyond this percentage, compressive strength began decreasing, and this behavior may because of the effects of creation agglomeration sites and non-homogenously structure that associated with high nano particles weight fractions as mention previously.

4. Conclusions

1. Nano-size ZrO_2 particles could effectively improve the physical and mechanical properties of cement paste.
2. Using high weight percentage of cement replacement NZ, more than 2.25 wt. %, could improve cement paste properties with less efficiency.
3. Addition of NZ to cement paste, can accelerate development properties of cement.

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