Enhancement of Some Mechanical Properties of White Cement Mortar by Adding Nanoparticles of Zirconium Oxide

Ahmed K. Al-kamal, Ismail Ibrahim Marhoon, Ali A. Salman, Ahmed K. Muhammad

Abstract—This paper will study mortar compressive strength (fc) and flexural strength (fr) by cement replacement which is partial with the particles of Nano-ZrO2. ZrO2 nanoparticles are used as well as using average diameter of 35 nm with four various contents by weight of cement (0.25%, 0.75%, 1.25% and 1.75%). The (fc) and (fr) tests were performed after the process of curing at the 28-days which is the standard age. The preparation of mortar of Nano-cement was done by using the ratio of cement-sand by weight which is 1:3 with the ratio of water-binder materials (w/b) ratio as 0.5. The results demonstrated that the (fc) and (fr) of the mortars of cement with ZrO2 nanoparticles were registered higher than cement mortar that is pure. The ultimate Nano-cement mortar strength was obtained at 1.25% of the replacement of cement. The improvement in (fc) and (fr) were 15.6 % and 18.4% in a respective way at 28 days.

Index Terms—White Cement; ZrO2 Nanoparticles; Mechanical Properties.

I. INTRODUCTION

Concrete is regarded as construction material that are the most widely used extending throughout the world. Recently, many efforts have been exerted to enhance the concrete environmental friendliness to make it convenient as a material of a Green Building. The most successful and Foremost in this respect is the use of substitutes suitable for cement that is white [1].

Materials that are supplementary and cementitious are added to concrete as a part of the total system that is cementitious to decrease the cement total quantity to be used and most importantly to raise the concrete strength from its normal state to strength that is higher [2].

The use of nanoparticles in concrete samples were studied by many works the as mineral admixtures to enhance mechanical and physical properties [3]. Hui et al. [4] investigated the cement mortars characteristics that are mixed with nanoparticles to explore their smart and better mechanical properties. Porro et al. [5] shows the nano-silica particles use as raising the strength of compression of pastes of cement. Sobolev et al. [6] remarked that adding nano-silica generated a strength rise of 15–20%. Konsta-Gdoutos et al. [7] observed the carbon nano-fibers effect on pastes of cement (0.08% by mass of binder) and examined the strength increase.

Mohammed Ali Abdulrehman et al. explored decreasing white Portland cement cracks by having some additive [8]. Ahmed K Al-kamal et al. observed of mechanical properties modification of mortar of cement by the addition of nanoparticles of zinc oxide [9]. Dalia Adil et al. explored the effect of modifier added on the mixture of the concrete [10] where it was discovered that the (epoxy) is a modifier that is good for mortar.

Metaxa et al. [11] made concentration process of an ultracentrifugation more advanced for producing suspensions that are highly concentrated of nanotubes of carbon.

The pozzolanic reaction rate is proportional to the surface area amount that is available for reaction. Thus, it is reasonable to mix nanoparticles of ZrO2 of a purity that is high (99.9%) and a value of Blaine fineness which is high (68 m²/g) so as to improve the cement mortars properties [12].

In this study an attempt has been done to demonstrate that by having new materials, there is a possibility to gain performance concrete that is high (HPC) or strength concrete that is high (HSC) with slight rise in cost. Due to its ability to decrease the structural fundamentals area which is cross-sectional, HPC and HSC are greatly used in multistory buildings and constructions.

II. MATERIALS AND MIXTURE

A. Materials

1) Nano-ZrO2 particles

Nano—ZrO2 with particle of average size of 35 nm gained from NANOSHEL US company, was used as it was received.

Table I: Nano-ZrO2 particles properties

| Name | Nano powder of zirconium Oxide |
|------|-------------------------------|
| Chemical composition | ZrO2 |
| Appearance | White powder |
| pH | 6.8 |
| Reactivity | Non-reactive |
| Stability | Completely stable |
| Purity | >99.9% |

2) Cement

The cement that is used in this work is the type known as White Cement (OPC) from (MASS) company; it is manufactured in Iraq. The results of test show that the MASS OPC meet the specified standard of the Iraqi standard (L.O.I.S.) No. 5 / 1984. The physical properties and chemical composition of MASS OPC are illustrated in Table
II. TABLE II: PHYSICAL PROPERTIES AND CHEMICAL COMPOSITION OF WHITE CEMENT

| Item                        | % by weight | Limit of (L.O.L.) No.5:1984 |
|-----------------------------|-------------|-----------------------------|
| Al₂O₃                        | 4.75        | -                           |
| Fe₂O₃                        | 0.5         | -                           |
| SiO₂                        | 24.03       | -                           |
| MgO                         | 0.77        | <5.00                       |
| CaO                         | 68.12       | -                           |
| SO₃                         | 2.57        | <3.00                       |
| Physical Properties         |             |                             |
| Insoluble residue (IR.)     | 0.61        | <1.50                       |
| Fineness (cm²/g) by Blaine method | 27.93     | >2300                       |
| Time saturation Factor (T.S.F.) | 0.92      | 0.66 — 1.02                |
| Loss on ignition (L.O.I.)   | 3.41        | <4.00                       |
| Soundness by using Auto clave% | 0.25        | <0.8                        |
| (fc) for cube of cement mortar (70.7 mm) at, 3 days 7 days (MPa) | 17.15 - 24.54 MPa | >15 × 23 MPa |

3) Aggregate

White cement is available locally in Iraq, with diameter of sand that is less than 4.75 mm; it is used in this study which has (S.G.) specific gravity of (2.61), but the (F.M.) fineness modulus of (2.57) and (SO₃%) sulfate content is an of (0.08%) from weight of sand, which is done based on Iraqi standard specification limit No. 45 / 1984.

B. Mixture:

The preparation of mixtures with the replacement of cement by weight of 0.25%, 0.75%, 1.25% and 1.75% was done. The sand to cement ratio for all mixture groups was recorded to be at (3:1), and the ratio of water to binder materials ratio was recorded at (0.5). The mixtures proportions are shown in Table III.

III. PREPARATION OF SPECIMENS

A. Procedure of Work

Mixtures Preparation was conducted in method that similar to ASTM C 305-14 [13].

B. Specimens of (fc):

This test conducted based on ASTM C109-14 [14]. The cubic specimens of (50 × 50 × 50) mm were tested at the period of 28 days.

C. Specimens of (fr):

This test was conducted based on ASTM C 293-14 [15]. The prism specimens (160 × 40 × 40) mm were tested at the period of 28 days.

IV. RESULTS AND DISCUSSION

A. fc

The results of (fc) of the white mixes are illustrated in Table IV. Comparing the results of specimens for 28 days reflects that the rise in (fc) with particles of nano-Zr₂O₃ reach around 1.25% and then it witnesses a decline.

TABLE IV: RESULTS OF THE (fc)

| Name | Zr₂O₃ % | Result of 28 days (MPa) | Percent of Enhanced extent |
|------|---------|------------------------|---------------------------|
| ZM0  | 0       | 28.61                  | -                         |
| ZM1  | 0.25    | 31.98                  | 11.7                      |
| ZM2  | 0.75    | 32.26                  | 12.7                      |
| ZM3  | 1.25    | 33.09                  | 15.6                      |
| ZM4  | 1.75    | 32.01                  | 11.8                      |

B. fr

The results of (fr) are illustrated in Table V. The specimens (fr) rises with particles of nano-Zr₂O₃ to reach around 1.25% and then it witnesses a decline.

TABLE V: RESULTS OF THE (fr)

| Name | Zr₂O₃ % | Result of 28 days (MPa) | Percent of Enhanced extent |
|------|---------|------------------------|---------------------------|
| ZM0  | 0       | 5.21                   | -                         |
| ZM1  | 0.25    | 5.83                   | 11.9                      |
| ZM2  | 0.75    | 6.09                   | 16.8                      |
| ZM3  | 1.25    | 6.17                   | 18.4                      |
| ZM4  | 1.75    | 5.61                   | 7.67                      |

V. CONCLUSION

Regarding the results that are experimental of and flexural and (fc) it has been found that:

1. The maximum value of strength that is (fc) can be gained with the addition of 1.25% Zr₂O₃ and improvement reached 15.6%.
2. The maximum value of strength that is flexural can be gained with the addition of 1.25% Zr₂O₃ and improvement reached 18.4%.

REFERENCES

[1] Elkady, H., Serag, M. I, and Efieky, M. S., (2013), “Effect of Nano Silica De-agglomeration, and Methods of Adding Super-plasticizer on the Compressive Strength, and Workability of Nano Silica Concrete”, Civil and Environmental Research Vol.3, No.2, PP.2222-2863.
[2] Katikeyan, B., Sumanth, K., Harshavardhan, G., Rajaksharaddey, A., and Dinakaran, G., (2014), “Microstructure analysis and Strength properties of concrete with Nano SiO2", International Journal of ChemTech Research, Vol.6, No.5, PP.3004-3013.
[3] Nazari, A. and Rahi, S., (2011), “The effects of TiO2 nanoparticles on physical, thermal and mechanical properties of concrete using ground granulated blast furnace slag as binder”, Materials Science and Engineering, Vol. 528, PP.2085-2092.
[4] Li, H., Xiao, H., Yuan, J., and Ou, J., (2003), “Microstructure of cement mortar with nanoparticles”, Composites Part B: Engineering, Vol.35, PP.9-185.
[5] Porro, A., Dolado, J., Campillo, I, Erkizia, E., de Miguel, Y., de Ybarra, Y., and Ayuela, A., (2005), “Effects of nano silica additions on cement pastes”, Proc International Conference on Applications of Nanotechnology in Concrete Design, PP.87—96.
[6] Sobolev, K., Flores, I., Hermosillo, R., and Martinez, L., (2008), “Nanomaterials and nanotechnology for high-performance cement composites”, American Concrete Institute, ACI Special Publication, Vol.254, PP.93–120.

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7 Konsta-Gdoutos, M., Metaxa, Z., and Shah, S., (2010), “Highly dispersed carbon nanotube reinforced cement based materials”, Cement and Concrete Research, Vol.40, PP.1052—1059.
8 Abdulrehman, Mohammed Ali, Mais A. Abdulkareem, and Ali Abed Salman. "Reducing Cracks of the White Portland Cement Mortar.", Applied Research Journal, Vol.2, Issue, 9, pp.370-378 (2016).
9 Al-kamal, A. K., Abdulrehman, M. A., Salman, A. A., Rasoul, D. A., & Tlaiaa, Y. S. (2017). Modification of mechanical properties of cement mortar by adding zinc oxide nanoparticles. ЕВРАЗИЙСКИЙ НАУЧНЫЙ, 177.
10 Rasool, Dalia Adil, Ismail Ibrahim Marhoon, and Mohammad Ali Abdulrehman. 2018. “The Effect of Adding Modifier on the Concrete Mixture.” Journal of Advanced Cement & Concrete Technology 1(3): 27–33.
11 Metaxa, Z., Seo, J., Konsta, M., Hersam, M., and Shah, S., (2012), “Highly concentrated carbon nanotube admixture for nanofiber reinforced cementitious materials”, Cement and Concrete Composites Vol.34, PP.612—617.
12 Jo, B., Kim, C., Tae, G., and Park, J.B., (2007), “Characteristics of cement mortar with nano-SiO2 particles”, Construction and Building Material, Vol.21, No.6, PP.1351-1355.
13 ASTM C 305-14, “Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency”.
14 ASTM C 109/ C 109M-14, Standard Test Method for Compressive Strength of Hydraulic Cement mortars (Using 2-in. or [50-mm] Cube Specimens)
15 ASTM C 293, “Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)".