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Nano Titanium Dioxide Application in Various Concrete Mixes

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الملخص العربى :

يتناول هذا البحث دراسة تأثير الاضافة الجزئية للنانو تيتانيوم الى حبيبات الاسمنت و دراسة تأثير هذه الاضافة على مقاومة الانضغاط للخلطات الخرسانية المختلفة التى تحتوى على نسب مختلفة من النانو تيتانيوم (1.5,1,0.5,0 %) من وزن الاسمنت عند اعمار مختلفة من المعالجة 28,7 يوم. كما يهدف هذا البحث لتحديد النسبة الافضل لإضافة النانو تيتانيوم الى حبيبات الاسمنت. أظهرت النتائج ان زيادة محتوى النانو تيتانيوم فى الخلطات الخرسانية الى نسبة 1% يؤدى الى زيادة مقاومة الانضغاط. النسبة 1% هى النسبة المثلى للإضافة.

Abstract:

Nanomaterials create a new field of scientific research that attracts many researchers due to its effective impact in the creation of new materials with distinctive characteristics. Also, it has high performance, high compression resistance, durability and many other advantages. Cement is one of the main components in concrete. The application of nanomaterials in concrete mixtures changes their properties and improves their compressive strength. This study deals with the influence of the application of Nano-TiO2 with different levels (0%, 0.5%, 1.0% and 1.5%) of cement weight on concrete compressive strength. This research includes an experimental study for several concrete mixtures containing different ratios of Nano-TiO2 as a partial additive to cement granules. This research program includes performing compressive strength test forseveral cubes of each mixture at different ages of 7 and 28 days to demonstrate the effect of the application of Nano-TiO2 granules on the concrete compressive strength and determine the optimum ratio for partial addition to cement particles with Nano-TiO2. The results indicated that increasing the Nano-TiO2 content in the mixtures to 1.0% leads to a higher compressive strength. The percentage 1.0% Nano-TiO2 is the optimum ratio.

Keywords: nanotechnology; nanomaterials; Nano-TiO2; concrete mixture;compressive strength.

1. Introduction

Cement is an important component of concrete. It is characterized by the small size of the granules, so the cement granules act as a filler for voids in the concrete mixture. Cement acts as a binding material for bonding components of the concrete mixture. Despite the multiple advantages of cement, one of its disadvantages is that it pollutes the environment as the cement industry leads to the emission of extra- large quantities of carbon dioxide gas, therefore the addition of Nano-TiO2 particles can reduce this pollution [1-2]. The use of nanomaterials is now widely used to improve the properties and the performance of both cement paste as well as concrete. Nano-TiO2 is one of the used nanomaterials to raise and enhance the performance and characteristics of cement paste as well as concrete. Nano-TiO2 is characterized by its pozzolanic nature and ultra-small size of its granules, so it acts as a filler material for voids, which leads to reduce voids in the concrete mixture and make it denser, improve durability, enhance workability and increase compressive strength [3-7].

Previous experimental studies have shown that the use of Nano-TiO2 in the concrete industry as a partial addition to cement in small quantities vary their characteristics and improve concrete performance as it can reduce setting time of concrete, accelerates the hydration process, improve workability, increase compressive strength, reduce porosity and permeability and also improvement of concrete microstructure [6-10]. This study investigate the impact of the application of Nano-TiO2 as a partial addition for cement at different levels (0.0%, 0.5%, 1.0% and 1.5%) of the weight of cement on concrete compressive strength at different ages of curing

2. Experimental Work

2.1. Materials

2.1.1. <u>Cement</u>

Ordinary Portland cement (OPC) of Grade 42.5N was used in this experimental work. The content of cement in this research is 500 kg/m^3 to achieve a target concrete compressive strength of value of 50 MPa.

2.1.2. <u>Water</u>

Water used for mixing and curing specimens in this work is tap water and must be free of salts, acids, sulphates and other impurities.

2.1.3. <u>Aggregates</u>

Natural well-graded gravel used in this study as coarse aggregates with a nominal maximum size of 20 mm. Fine rounded natural sand used as fine aggregate.

2.1.4. **Superplasticizers**

In this experimental study, Sika ViscoCrete-3425 used in order to maintain concrete mixtures workability and also to ensure a uniform Nano-TiO2 particles dispersion.

2.1.5. **Nano Titanuim**

Nano-TiO2 have ultra-small particles size. Nano-TiO2 can be used as a partial addition material for cement. In this work amorphous Nano-TiO2 used as a partial addition to cement with four different levels of (0.0%, 0.5%, 1.0% and 1.5%) of cement weight.

2.2. Mixing

In order to investigate the impact of applying Nano-TiO2 in concrete mixes, six different concrete mixes with various percentages of Nano-TiO2 were mixed, casted, cured and prepared for testing at different ages of curing. Concrete mixes composition and mix design quantities are presented in Table (1). Mixes were designed to give a target compressive strength about 50 MPa after 28 days of curing. Concrete mixes were prepared by mixing concrete main constituents (cement, silica fume, water, fine and coarse aggregates) with superplasticizer and different Nano-TiO2 levels of 0.0, 0.5, 1.0 and 1.5% of mass of cement as a partial addition for cement.

Table (1): Concrete mixtures proportions.

	NT(0.0%) Control	NT (0.5%)	NT (1.0%)	NT (1.5%)
Cement (Kg/m^3)	500	500	500	500
Nano-TiO2 (Kg/m^3)	0.0	2.5	5	7.5
Silica Fume (Kg/m^3)	75	75	75	75
Superplasticizers (Kg/m^3)	14	14	14	14
Fine Aggregates (Kg/m^3)	1180	1180	1180	1180
Coarse Aggregates (Kg/m^3)	620	620	620	620
Water (Kg/m^3)	190	190	190	190

Portland cement, silica fume, fine and coarse aggregates were mixed dry mixing for two minutes using laboratory concrete mixer. During mixing dry mixed component, Nano-TiO2 particles, superplasticizer and part of mixing water were mixed together for two minutes using rotary machine. After that, remaining mixing water and Nano-TiO2 mixture were gradually added to dry mixed component inside concrete mixer and mixed together for about four minutes until obtaining a homogenous concrete mix. Six standard cubes with dimensions of (150×150×150) mm were prepared for each concrete mix. After completely mixing of concrete component, concrete mixtures were casted in the standard cubes moulds then Cubes specimens were compacted using standard rod and vibrator to avoid existence of voids in concrete. Specimens surfaces were levelled. After 24 hours of casting, Specimens removed from casting moulds and placed inside water curing tanks till the age of testing. Figure 1 shows mixing, casting procedures and curing of concrete cubes specimens.

Figure 1: Mixing, Casting and Curing for Concrete Cubes Specimens.

2.3. Compressive Strength Test of Concrete Cubes

Compressive strength test was performed using Forney Universal Testing Machine after 7 and 28 days of curing. Cubes specimens removed from curing tanks at the age of testing, left to dry then tested for compressive strength using universal testing machine that gradually loaded until the cubes failure occur as shown in Figure 2.

Figure 2: Compressive Strength Test.

3. Test Results for Concrete Cubes

Concrete specimens compressive strength values are illustrated in Table (2). From table values it can be noticed that increasing Nano-TiO2 content up to level of 1.5% leads to increased compressive strength value at all testing ages comparing with normal concrete without addition of Nano-TiO2 as a result of pozzolanic nature and filling effect of Nano-TiO2 particles.

Table (2): Cubes Compressive Strength Test Results.

NT %	Compressive Strength (Mpa)		
	S.F	7 days	28 days
Control NT (0.0%)	15%	36.98	49.86
NT (0.5%)		40.97	55.74
NT (1.0%)		43.21	58.79
NT (1.5%)		42.56	57.42

Figure 3 show the relations between various NT levels and the corresponding compressive strength values at different ages of curing 7 and 28 days. From figure it is observed that cubes compressive strength values increased by increasing Nano-TiO2 percentage up to 1.0%. Increasing Nano-TiO2 percentage greater than 1.0% gives no significant increase in compressive strength value. Compressive strength values decreases slightly by increasing Nano-TiO2 content from 1.0% up to 1.5%. Thus, the optimum Nano-TiO2 ratio for addition is 1.0%.

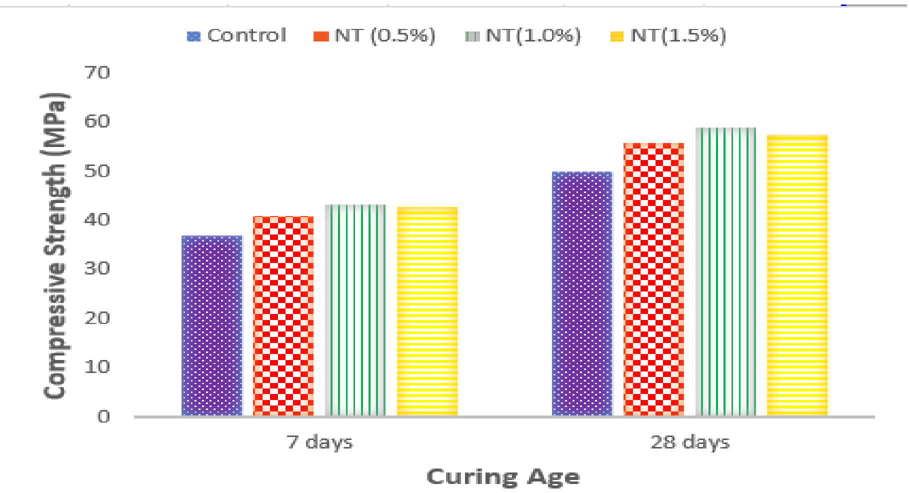

Figure 3: Compressive Strength Test Results for all concrete mixes at different Curing ages.

4. Conclusions

This paper study the influence of applying various Nano-TiO2 ratios (0.5%, 1.0% and 1.5%) as a cement addition material in concrete mixes on cubes compressive strength and then comparing results with control mix without Nano-TiO2 addition. Compressive strength test for cubes specimens were performed using Forney Universal Testing Machine at curing ages of 7 and 28 days respectively and the specimens compressive strength values were obtained and analyzed. From the obtained results, several general conclusions were drawn:

- Using a small percentage of Nano-TiO2 as a cement addition material leads to an increase in the compressive strength of concrete specimens.
- Comparing to control specimens, increasing NT content up to 1.5% causes anincrease in the compressive strength of concrete specimens at all testing ages.
- Compressive strength values Increases by increasing Nano-TiO2 level up to 1.0%. It was observed that the rate of increase of the compressive strength is no longer significant when the content of Nano-TiO2 particles is greater than 1.0%. There is also a slight decrease in compressive strength when the Nano-TiO2 content increases to 1.5%. This indicates that the content of the Nano-TiO2 1.0% is the optimum.
- Increasing Nano-TiO2 content increase the bond-strength between cement paste-aggregates by the effect of pozzolanic nature and filling effect of nano particles.

References:

1. Carlos Moro, MirianVelay-Lizancos, "Modification of CO_2 Capture and Pore Structure of Hardened Cement Paste Made with Nano-TiO_2 Addition: Influence of Water-to-Cement Ratio and CO_2 Exposure Age", Elsevier, Vol. 275, 2021.

2. Jing Menga,b, Jing Zhonga,b, Huigang Xiaoa,b and Jinping Oua,b, "Interfacial Design of Nano-TiO_2 Modified Fly Ash-Cement Based Low Carbon Composites", Elsevier, Vol. 270, 2021.

3. Mohamed S. Khalafalla, Osama A. Hodhod and Ihab A. Adam, "Improving the Mechanical and Durability Properties of Cement Mortar by Nano Titanium", Assiut University, Vol. 43, pp. 663--681, 2015.

4. M. Suneel, K. Jagadeep, K. K. MahaLakshmi, G. Praveen Babu and G. V. Ramarao, "An Experimental Study on Workability and Strength Characteristics of M40 Grade Concrete by Partial Replacement of Cement with Nano-TiO_2", Sustainable Construction and Building Materials, Vol. 25, pp. 253-263, 2019.

5. Mostafa Jalal, "Durability Enhancement of Concrete by Incorporating Titanium Dioxide Nanopowder into Binder", Journal of American Science, 2012.

6. Jay Sorathiya, Dr. Siddharth Shah and Mr. Smit Kacha, "Effect on Addition of Nano “Titanium Dioxide” (TiO_2) on Compressive Strength of Cementitious Concrete", Civil Engineering, Vol. 1, pp. 219--225, 2017.

7. Abhishek Singh Kushwaha, Rachit Saxena and Shilpa Pal, "Effect of Titanium Dioxide on the Compressive Strength of Concrete", Journal of Civil Engineering and Environmental Technology, Vol. 2, pp. 482--486, 2015.

8. Decheng Feng, Ning Xie, Chunwei Gong, Zhen Leng, Huigang Xiao, Hui Li and Xianming Shi, "Portland Cement Paste Modified by TiO_2 Nanoparticles: A Microstructure Perspective", American Chemical Society, 2013.

9. Ali Nazari, Shadi Riahi, Shirin Riahi, Seyedeh Fatemeh Shamekhi and A. Khademno, "Assessment of the Effects of the Cement Paste Composite in Presence TiO_2 Nanoparticles", Journal of American Science, 2010.

10. Ali Nazari, Shadi Riahi, Shirin Riahi, Seyedeh Fatemeh Shamekhi and A. Khademno, "Improvement the Mechanical Properties of the Cementitious Composite by Using TiO_2 Nanoparticles", Journal of American Science, 2010.