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Nano Silica Application in Various Concrete Mixes

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ملخص البحث

يتناول هذا البحث دراسه تاثير الاستبدال الجزئي لحبيبات الاسمنت بالنانوسيليكا و دراسة تاثير هذا الاستبدال علي مقاومه الانضغاط للخلطات الخرسانيه المختلفه التي تحتوي علي نسب مختلفه من النانوسيليكا (0,1,2,3%) من وزن الاسمنت عند اعمار مختلفه من المعالجه 7,28,90 يوم . كما يهدف هذا البحث لتحديد النسبه الافضل لاستبدال حبيبات الاسمنت بالنانوسيليكا. اظهرت النتائج ان زيادة محتوي النانوسيليكا في الخلطات الخرسانيه يؤدي الي زيادة مقاومة الانضغاط , وان النسبه 2% هي النسبه الافضل للاستبدال.

Abstract

Nanomaterials create a new field of scientific research that attracts many researchers because of its effective influence in the creation of new materials with distinctive characteristics. It also has high performance, high compression resistance, durability and many other advantages. One of the major ingredients in concrete is cement. The application of nanomaterials in concrete mixes changes their properties and improves their compressive strength. This study deals with the influence of the application of nano-silica with different levels (0%, 1%, 2% and3%) of cement weight on concrete compressive strength. This research includes an experimental study for several concrete mixtures containing different ratios of nano-silica as a partial alternative to cement granules. This research program includes performing compressive strength test for several cubes of each mixture at different ages of 7, 28 and 90 days to demonstrate the effect of the application of nano-silica granules on the concrete compressive strength and determine the optimum ratio for partial replacing of cement particles with nano silica. The results indicated that the increase in the nano-silica content in the mixes leads to a higher compressive strength and the percentage 2% NS is the optimum ratio.

Keywords: nanotechnology; nano materials; nano silica; concrete mix; compressive strength.

1. Introduction

Cement is an important component in the concrete, characterized by the small size of the granules and therefore the cement granules work as a filler for the voids in the concrete mixture. Cement acts as a binding material to bind the 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 replacement of cement with nano silica particles can reduce this pollution [1,6]. The use of nanomaterials to improve the properties as well as the performance of both cement paste and concrete is now widely used. Nano-silica is one of the used nanomaterials to raise and enhance the performance and characteristics of cement paste as well as concrete. Nano-silica is characterized by

its pozzolanic nature and ultra-small size of its granules, therefore 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 raise compressive strength [2-8].

Many previous experimental studies have shown that the use of nano-silica in the concrete industry as a partial replacement of 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 [5-9]. This study investigate the impact of the application of nano-silica as a partial substitute for cement at different levels (1%, 2% and 3%) of the weight of cement on concrete compressive strength at different ages of curing.

2. Experimental Work

2.1. Materials

2.1.1. Cement

Ordinary Portland cement (OPC) of Grade 42.5N was used in this experimental work. The content of cement in this research is 400 kg/m^3 to achieve a target concrete compressive strength of value of 35 MPa.

2.1.2. Water

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

2.1.3. Aggregates

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

2.1.4. Superplasticizers

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

2.1.5. Nano Silica

Nano-silica SiO2 have ultra-small particles size. Nano-silica can be used as a partial replacement material for cement. In this work amorphous nano-silica used as a partial replacement of cement with three different levels of (1%, 2% and 3%) of cement weight.

2.2. Mixing

In order to investigate the impact of applying nano silica in concrete mixes, six different concrete mixes with various percentages of nano silica 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 35 MPa after 28 days of curing. Concrete mixes were prepared by mixing concrete main constituents (cement, water, fine and coarse aggregates) with superplasticizer and different nano-silica levels of 0, 1, 2 and 3% of mass of cement as a partial replacement for cement.

Table (1) Concrete mixtures proportions

	Control	NS (1.0%)	NS (2.0%)	NS (3.0%)
Cement (Kg/m^3)	400	396	392	388
NS (Kg/m^3)	0.0	4.0	8.0	12.0
Superplasticizers %	0.5	0.5	0.5	0.5
Fine Aggregates (Kg/m^3)	634	633	631	630
Coarse Aggregates (Kg/m^3)	1270	1266	1262	1260
Water (Kg/m^3)	160	160	160	160

Portland cement, fine and coarse aggregates were mixed dry mixing for two minutes using laboratory concrete mixer. During mixing dry mixed component, nano-silica particles, superplasticizer and part of mixing water were mixed together for two minutes using rotary machine. After that, remaining mixing water and nano-silica mixture were gradually added to dry mixed component inside concrete mixer and mixed together for about four minutes until obtaining a homogenous concrete mix. Nine 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. Samples surfaces were levelled. After 24 hours of casting, Samples 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 samples.

Figure 1. Mixing, Casting and Curing for Concrete Cubes Samples

2.3. Compressive Strength Test of Concrete Cubes

Compressive strength test was performed using Forney Universal Testing Machine after 7, 28 and 90days of curing. Cubes samples 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 samples compressive strength values are illustrated in Table (2). From table values it can be noticed that increasing nano-silica content up to level of 3% leads to increased compressive strength value at all testing ages comparing with normal

concrete without addition of nano-silica as a result of pozzolanic nature and filling effect of nano silica particles as concluded in [8,9].

Table (2) Cubes Compressive Strength Test Results

NS % Replacement	Compressive Strength (Mpa)		
	7 days	28 days	90 days
Control	22.62	28.07	36.59
NS (1.0%)	26.97	36.32	42.57
NS (2.0%)	27.76	38.63	44.89
NS (3.0%)	29.15	38.38	41.79

Figure 3 show the relations between various NS levels and the corresponding compressive strength values at different ages of curing 7, 28, and 90 days. From figure it is observed that cubes compressive strength values increased by increasing nano-silica percentage up to 2%. Increasing nano-silica percentage greater than 2% gives no significant increase in compressive strength value. Compressive strength values decreases slightly by increasing nano-silica content from 2% up to 3%. Thus, the optimum nano-silica ratio for replacement is 2% as concluded in [10-12].

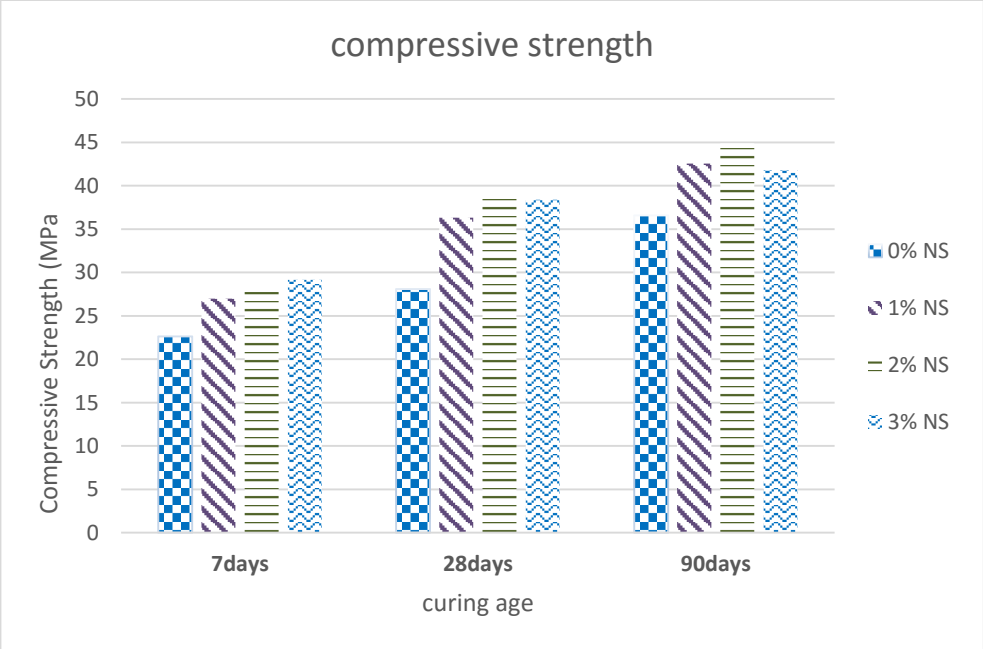

Figure 3. Compressive Strength Test Results for all concrete mixes at different Curing ages

Failure shape shown in Figure 2 indicated that the failure of cubes specimens take place in aggregates and it means that addition of nano-silica particles to concrete mixes causes improved bond strength among cement paste and aggregates by the filler effect of nano particles , the same results are given in [13,14].

4. Conclusions

This paper study the influence of applying various nano-silica ratios (1.0%, 2.0% and 3.0%) as a cement replacement material in concrete mixes on cubes compressive strength and then comparing results with control mix without nano-silica addition. Compressive strength test for cubes specimens were performed using Forney Universal Testing Machine at curing ages of 7, 28 and 90days 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 silica as a cement replacement material leads to an increase in the compressive strength of concrete specimens.

- Comparing to control specimens, increasing NS content up to 3% causes an increase in the compressive strength of concrete specimens at all testing ages.

- Compressive strength values Increases by increasing nano-silica level up to 2%. It was observed that the rate of increase of the compressive strength is no longer significant when the content of nano-silica particles is greater than 2%. There is also a slight decrease in compressive strength when the Nano-silica content increases to 3%. This indicates that the content of the Nano silica 2% is the optimum.

- Increasing Nano silica content increase the bond-strength between cement paste-aggregates by the effect of pozzolanic nature and filling effect of nano particles, thus the cubes failure occurs in aggregates.

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