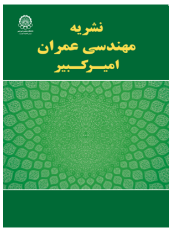

Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 53(8) (2021) 735-738
DOI: 10.22060/ceej.2020.17893.6705

Investigation of Some Durability Properties of Concrete Pavements Containing Nanoparticles

F. Ghadim Tekmehdash, A. Mohammadjafari Sadeghi*, H. Afshin

Faculty of Civil Engineering, Sahand University of Technology, Tabriz, Iran

ABSTRACT: Mechanical and durability properties of concrete structures, including concrete pavements, have been a focus of attention. In this regard, the potential of nanomaterials needs to be discussed more. Water permeability, abrasion, and compressive strength are assessed in this study. So far, the incorporation of diverse types of nanomaterials with different methods has caused the enhancement of some mechanical and durability properties of concrete. In the present study, five types of nanoparticles as nanoSiO2, nanoTiO2, nanoAl2O3, nanoFe2O3, and nanoFe3O4 in different amounts were uniformly dispersed and added to the concrete. To reduce the cost and decrease the required nanomaterials, specimens were made in two layers. The surface layer of specimens was made from self-compacting concrete containing nanoparticles with 1 cm depth, which was placed over the bottom layer from conventional concrete with different depths depending on the tests. The test results indicated that the properties of concrete pavements containing nanoparticles are improved comparing to the control specimen. For instance, in specimens containing nanoTiO2 as much as 3% by the weight of cement, the water permeability improved by 84.6%. Furthermore, the abrasion resistance of specimens containing nanoSiO2 at an amount of 1% was enhanced by 88.1%, and the addition of 3% of nanoSiO2 raised compressive strength by 88%.

Review History:

Received: Feb. 09, 2020
Revised: Apr. 17, 2020
Accepted: May, 08, 2020
Available Online: May. 28, 2020

Keywords:

Concrete pavements
Abrasion
Permeability
Compressive strength
Nanoparticles

1. INTRODUCTION

The durability of concrete pavements is an important issue. They are exposed to external detrimental factors such as abrasion and freezing of permeated water. Some nanomaterials are incorporated in concrete to enhance its mechanical strengths and improve its water permeability. Incorporation of oxide of some metals in the form of nanoparticles such as nano-silica, nano-titania, nano-alumina, nano-hematite, and nano-magnetite has led to positive effects on the mechanical and duration properties of concrete [1-7].

Uniform dispersion of nanomaterials in a composite plays a pivotal role in its effectiveness in improving the expected properties of the composite. Otherwise, the formed agglomerates hinder the anticipated enhancements through the formation of weak zones. Different methods of dispersing nanomaterials in cementitious matrices are discussed in the literature [8, 9].

In the present study, water permeability, abrasion resistance, and compressive strength of concrete pavements containing five different nanoparticles have been investigated. The tested specimens are made of two layers to reduce the cost of nanomaterials and the amount used. The top layer consists of self-compacting concrete incorporating nanoparticles with a depth of one centimeter, which is cast over a layer of normal concrete placed underneath. The proposed method in this paper could be applied both in the construction of new concrete pavements and in the retrofit of existing ones. Comparing mechanical and duration properties of specimens containing different amounts of nanoparticles in an identical experimental condition provides useful information on optimum amounts and improvement rates, which could be a supplement to the previous literature.

*Corresponding author’s email: mohammadjafari@sut.ac.ir

2. METHODOLOGY

The nanoparticles used in this study are five types of metal oxides with the specifications, as shown in Table 1. The maximum aggregate size in self-compacting and normal concrete is 2.38 mm and 19 mm, respectively. The fineness modulus of the sand used in the mentioned concrete types is 3 and 3.4, respectively. Type II Portland cement and a poly carboxylic superplasticizer with a pH of 6.5, as well as potable water, are used in concrete mixes.

Mix proportions, according to Table 2, are selected after investigating some mixes. All specimens were demolded after 24 hours and then cured in water at a temperature of 24ºC until the age of 28 days.

Cubic specimens of self-compacted concrete with 5 cm dimensions were tested according to the ASTM C109 standard to evaluate their compressive strength. Water permeability tests were conducted on two-layered cubic specimens, cast

Table 1. Specifications of incorporated nanomaterials

Nano Particles	Diameter (nm)	Specific surface area (m^2/gr)	Used amounts (wt.% of cement)
$NanoSiO_2$	20-30	180-600	1,3,5
$NanoTiO_2$	20	10-45	1,2,3
$NanoAl_2O_3$	50	>19	1.5,2,3
$NanoFe_2O_3$	20-40	20-60	1,3,4
$NanoFe_3O_4$	20-30	40-60	1,3,4

as mentioned in the previous section, with 15 cm dimensions in accordance with BS EN 12390-8 standard. For evaluating abrasion resistance, two-layered 3×15×15 cm specimens were used in a way that agrees with the ASTM C944 standard.

Each test was conducted on a group consisting of three specimens and the average of three measured values was reported as a result. Furthermore, for each of the three tests mentioned above, a group of control specimens is prepared without any nanoparticles to measure the improvement rates. Overall, 144 specimens were prepared and tested in this study, taking into account five types of nanoparticles at three different amounts.

Self-compacting concrete on the top layer of specimens contains five types of nanoparticles at three different amounts, which are considered as weight percentages of cement, as shown in Table 2.

Superplasticizer as a surfactant in combination with mechanical stirring was used to reach a uniform dispersion of nanoparticles in the water, which was added to the concrete subsequently.

3. RESULTS AND DISCUSSION

Results of the water permeability, abrasion resistance, and compressive strength tests are shown in Table 3. The increase of compressive strength in specimens containing $nanoTiO_2$ and $nanoFe_2O_3$ was accompanied by improvement in abrasion resistance and permeability, and maximum values were measured in those with higher nanoparticle content. This trend was observed in the specimens containing $nanoAl_2O_3$ and $nanoSiO_2$ to some extent, although the best results are almost associated with the medium content of nanoparticles. The incorporation of $nanoFe_3O_4$ raised the porosity due to foam formation, which consequently diminished the compressive strength.

In the case of uniform dispersion of nanoparticles in the concrete, if a suitable amount and distance are provided, nanoparticles can be placed in cement hydration products as a core, and limit the growth of $Ca(OH)_2$ crystals and make a homogeneous and dense cement matrix, which leads to higher mechanical properties. On the other hand, an increased amount of nanoparticles by impeding enough growth of $Ca(OH)_2$ crystals lessens their ratio against Calcium-silicate-hydrate, which results in a porous matrix. It should be noted that rising the content of nanoparticles declines the workability of concrete. Moreover, dispersion of higher amounts of nanoparticles is difficult, which increases the probability of agglomeration and diminishing mechanical properties.

Table 2. Mix proportions of self-compacting and normal concrete

Mix	self-compacting concrete	normal concrete
Cement	564.6	345
Water	179	189
Micro Silica	77	--
Limestone powder	185	--
Superplasticizer	13	--
Sand	1304	1064
Coarse aggregate	--	867
Specific weight	2320	2517

All values are in (kg/m^3).

Table 3. Results of the compressive strength, permeability, and abrasion resistance tests (improvement percentages)

Nanoparticles	Amount (wt.%)	Permeability	Abrasion resistance	compressive strength
$NanoSiO_2$	1	39.8	88.1	65.4
	3	73.8	81.1	88.1
	5	73.8	80.4	68.6
$NanoTiO_2$	1	34.6	58.9	4.2
	2	71.3	62.8	56.8
	3	84.6	67.2	85.8
$NanoAl_2O_3$	1.5	2	59.9	8.8
	2	69.2	86.6	77
	3	23.1	84	85.8
$NanoFe_2O_3$	1	13.8	-20.7	3.3
	3	18.5	84	54.1
	4	29.2	87.1	59.5
$NanoFe_3O_4$	1	-13.3	-347	-51.4
	3	56.9	29.5	-65.9
	4	23.1	29.5	-60.3

4. CONCLUSION

The effect of five different nanoparticles in some mechanical and durability properties of concrete pavements was investigated in this study.

According to the results, the compressive strength, permeability, and abrasion resistance can be enhanced by the incorporation of nanoparticles as they can improve the structure of concrete both by pozzolanic activity and filling the pores.

REFERENCES

[1] H. Li, M.-h. Zhang, J.-p. Ou, Abrasion resistance of concrete containing nanoparticles for pavement, Wear, 260(11) (2006) 1262-1266.

[2] A. Nazari, S. Riahi, Abrasion resistance of concrete containing SiO_2 and Al_2O_3 nanoparticles in different curing media, Energy and Buildings, 43 (2011) 2939-2946.

[3] M. Oltulu, R. Şahin, Effect of nano-SiO_2, nano-Al_2O_3 and nano-Fe_2O_3 powders on compressive strengths and capillary water absorption of cement mortar containing fly ash: A comparative study, Energy and Buildings, 58 (2013) 292-301.

[4] A. Shekari, M. Seyed Razzaghi, Influence of Nano Particles on Durability and Mechanical Properties of High Performance Concrete, Procedia Engineering, 14 (2011) 3036-3041.

[5] M.-h. Zhang, H. Li, Pore structure and chloride permeability of concrete containing nanoparticles for pavement, Construction and Building Materials, 25(2) (2011) 608-616.

[6] M. Oltulu, R. Şahin, Single and combined effects of nano-SiO_2, nano-Al_2O_3 and nano-Fe_2O_3 powders on compressive strength and capillary permeability of cement mortar containing silica fume, Materials Science and Engineering: A, 528(22) (2011) 7012-7019.

[7] A. Rashad, A synopsis about the effect of nano-Al_2O_3, nano-Fe_2O_3, nano-Fe_3O_4 and nano-clay on some properties of cementitious materials – A short guide for Civil Engineer, Materials & Design, 52 (2013) 143–157.

[8] A.H. Korayem, N. Tourani, M. Zakertabrizi, A.M. Sabziparvar, W.H. Duan, A review of dispersion of nanoparticles in cementitious matrices: Nanoparticle geometry perspective, Construction and Building Materials, 153 (2017) 346-357.

[9] S. Parveen, S. Rana, R. Fangueiro, A Review on Nanomaterial Dispersion, Microstructure, and Mechanical Properties of Carbon Nanotube and Nanofiber Reinforced Cementitious Composites, Journal of Nanomaterials, (2013).

HOW TO CITE THIS ARTICLE

F. Ghadim Tekmehdash, A.R. Mohammadjafari Sadeghi, H. Afshin, Investigation of Some Durability Properties of Concrete Pavements Containing Nanoparticles, Amirkabir J. Civil Eng., 53(8) (2021) 735-738.

DOI: 10.22060/ceej.2020.17893.6705