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Reduction in Environmental Damage of the Building Materials Using Nanomaterials

Ramin Mohammadi-Aloucheh[1*], Yaver Noormohammadi-Ziba[2], Enes Şayan[3]

1. Department of Biology, Central Tehran Branch, Islamic Azad University, Tehran, Iran
2. Department of Chemistry, Ardabil Branch, Islamic Azad University, Ardabil, Iran
3. Department of Process and Reactor Desing, Faculty of Science, Ataturk University of Erzurum, Turkey

*Correspondence author: Ramin Mohammadi-Aloucheh

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Abstract: Nanotechnology will lead to dramatic changes in the use of natural resources, energy, and water will reduce wastewater and pollution. One widely-used technique for improving the engineering properties is the use of different additives, and it is worth noting that in the past, these additives included bitumen, lime, fly ash, etc. Among the newest of these additives, one can point to nanoparticles that cause an improvement in physical, mechanical, and in general, geotechnical properties. The aim of this research is to study the effect of two types of nanoparticles, namely, nano silica and nano aluminum oxide on the compressive strength of poorly graded sand. To this end, different proportions of 0.3, 0.6, and 0.9 percent of the dry cement weight for each nanoparticle, homogenized with cement slurries with water to cement ratios of 1, 1/4, and 1/8, were injected into poorly graded sand with a relative density of 70 percent and a pressure of 2 bar. Based on the compressive strength in 7-day and 28-day samples, it can be understood that the samples' compressive strength increases with increasing the nanoparticles up to a certain point, and is stopped or reduced after this particular point. Furthermore, the effect of water to cement ratio on the samples' compressive strength is more than the effect of nanoparticles.

Keywords: Cement Injection, Environment, Nano alumina, Nano Silica.

1. Introduction

Nanotechnology includes the physical, chemical, and biological production and application of systems ranging in scale from a monoatomic or molecular area to submicron level, such as adding nanostructures to larger systems. Nanomaterials are defined as microstructures with at least one dimension in nanometer scale. The properties of nanoparticles include small size, grading distribution with a low level of agglomeration, and high release rate (Omrani and Fataei, 2018). These unique features of nanoparticles have caused nanotechnology to enter different sciences including environmental issues and solve the related problems. The science of geotechnical engineering is not an exception, and in the past few years a lot of efforts have been made to apply this new technology on different fields of geo-technics (Majdi, 2014). Most of the nanomaterials used for modifying the geotechnical properties of soils are silica nanoparticles that affect soil characteristics such as stabilization, permeability index, and strength parameters. The silica nanoparticles are used by Gallagher for increasing soil cohesion and reducing its viscosity. It is concluded that cohesion is dependent on the amount of increase in nanoparticles (Bao et al., 2019). In 2007, Patricia and colleagues in the US use nanomaterials in a special soil made of high-viscosity sand. Through applying an artificial earthquake and evaluating the settlement of soil, 40 percent improvement in soil settlement is obtained and it is shown that soil strength increases with the passage of time. Furthermore, it is found out that soils containing nanoparticles are formable in their early stages but their behavior is later changed to elastoplastic (Huang and Wang, 2016). In general, the soil available for designing from an engineering perspective is not ideal and desirable for construction, and should be prepared for specific purposes through making specific modifications. There are several approaches for making these modifications, the aim of which is to change the properties of a particular type of soil for the purpose of designing (Poor

Ahmadi, 2014). These approaches are called soil improvement. Soil improvement is performed for improving the engineering function of soil in achieving different aims, and is described as a series of operations that leads to the elimination of undesirable behaviors of soil, and imposition of proper behaviors. Among these, one can point to adding bitumen, lime, fly ash, etc. that can lead to reducing in plasticity, an improvement in density, strength, and stability of soil, and is usually used for fine grained soils. Furthermore, in granular soil, this can lead to reducing in permeability and corrosion, and increasing in strength (Lin et al., 2006, Ochoa-Cornejo et al., 2014).

Using nanomaterials for soil improvement, controlling the strength characteristics of soil, and reducing the amount of cement used can be cost-effective. Materials in nanoscale usually show different physical behaviors compared with atoms and bulk materials. The properties of nanoscale materials cannot be predicted based on the properties of materials in larger scales. Significant changes in the behavior of materials is not only caused by constant changes in the behavior of materials in smaller scales, but also is a result of the emergence of new phenomena such as quantum size limited and domination of the surface phenomena (Sun et al., 2016). Using nanoparticles can lead to an improvement in the soil's mono-axis strength, an increase in its bearing power, and finally an increase in the bearing capacity of the foundation (Ochoa-Cornejo et al., 2016).

In the current research, the effect of nanoparticles (nano silica and nano alumina) on mono-axis strength of poorly graded sand is studied. Due to the fact that a comprehensive study of the effect of nanomaterials has not been done yet, this research can lead us to a better understanding of the effect of nano silica on soil, and therefore can be used as a further step towards using nanotechnology in geotechnical engineering. Fortunately, this paper tries to rely on the applications of nanotechnology to solve the problems of the construction industry by relying on the construction industry and its role in environmental pollution. Some of the advantages of nanostructures include lighter, stronger materials, cost reduction by reducing the number of technical defects, new tools based on new principles and architecture.

2. Materials Used

Soil

The soil used for the purpose of this research was provided by Polad Insaat mine in Erzurum, Turkey. Selection of the samples was done based on the grading shown in Figure 1. Based on the USCS classification criteria, the soil used in this research is called fine grained poorly-graded sand (SP). Furthermore, the physical properties of the soil used in this research are shown in Table 1.

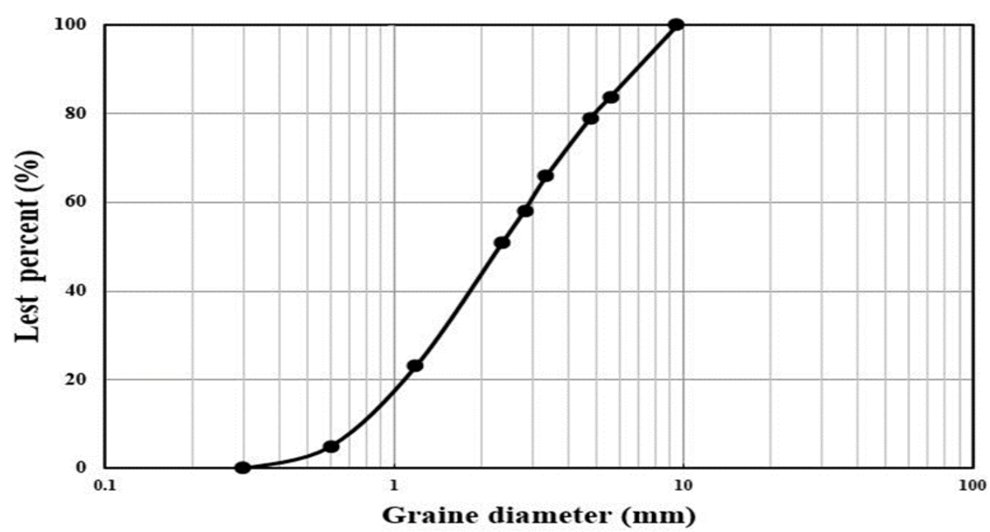

Fig.1- The grading curve

Table1: The physical properties of the soil in use

Gs	e_{min}	e_{max}	D_{10}	D_{30}	D_{60}	C_u	C_c	Soil	γ_{dmax}	γ_{dmin}	$\gamma_{d0.75}$	$\gamma_{d0.50}$

2.64	0.57	0.98	0.76	1.67	2.8	3.68	1.31	SP	1.68	1.33	1.58	1.48

Cement

The cement used in this research is the type 2 provided by Sufian cement factory, Tabriz, Iran, and corresponds with EN1971 standard. This cement type is mixed with combinations of lime (CaO), silicate (SiO_4^{2-}), aluminate (AlO_2^- and AlO_3^{3-}), and iron oxide. The size of a wet cement grain is approximately 10 micrometers, and its surface area to weight ratio is 0.3 that is increased up to 300 as a result of hydration (mixing water with cement) (Tsampali et al., 2019).

Silica Fume

It is a highly active pozzolanic material that easily reacts with CH and water, and is changed into C-S-H secondary form. The pozzolanic reaction of micro-silica can consume much of the CH, and the production of C-S-H fills the capillary cavities. This process in turn reduces the permeability of the concrete and decreases the possibility of CH reacting with other ions to form harmful products. Since micro-silica is twice smaller than Portland cement, it can easily fill the space between the cement grains. This material has a specific surface area of 20 m^2/g and a density of 586 g/cm^3. The silica fume used for the purpose of this research is provided by Iran's Pishgaman-e Nano Mavad Company.

Nano-silica

Silica is one of the most prominent materials that play a part in efficient cohesion and filling. A usual product is silica fume or micro silica with a diameter of 0.1 to 1 millimeter, and 90 percent of silica oxide. It can be said that micro silica is a product in the upper limit of nanometer size echelon, and is used to improve the efficiency of cementitious materials composite. Suspended Nano-silica has multiple functions such as:

- Anti-wear property
- Anti-slip property
- Flame retardancy property
- Anti-reflective property

All of the researches on the application of nano-silica are done in areas such as the improvement of workability, and also rheological and mechanical properties. The primary result is nano-silica with a diameter of 5 to 100 nanometers. Nano-silica causes an improvement in the density of particles. The Nano-silica used for the purpose of this research is provided by Iran's Pishgaman-e Nano Mavad Company. The structure of nano-silica showed in Figure 2.

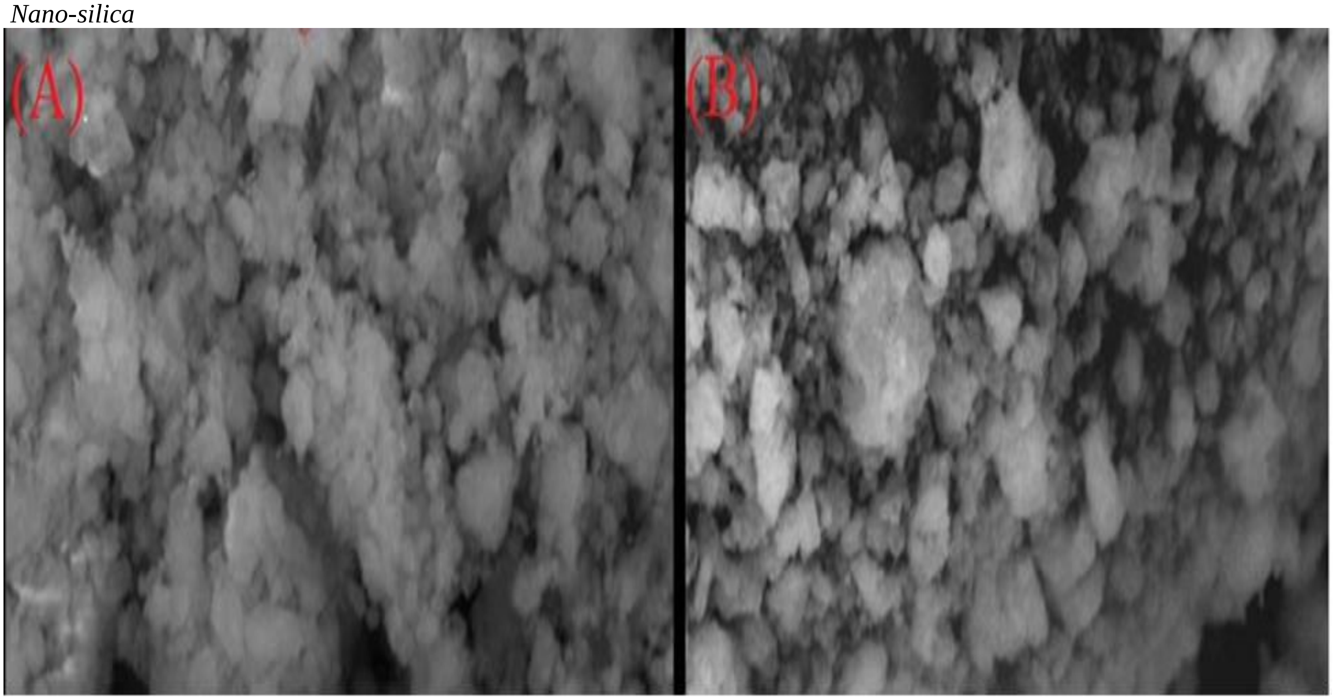

Fig.2- SEM images for the nano-silica (A) and nano alumina (B). (Sarojini et al., 2013)

Nano Aluminum Oxide

Nano alumina is a powder with the following properties that is provided by Iran's Pishgaman-e Nano Mavad

Company. Phase stability, high degree of hardness, and materials with high dimensional stability are among the evident characteristics of this product. It is widely used in plastics and other strong products to maintain and improve density, thermal fatigue, and resistance to creep and wear. Due to the fact that nano alumina involves tiny particles, it is highly efficient in the emission of infrared ray. This spherical and white material is powdery and hydrophilic, with a purity of 99 percent, and a particle size of 80 nanometers. The Nano aluminum oxide used in this research is provided by Iran’s Pishgaman-e Nano Mavad Company.

Laboratory Plan and Producing the Samples

First, in order to prepare the samples, they were weighed and prepared according to the grading of the soil, and volume of the molds (cylinders with an internal diameter of 9.6 centimeters, and a height of 20 centimeters), and also considering the fact that the grains’ relative density is 30 percent. In order to homogenize the mixture before pouring it into the molds, it is mixed in the rotary drum for 5 minutes. Then, the samples were produced based on the laboratory plan, the values determined for nanomaterials and the cement, and also water to cement ratio (1, 1/4, 1/8). Furthermore, 5 percent of silica fume was used in all of the samples, except for the witness sample. For nano-silica and nano-alumina, 0.3, 0.6, and 0.9 percent of the dry cement weight in the injection slurry was taken into account. To achieve a homogeneous mixture in the slurry, first, the nanoparticles were mixed with water for 5 minutes, and then the cement was added. Next, the combination was mixed for 10 minutes at a speed of 5000 rounds per minute. Finally, the mixture was poured into the injection container and injected by a compressor with a 2 bar pressure. After 24 hours, the samples were taken out of the molds, and were examined according to ASTMD2166-87 standard after 7, and 28 days of curing (Sarojini et al., 2013, El-Didamony et al., 2013, Singh et al., 2013, Jaishankar et al., 2017, Raje Gowda et al., 2017, Tsampali et al., 2019, Yao et al., 2018). As it was seen after taking the samples out of the molds, some of the samples were imperfectly injected. Therefore, they were reinjected by preparing the repetitive samples, and were finally examined after curing.

3. Results

After curing the samples, they were examined regarding their compressive strength. The results obtained from the different modes regarding water to cement ratio are indicated in what follows. The results of the 7-day and 28-day examination of compressive strength were shown in figure 3. Compressive strength of the samples containing 5 percent of silica fume led to an increase in the compressive strength in both 7-day and 28-day samples. Increasing the amount of nano-silica led to an increase in the compressive strength of the 28-day sample, while this property decreased in the 7-day sample. Furthermore, 0.6 percent of nano-aluminum oxide led to the highest increase in strength for both 7-day and 28-day samples.

Fig.3- Injection procedure and producing the samples

The positive effect of 5 percent of silica fume on the samples with 1/4 water to cement ratio could be seen in figure 4. The increasing trend of the samples containing nano-silica was stopped with increasing it at a value of 0.9 percent. Therefore, the optimal nano-silica value for samples with water to cement ratio of 1/4 was 0.6 percent. Studying the effect of nano-aluminum, it could be seen that the compressive strength of the samples was increased compared with the witness sample S (0%). However, increasing the amount of nano-aluminum did not significantly increase the strength.

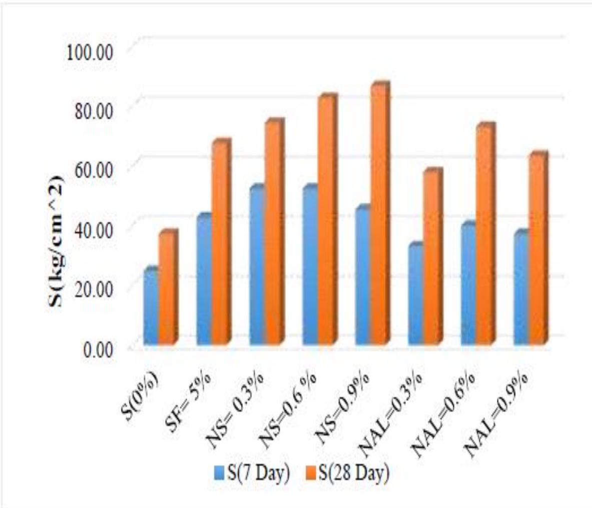

Fig.4-day and 28-day compressive strength of the samples (water to cement: 1)

Regarding figure 5, it could be seen that the strength of the 7-day and 28-day samples increased with increasing the amount of nano-silica. However, this trend was decreasing in samples containing nano-aluminum. Generally, except for the samples containing 0.9 percent of nano-silica, the samples' strength did not significantly increase or decrease compared with the witness sample.

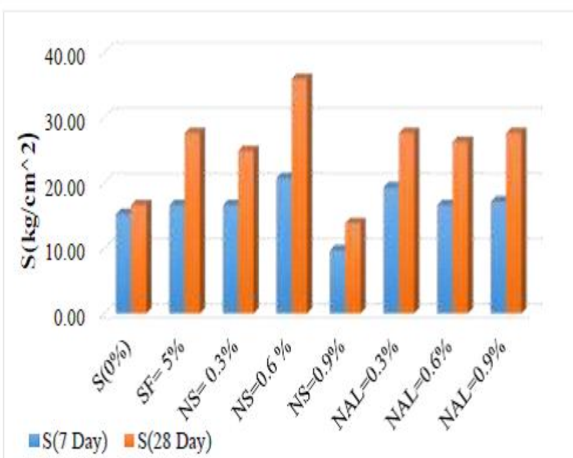

Fig.5-day and 28-day compressive strength of the samples (water to cement:1/4)

Regarding the figures 6-8, it could be seen that 7-day and 28-day compressive strength of the samples with water to cement ratio of 1 was more significant compared with other samples. This, in turn, was an indicator of the effect of water to cement ratio on the samples' strength. Furthermore, it could be said that 0.9 percent of nano-silica was not significantly effective on increasing the compressive strength of the samples with water to cement ratio of more than 1. In general, it could be seen that the effect of water to cement ratio was significantly more than nano-silica, nano-aluminum, and silica fume.

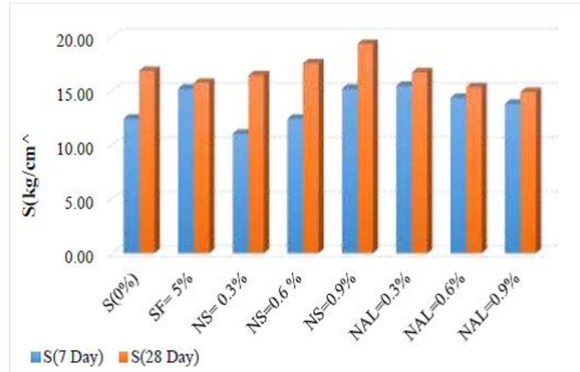

Fig.6-day and 28-day compressive strength of the samples (water to cement:1/8)

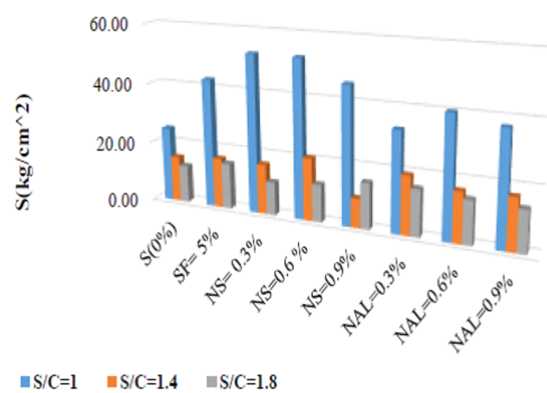

Fig.7-day compressive strength of the samples with various water to cement ratios

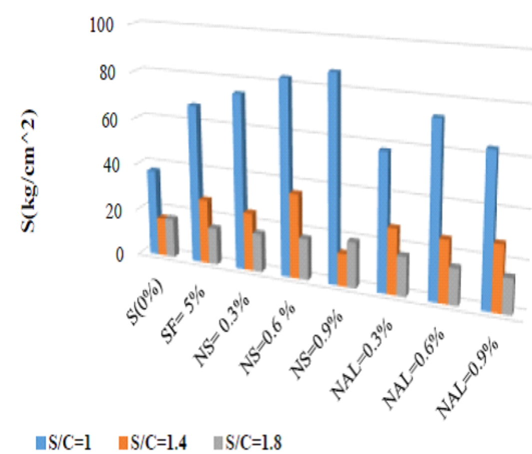

Fig.8-day compressive strength of the samples with various water to cement ratios

4. Discussion and Conclusions

The basis of the life of buildings in design is 50 years, but the useful life of buildings in the country is usually 15 years, which unfortunately is very short. At present, the world is looking to increase the useful life of structures, and after 15 years, a new building must be demolished and rebuilt. Part of the spaces around the city is full of garbage from destructive buildings, which due to the lack of decomposition of this garbage in nature, occupies a very large volume and accumulation around the city, which has both an unsuitable appearance and a lot of pollution for the environment. Creates human, animal and plant. There are two solutions to solve this problem:

1- Increasing the useful life of the building to prevent the increase of this garbage.

2 - Reuse of construction waste in the construction of new buildings.

To advance the first approach should be the useful life of structures, particularly concrete structures increased in this way increase the strength of concrete for structural strength and at the same time increasing the durability and reliability of concrete to prevent corrosion of reinforcement and longer life an important role plays.

Several experiments were performed for studying compressive strength, with various amounts of nanoparticles and various water to cement ratios to attain minimal damage to the environment. The results are as follows:

- 7-day and 28-day compressive strength of the samples with a water to cement ratio of 1 is more significant compared with other samples. This is an indicator of the effect of water to cement ratio on the samples' strength.
- The effect of water to cement ratio on the samples' compressive strength is significantly more than Nano silica, Nano aluminum, and silica fume.
- With an exception in the 28-day samples containing 5 percent of silica fume (water to cement ratio: 1/8), the positive effect of silica fume on compressive strength could be seen in all of the samples.
- Increasing the amount of Nano alumina is not significantly effective on increasing compressive strength.
- Increasing the amount of Nano silica leads to an increase in the compressive strength of the 28-day samples, except for samples with a water to cement ratio of 1/4.

Nowadays, researchers have begun examining some new nanomaterials as alternatives to cement used as bounding materials.

This investigation is done to minimize environmental pollution that rise from the use of large amounts of cement. One of these nanomaterials is comprised of silica and alumina (Tsampali et al., 2019).

These materials have the specific surface area which is large and a porous honeycomb structure, with particle size range of 0.5–300 μm and higher adsorption activity.

For example Keramatikerman et al showed that these materials were fly ash as a filler material that were added in the liquefiable sand; these materials play a role as a chemical additive to improve liquefaction resistance of sand (Das et al., 2009, Keramatikerman et al., 2017, Tsampali et al., 2019).

Accordingly, new methods and techniques should be developed for concrete construction in the large-area construction that are non-damaging and non-high cost to existing structures while at the same time being pollution free, and environment-friendly (Huang et al., 2015, Zamani et al., 2016 Keramatikerman et al., 2017).

Altogether, due to the high price of nanomaterials, the use of these materials in the construction industry may not be economically justified, but with a deeper look and a closer look at this issue, we can see that the use of nanoparticles in the construction industry, especially in terms of costs. Reducing environmental pollution is economically viable. For example, considering that the economic costs of rebuilding a building are much higher than the costs of using nanoparticles to strengthen and retrofit buildings under construction. Similarly, the cost of collecting and disposing of construction waste is far greater than the cost of reusing it with the help of nanomaterials.

5. Conflict of interest

The authors declare that they have no conflict of interest.

6. Additional Information And Declarations

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Competing Interests

The author declare there is no competing interests, regarding the publication of this manuscript

References

Bao, X., Jin, Z., Cui, H., Chen, X., & Xie, X. (2019). Soil liquefaction mitigation in geotechnical engineering: An overview of recently developed methods. Soil Dynamics and Earthquake Engineering, 1;120, 273-291.

Zhou, Y. F., Li, J. S., Lu, J. X., Cheeseman, C., & Poon, C. S. (2020). Sewage sludge ash: A comparative evaluation with fly ash for potential use as lime-pozzolan binders. Construction and Building Materials, 242, 118160.

Yoobanpot, N., Jamsawang, P., Krairan, K., Jongpradist, P., & Likitlersuang, S. (2020). Laboratory investigation of the properties of cement fly ash gravel for use as a column-supported embankment. *Construction and Building Materials*, *257*, 119493.

El-Didamony, H., Abd El-Aleem, S., & Ragab, A. E. R. (2016). Hydration behavior of composite cement containing fly ash and nanosized-SiO2. American Journal of Nano Research and Applications, 4(2), 6-16.

Huang, Y., & Wang, L. (2016). Experimental studies on nanomaterials for soil improvement: a review. Environmental Earth Sciences, 75(6), 497.

Huang, Y., & Wen, Z. (2015). Recent developments of soil improvement methods for seismic liquefaction mitigation. Natural Hazards, 76(3), 1927-1938.

Jaishankar, P., Karthikeyan, C., (2015). Characteristics of cement concrete with nano alumina particles. InIOP Conference Series: Earth and Environmental Science, 80(1), 012005.

Keramatikerman, M., Chegenizadeh, A., & Nikraz, H. (2017). Experimental study on effect of fly ash on liquefaction resistance of sand. Soil Dynamics and Earthquake Engineering, 93, 1-6.

Majdi, M. (2014). Studying the Effect of Nano Silica on Geotechnical Properties of Clay. In 1st national conference on soil mechanics, and foundation engineering. Tehran.

Ochoa-Cornejo, F., Bobet, A., Johnston, C., Santagata, M., Sinfield, J.V. (2014). Liquefaction50 years after Anshorage 1964; how nanoparticles could prevent it. Tenth U.S. National Conference on Earthquake Engineering Frontiers of Earthquake Engineering. Anchorage, Alaska, 21–25.

Ochoa-Cornejo, F., Bobet, A., Johnston, C. T., Santagata, M., & Sinfield, J. V. (2016). Cyclic behavior and pore pressure generation in sands with laponite, a super-plastic nanoparticle. Soil Dynamics and Earthquake Engineering, 88, 265-279.

Omrani, M., Fataei, E. (2018). Synthesizing Colloidal Zinc Oxide Nanoparticles for Effective Disinfection; Impact on the Inhibitory Growth of Pseudomonas aeruginosa on the Surface of an Infectious Unit. Polish Journal of Environmental Studies, 27(4), 1639-1645.

Poorahmadi, A. (2018). Increasing Shear Strength Parameters of Clay and Sand Soil Using Nanoparticles. 1st national conference on soil mechanics, and foundation engineering. Tehran 2014.

Gowda, R., Narendra, H., Rangappa, D., & Prabhakar, R. (2017). Effect of nano-alumina on workability, compressive strength and residual strength at elevated temperature of Cement Mortar. Materials Today: Proceedings, 4(11), 12152-12156.

Sarojini, S., Avatar, S.R., Subhendu, B., Lokesh, C. (2013) Effects of nano-silica/nano-alumina on mechanical and physical properties of polyurethane composites and coatings. Transact Electric Electron Mater.14:1-8.

Singh, A., Gupta S., Singh J., Singh, N.P. (2015). Hydration Mechanism and Strength of OPC and Blended OPC with fly ash in the of metakaolin. International Journal of Research in Engineering and Technology. 04 (05),60-68.

Sun, J., Wu, W., Xue, W., Tong, J., & Liu, X. (2016). Anisotropic nanomechanical properties of bovine horn using modulus mapping. IET nanobiotechnology, 10(5), 334-339.

Tsampali, E., Tsardaka, E. C., Pavlidou, E., Paraskevopoulos, K. M., & Stefanidou, M. (2019). Comparative study of the properties of cement pastes modified with nano-silica and Nano-Alumina. In Solid State Phenomena. 286, 133-144.

Yao, W., Pang, J., & Liu, Y. (2018). An experimental study of Portland cement and superfine cement slurry grouting in loose sand and sandy soil. Infrastructures, 3(2), 9.

Zamani A, Montoya BM. (2018). Permeability reduction due to microbial induced calcite precipitation in sand. Geo-Chic 94–103.