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Choose the Best Mix of Light Weight Nano Silica Composite Concrete with Mineral Pumice in Bending and Compressive Behavior of Concrete Beams

Alireza Taherizadeh , Maryam Abbasi, Alireza Ashofteh
1- M.S.C. in Civil engineering in field of Structure, Islamic Azad University, Rudehen, Tehran Iran, Alireza.Taherizadeh@ieer-ac.ir
2- M.S.C. in Civil engineering in field of Structure, Islamic Azad University, Rudehen, Tehran Iran, Maryam.Abbasi@ieer-ac.ir
3-PhD in Economic Geology, Faculty member of Institute of Engineering Education and Research, Alireza.Ashofteh@ieer-ac.ir

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Abstract

In recent years, with nanotechnology, new approaches to the development of concrete technology have been introduced. Nanoparticles, due to their dimensions, can play the role of filling the cavities. These particles are used to increase concrete strength and bonding among concrete components.In addition, nano-silica is used to accelerate the hydration reactions of ordinary cement in cement mortar. In most structures, concrete is considered as the main section of structure or part of it. Reducing dead load, and ultimately the force on the building, make necessary using lightweight concrete for countries like Iran, which are among the world's most seismically affected areas, and with high financial and fatal damage caused by the earthquake.In this study, 9 samples were prepared by experimental methods of mixing designs with 1, 2, 3,4 and 5% weight percent nano-silica as the substitute of cement material with mineral pumice to produce lightweight concrete with proper compressive and flexural strength record of 7, 28, and 90-day samples evaluated and it showed that adding 3% nano silica to lightweight concrete with mineral lacquer caused compressive resistance as 280, 314 and 341 and flexural strength as 110.4, 115.8 and 139 kg / cm^2 for ages 7, 28 and 90 days old.

Keywords: light concrete beams, Nano Silica, mineral pumice, Flexural Strength, Compressive Strength

1- Introduction

Today, in most structures, concrete is the main component of the structure or part of it. So, annual capital is great for concrete production. In this order, in many developed countries, numerous research centers and organizations are undertaking research on building materials.

Nowadays nanocrystalline materials technology is developing rapidly. Nano-

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silica particles are used to enhance concrete strength and increase penetration. In addition, nano-silica is also effective in accelerating the hydration reactions of ordinary cement in cement mortar.

In recent years, the use of Nano-science technology has been developing and the impact of these materials on the continuity and resistance of concrete is very evident, So that the use of nano-scale materials and their impact on concrete strength is increasing day by day. New science of nano-materials effects and its extraordinary effect on the construction industry has increased the need for research and development on these materials. This concrete can be used in constructing atomic energy bases and strategic instruments and highways and urbanization, resistant grounding and places that require high impact resistance and high strength. [1]

The main objective of this research is to reduce the dead load and ultimately the force applied to the building and the use of light concreteto reduce the number of earthquake-related financial and life-damages, especially in countries such as Iranwhich are part of the seismic regions of the world.

The researchers studied the effect of nano-silica (NS) with adding 1, 2 and 4% of weight percentageas replaced ofPortland cement on the alkali and silicate reactions of dolomite concrete.They found that nano-silica up to 2% by weight resulted in increased compressive strength and reduction of porosity and up to 181 days in water. This is due to the fact that nano silica has pozzolanic materials increases the bonding of the dolomite concrete components and the rate of hydration of the cement. Due to the use of dolomitic aggregates with the addition of nano silica and the formation of sodium hydroxide (NAOH) concrete strength is increased. [2&18]

Kesinijah et al. (2016) examined the effect of nano silica with barite and quartz aggregate and with the replacement of 2 and 5% nano silica on the properties of high-performance concrete and found that a mixture of 2% nano-silica and quartz and barite aggregate due to the proper dispersion and creation of bonding between the concrete particles improves the compressive and flexural strength of the concrete and the addition of 5% nano silica to the samples due to the lack ofdensity and uniformity between hardened cement with aggregates leads to a decrease in the flexural strength and compression of concrete. [3]

Mariana et al. (2016) improves the electrochemical properties of concrete containing 1% iron nano-oxide for 300 days in the vicinity of the chloride and Sulfated environment. They used multiple technologies and impedance spectroscopy and spin-on voltage(Cyclic voltammetry) found that concrete containing 1% of iron nano-oxide in addition to increasing the compressive strength and modulus of elasticity reduces sensitivity of the concrete to corrosion than the reference sample. [4]

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Anvar Mohammad et al. (2015) studied the effect of nanoparticles on the mechanical properties of concrete at different ages. In this study, the different mixturetypes of nanosilica (ns) (nanoclay (nc) and a combination of both together with different weight percentages have been investigated and flexural and compressive strength on samples at age 7, 28 and 90 days considered to investigate the effect of these nanoparticles on the mechanical properties of concrete. The results of this study showed that nanoparticles can be very effective in improving the mechanical properties of concrete which nanosilica is more effective than mechanical properties in nano-clay and mixing in a wet state increases the amount of dry matter in a dry state .The combination of nano-silica and nanoclay increases the physical properties of concrete. This improvement can be attributed to the reaction of nano-materials withCalcium hydroxide ca (oh) $_2$ Crystals that are bound in the surface area (itz) between hardened paste and special grains which eventually C-s-h gel productionand the nano-particle filling processes increase diffusion structure.[5]

The researchers studied the effects of nano-silica on water and the structure of ultra-high performance of concrete (uhpc) with low adhesion and it was found that due to the high amount of super lubricant used to produce uhpc, the duration of treatment was increased in this study, and due to the use of nano-silica, the duration of concrete treatment can be substantially compensated. Also, Nanosilica makes the air more confined in the freshly mixed concrete and the porosity of the hardened concrete increases proportionally, in spite of the effect of nanosilica, cement hydration can be improved gradually and with production of c-s-h gel. [6 &17&19]

Mohammad Amin et al. (2015), studied the effect of using different types of nanoscale materials on mechanical properties of high strength concrete.

They studied nano silica effect, 5Fe2O4, 5Zn, Cu(cu-zn ferrite) and Nickel ferrite (nife2o3) in compressive strength, tensile strength, flexural strength and modulus of elasticity of concrete using two coarse grains (dolomite and granite) and its effect on mechanical properties of concretes containing nano-materials. The results showed that the improvement in compressive strength of concrete was increased when nanosilica and nano-ferrite were added included 21% and 17% respectively. Moreover, the improvement percentage in the tensile strength of concrete increases with the addition of nano silica and nano ferritecompared to the control mixture by 44% and 21%approximately. Concrete samples containing nano-silica compared to samples containing nano ferrite have achieved a better result about 10%. Granite concrete samples yield better results than those containing dolomite in a similar level of about10%.[7]

Hang Dave et al. (2014) studied the durability of concrete containing nano-silica.In this study, durability of concrete with nano-silica was studied in doses 0.3%

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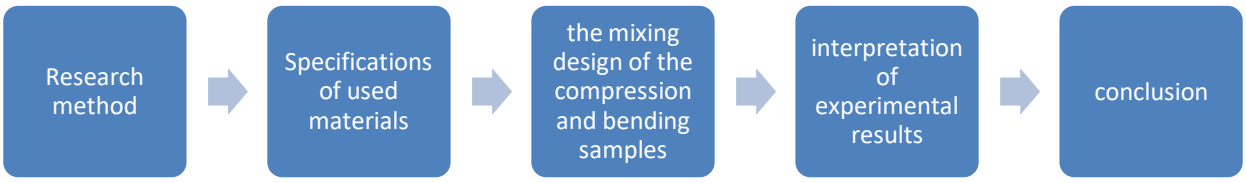
and 0.9%. Due to the effect of nano filling and pozzolanic reaction, its microstructure is more homogeneous and porosity is less, especially in the surface transfer region (ITZ)which reduces permeability. Experiment on the durable properties of beneficial effects of Nanosilica has been approved. The pore size distribution also shows that the large pores of the capillary by nano silica, due to the combination of the nano effect filler and pozzolanic reaction and also nanosilica exhibited a clear pozzolanic reaction even in the early stages and increases compressive strength by 1 day. [8]

Researchers studied the effect of nano fe_2o_3 on the flexural strength and tensile strength and concluded that adding 2% an iron oxide nanoparticle with particle size as15nm increases the flexural strength and tensile strength.

Based on our research and studies, we studied the effect of adding mineral pumice along with an increase in the percentage of nano silica on 7,28 and 90 days samples and effect of increasing its compressive strength and flexural strength.[16&20]

In the following, the method is described firstly and then, after explaining the specification of the used materials, the mixing design of the compression and bending samples and interpretation of experimental results andfinally, the results of the research are described in the following table.

Table 1- Procedures for conducting research [Writer]



2. Research methods and materials characteristics and specimen details

The purpose of this study was applicable aspect of the objective and content and aspect ofdata collection method, laboratory use method has been considered which this method is one of the most documented methods of research and study. In our present research, we construct 9 samples of eachmixing design using 1,2,3,4 and 5% by percentage weight of nano silica as an alternative to cementations materials and mineral pumice to produce light concrete with optimal resistance and obtaining the mean compressive strength and flexural strength of 7,28 and 90 dayssamples.

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This section describes the properties of the materials used in the laboratory program of the project, including cement, nanosilica, aggregate, super lubricant, iron powder and water, and test methods. Test instrument is compressor and flexural strength measuring device of Italian ShenzarCompany which samples are subject to standard and the same loading speed were tested with it. In the following, the specifications of the used materials in this research are expressed briefly.

1.2 Pumice characterizations

Pumice is seen in bright colors including white, yellowish-white, gray, brownish-red, and pale red which due to the accumulation of volcanic ash and slow cooling with the expansion caused by the bubbles created by the steam and the gases are created. Consumable stone materials, especially aggregates under a little moisture fluctuations are best placed. For example, Pumice in Iran can absorb and retain more than 30% of the water. So between the totally "dry and completely saturated aggregates" exists a significant difference and can affect the resulting slump and the ratio of water to cement, and thus resistance and durability of structural reinforced concrete. However, if we know, for example, our aggregates have about 5% moisture content; we can adjust the amount of consumed water to achieve the desired mixing plan.

2 -2- Cement specifications

The cement used in the final construction of samples is Tehran Type II cement. This cement is produced according to the national standard ISIRI No. 380. Portland cement type 2 is used to manufacture concrete with moderate heat hydration and sulfate attack on them. The chemical specificationsand the physical characteristics are given in Tables 2 and 3 respectively.

Table 2- Chemical characteristics of cement type 2 according to National Standard No. 389 [10]

	% SiO2	% Al2O3	% Fe2O3	% MgO	% OS3 C3A <8	% LOI	% IR	% C3A
The amount in the standard 389	>20	<6	<6	<5	<3	<3	<0.75	<8

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Table 3- Physical Properties of Type 2 Cements according to National Standard No. 389 [10]

	Special Level (Blaine) Gr / cm2	Expansion autoclave%	stuck Time		Compressive strength Kg / cm2			Hydration Heat 7 days CaL / gr
The amount inthe standard 389	>2800	<0.8	Primary Minute	Final hour	3 days	7 days	28 days	
			>45	<6	>100	>175	>315	<70

3-2- Nano Silica Specifications

Nano- silica from Germany has been used in this project. Physical and chemical characteristics of nano-SiO2 are shown in Table 4

Table 4- Physical and Chemical Properties of Nano-crystalline Silica [11]

Certificate of analysis				
Sio 2	Ti	Ca	Na	Fe
≥ 99%	<120ppm	<70ppm	<50ppm	<20ppm
Silicon Oxide (Sio2)				
Purity	99+%			
APS	11-13 nm			
SSA	200 M^2 / g			
color	White			
Bulk density	0.10 g / cm^3			
True density	2/4 g / cm^3			

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4- 2- sand characteristics

The usedsand has been produced from Pakdasht Sands Mine by ParsianPakdasht Company. Used sand is washed sand. This sand has been screened according to standard granulation ASTM C778 and its specifications are shown in Table 5.

Table 5: used Sand specifications[12]

Aggregate	Kind	Specific gravity (gr / cm^2)	Water absorption% 55
Sand	normal	2.75	2.95

5- 2- Super lubricant specifications

Super-lubricating is one of a variety of additives. Their function is to disperse cement particles in water. Much effect of the material will be available for a short time and after 30 to 90 minutes, the performance will return to its normal level. It is necessary for this reason, adding the lubricant to the concrete to be conducted just before concrete pouring. In most cases, this material is added to the mix during concrete mixing and the mixing of the concrete continues for a short time. The technical specifications of the super lubricant are given in Table 6.

Table 6- Specifications of the super lubricant[13]

physical state	Liquid
Color	Yellow
Special Weight	2.1 gr / cm^3
Ion chlorine	-
Standard	G& ASTM C494 Type F
Mode, time of storage	For a year away from direct sunlight and frostbite
packing	Gallon 20 and barrels 220 liters

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6- 2-consumed water Specifications

Theconsumed water in making mortar samples is drinking water of Tehran, at a temperature of 20+1 ° C with a good quality.

7- 2- Specifications of iron powder

Due to the shape and size of the particles of iron, iron powder can provide the necessary properties for bonding concrete and aggregate mortar inconcrete components. The percentage of compounds in the iron powder is given in Table 7.

Table 7-percentage of compounds in the iron powder[14]

Composition %	
iron	98.2
carbon	0.01
Silicon dioxide	0.20
Hydrogen loss	0.26
sulfur	0.01
phosphorus	0.01

3-Mixing design for compressive and flexural samples

Based on studies, and trial and error to determine the values of the initial mixing scheme for samples in the case of silica-free nano -particles, experimental form was considered to reach the compressive strength 310 (Kg / m3) and bending strength 116 (Kg / m3) and with adding Nanosilica with different percentages, the effect of increasing the resistance in compression and bending samples has been obtained so that in producing mortar P0,mixing percentagesas water to cement ratio were selected %37and as 1,2,3,4 and5% Nanosilica is shown as a substitute for cement weights p, 1 p, 2 p, 3 p4 and p5, respectively.

Table 8-mixing scheme of flexible sample (Kg / m^3) [Writer]

Sample	Water weight	Cement	Water to cement	Sand weight	fine Pumice	Coarse Pumice	Super lubricant	Nano weight	Iron powder
P0	139.26	375.11	0.37	842.3	108.6	276.5	1.67	0	6
P1	139.26	375.11	0.37	842.3	108.6	276.5	1.67	3.75	6
P2	139.26	375.11	0.37	842.3	108.6	276.5	1.67	7.5	6
P3	139.26	375.11	0.37	842.3	108.6	276.5	1.67	12.25	6
P4	139.26	375.11	0.37	842.3	108.6	276.5	1.67	15	6
P5	139.26	375.11	0.37	842.3	108.6	276.5	1.67	18.76	6

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Table 9- mixing scheme of bending sample - (Kg / m^3) [Writer]

Sample	Water weight	Cement	Water to cement	Sand weight	fine Pumice	Coarse Pumice	Super lubricant	Nano weight	Iron powder
P0	166.67	527.68	0.32	166.67	278	402	2	0	6
P1	166.67	527.68	0.32	166.67	278	402	2	5.27	6
P2	166.67	527.68	0.32	166.67	278	402	2	10.55	6
P3	166.67	527.68	0.32	166.67	278	402	2	15.83	6
P4	166.67	527.68	0.32	166.67	278	402	2	21.172	6
P5	166.67	527.68	0.32	166.67	278	402	2	26.384	6

4- Interpretation of laboratory results:

After obtaining the design of the mixing of compression and bending samples and delivering the samples for the time required for treatment in standard laboratory conditions, to determine the compressive and flexural strength of the samples,pressing machine ofShen Company was used perfectly.

1- 4 - Interpretation of compressive strength test results

The purpose of the construction of samples and the use of nano silica with different weight percentages and separately in concrete samples to reach the referenceto compare the results with a constructed lightweight concrete sample. Compressive strength test was conducted according to ASTM CI09 standard on samples made with Type II cements and adding nano silica with weight percentages and differences at ages of 7,28 and 90 days.

For this purpose, a pumice specimen was made of Pumice aggregate. At any age, a cube sample of 15 cm requirements and standards, and the same loading speed, were tested by the press machine for measuring the compressive strength and flexural strength of the concrete by the laboratory of Shenzar Company in Italy in Fig. 1 and the compressive strength of the specimens and the experiments were recorded analyzed completely.

Figure 1-bending and compression strength test device [Writer]

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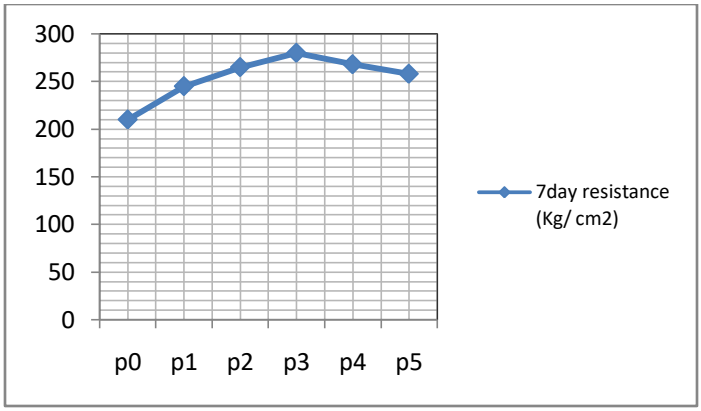
The compressive strength of Pumice Mineral Pump samples is given in Table 10

Table 10: Pumice Pressure Resistance [Writer]

sample	7day resistance(Kg / cm^2)	28day resistance(Kg / cm^2)	90day resistance(Kg / cm^2)
P0	210	263	301
P1	245	276	329
P2	265	304	333
P3	280	314	341
P4	268	307	334
P5	258	280	329

Charts relating to the compressive strength of light nano concrete samples at age 7, 28 and 90 days are listed below.



Graph 1- 7 days Compressive strength of Samples containing 1,2,3,4 and5 nano silica percentages[Writer]

As shown in Graph 1, the compressive strength of the samples containing nano-silica compared to the sample without nano-silica (p0) increases rapidly and this is due to an increase in the speed of cement hydration and c-s-h gel production at an early age, so that, the difference between the compressive strength of the sample containing 3% nano silica (p3) at 7 days of age respect to reference sample (p0) reach the highest difference in different ages, 70 kg per square centimeter.

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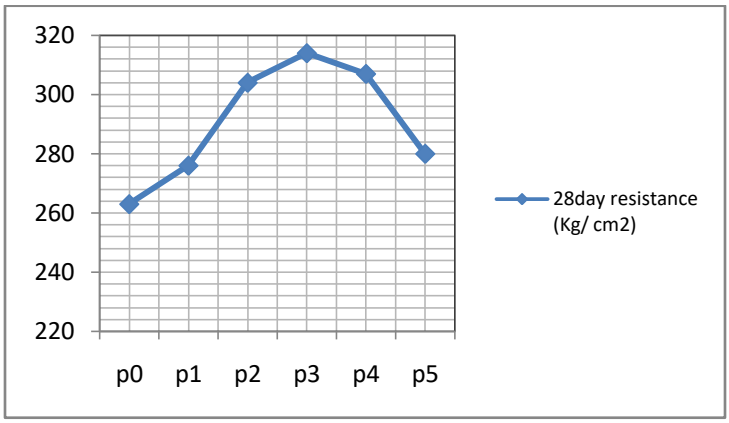
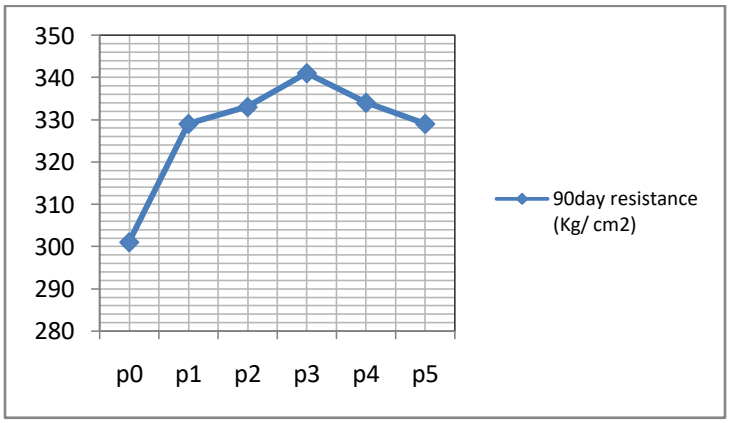


Graph 2- 28 days Compressive strength of Samples containing 1,2,3,4 and5 nano silica percentages[Writer]

As shown in Graph 2, the difference between samples containing 3% nano silica as a weight substitute for cement materials compared to the sample without nanosilica, the resistance of 28 days is 51 kg / cm^2, as well as the water contained in Pumice in the case of saturated concrete added toconcrete samples during the course of concrete treatment, nano-silica can be used to treat water and provides aggregates and prevents porosity of concrete and concrete stains.



Graph 3- 90 days Compressive strength of Samples containing 1,2,3,4 and5 nano silica percentages[Writer]

As shown in Graph 3, the difference between samples containing 3% nano silica as a weight substitute for cement materials relative to the sample without nanosilica, at a resistance of 90 days reaches 40 kg / cm^2 and the difference between the compressive strength of the samplesdecreases gradually, due to the inadequate dispersion of nanoparticles and the reduction of concrete performance of the sample containing 3%

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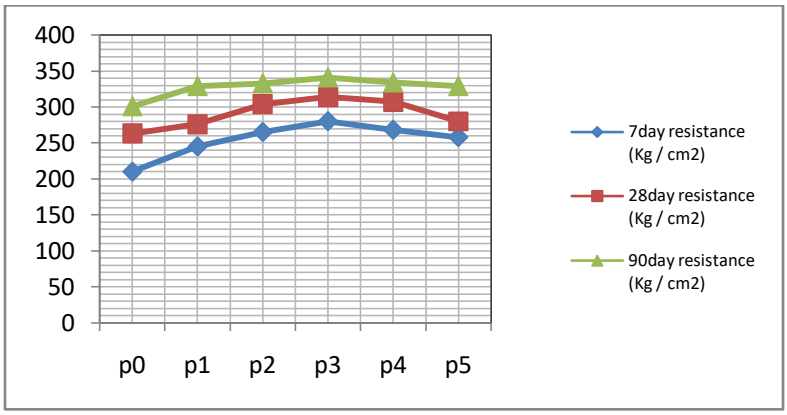
nano silica which can reduce the compressive strength of light concrete samples.



Graph 4- Compressive strength of Samples containing 1,2,3,4 and5 nano silica percentages[Writer]

According to Graph4 from samples containing 1,2,3,4 and5 nano silica percentages as a substitute for cement weighing, sample containing 3% nano silica (p3)has the highest compressive strength compared to other samples.

By observing the results of the experiments, we find that the compressive strength of concrete samples increase with the age and thisdistinguishes the difference between the compressive strength values obtained in the designs and also for all samples containing3% nano silica ascendingly and then it decreases with increasing the amount of nano silica in compressive strengthof concrete samples.Figure 2- shows the pressure specimens and a sample of broken pressure sample.

igure 2- Pressure samples and a sample of broken compression sample [Writer]

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2.4- Interpretation of the results of the flexural strength test

The purpose of making single-mortar samples is to use nano-silica with different weight percentages of concrete in concrete samples to achieve references to compare the results with light concrete sample. Flexural strength test was conductedaccording to standard ISIRI 12728 on samples made with cement of type 2 and adding nano silica at the ages of 7, 28 and 90 days.

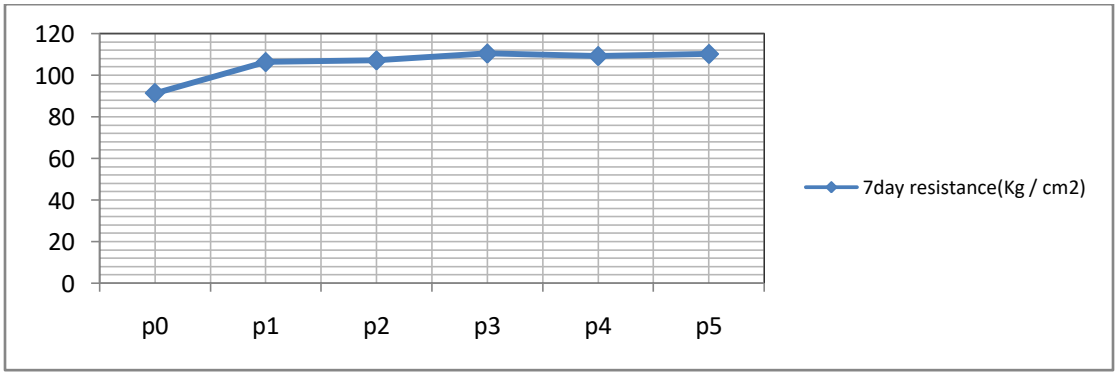
For this purpose, 9 bending samples were made of Pumice aggregates. At any age from each design, a rectangular template of 10*10*60 Centimeters was made and tested according to the standard and loading speed of the same and the bending strength of the samples was recorded.

The bending strength of mineral pumice samples is presented separately in Tables 3-4

Table 11: Pumice bending Resistance [Writer]

sample	7day resistance(Kg / cm^2)	28day resistance(Kg / cm^2)	90day resistance(Kg / cm^2)
P0	91.4	96.6	111.1
P1	106.3	108.1	123.8
P2	107.1	112.4	124.5
P3	110.4	115.8	139
P4	109.2	113.5	129
P5	110.2	114	129.3

Graphs for flexural strength of light nano concrete samples at ages 7, 28 and 90 days are listed below.



Graph 5- 7 days flexural strength of Samples containing 1,2,3,4 and5 nano silica percentages[Writer]

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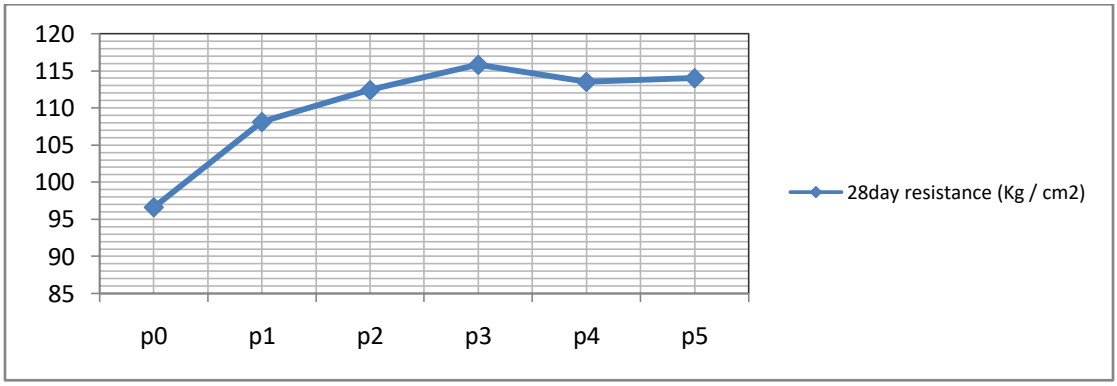
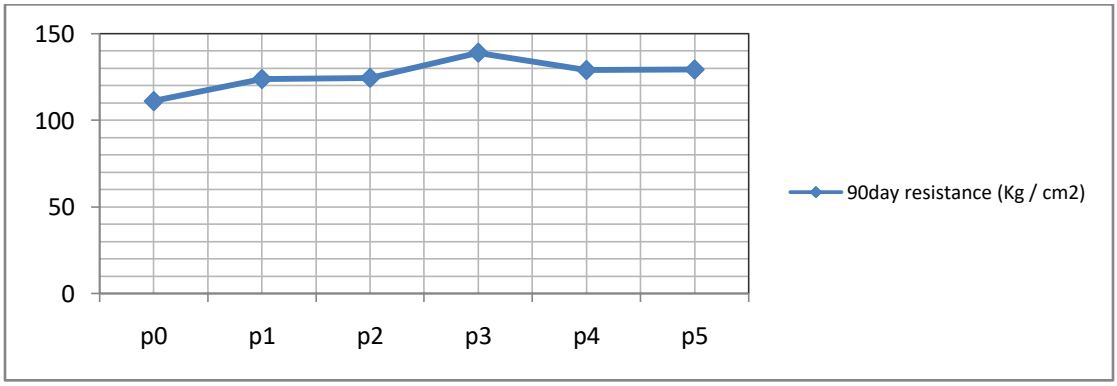
As shown in Graph 5, the flexural strength of the samples containing nano-silica compared to the sample without nano-silica (p0) increases and difference between7-day strength of the samples containing nano-silica and samples without nanosilica is evident, which is due to the increase in rate of cement hydration and c-s-h gel production At an early age, so that, the difference between the flexural strength of the sample containing 3% nano-silica (p3) at the age of 7 days relative to reference sample (p0) reaches 19 kg per square centimeter.



Graph 6- 28days flexural strength of Samples containing 1,2,3,4 and5 nano silica percentages[Writer]

As we see in Graph 6, the difference between a sample containing 3% nano silica as a weight gain of cement materials relative to non nano silica at 28-day resistance reaches 19.2 kg per square centimeter. The bending strength of 28 day- specimens reduce aftersample containing 3% nano silica (p3) and this trend decreases and resistance with a gentle slope.



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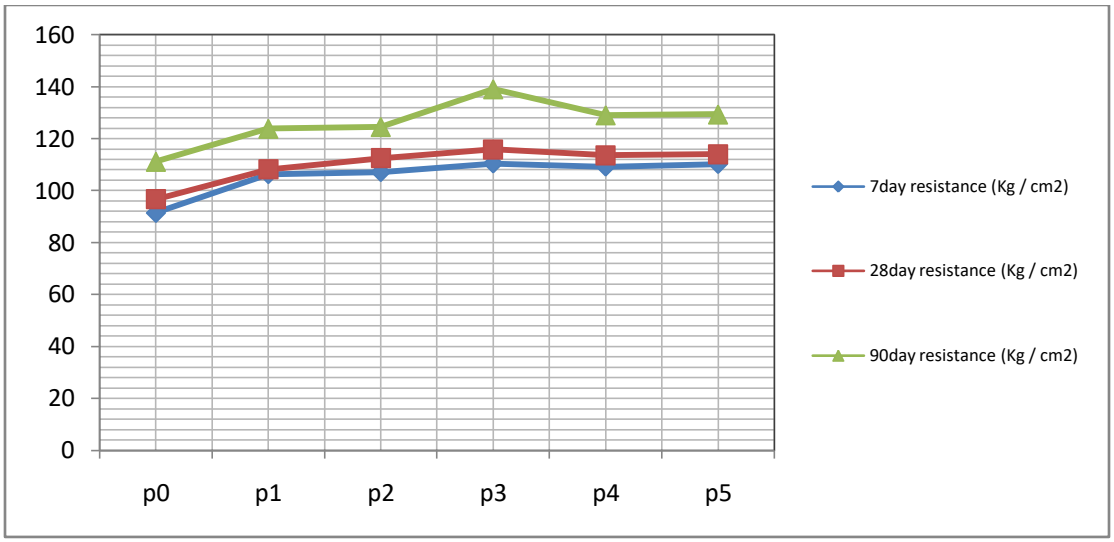
Graph 7- 90days flexural strength of Samples containing 1,2,3,4 and5 nano silica percentages[Writer]

As shown in Graph 7, the difference between the compressive strength of the sample containing 3% nano silica (p3) at the age 90 days respect to reference sample(p0) reaches the greatest difference at different ages as 27.9 kg per square centimeter.



Graph 8- flexural strength of Samples containing 1,2,3,4 and5 nano silica percentages as cement weight-substituting.[Writer]

By observing the results of the experiment, we find that, in general, the flexural strength of the concrete sample increased with age, and with increasing age of the samples, the difference between the values of the flexural strength obtained in the designs increases, as well as for all samples containing nano-silica to a value of 3% nano(p3)ascending and subsequently with increasing nano silica content in concrete samples, the compressive strength of the samples is reduced.Figure 3 shows the flexural samples and a sample of broken flexion samples

Figure 3 - Flexible specimens and a broken flexor sample [Writer]

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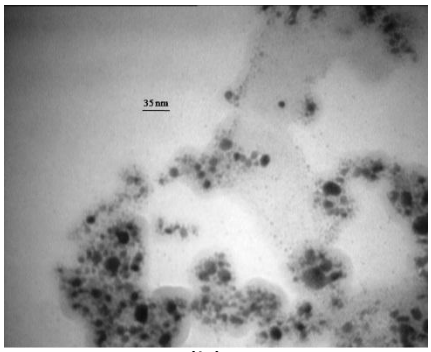
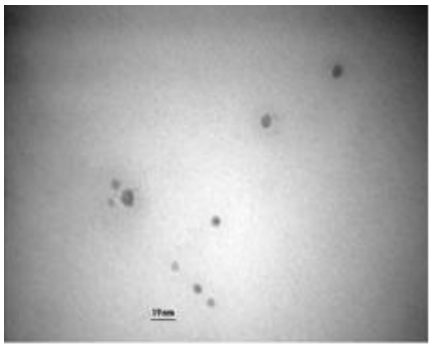
3-4- Investigating the diffusion of nano-silica particles

Before examining what is obtained from the interpretation of the compressive and flexural results of the samples, we will consider the results obtained from the diffusion rate of nanoparticles in dry and combined forms in water, as shown in Fig. 4. In mode (a) which the particles are dried powder and the particle size is 19 nm and in the mode(b) which the particles are combined in water the particle size reach 35 nanometers.



(b)



(a)

Fig. 4- Distribution of nano-silica particles in dry state - (a) and composition in water (b)[11]

5. Conclusion

In this experimental study, to determine the compressive strength and flexural strength of light nano concrete with mineral pumice, Nanosilica 1,2,3,4 and 5% percent was used as a substitute for concrete materials in concrete mixes, and to get the best mix of nano silica concrete and Mineral Pumice, pressure and flexural strength of 7, 28 and 90 days samples were evaluated and the following results were obtained.

1-Pumice used in lightweight concrete can absorb and retain more than 30% of water. So, there is a significant difference between aggregate "completely dry" and "completely saturated" and can affect the resulting slump and the ratio of water to cement and finally has remarkable effect on the strength and durability of structural reinforced concrete.

2- Based on the diagram of determining the compressive strength to add 3% of nano silica (p3), resistance increases for samples 7, 28 and 90 days samples with steep slope around 33, 19 and 13 percentages respectively and then reduces with a gentle slope for samples 7, 28 and 90 days around 12, 8 and 4 percentages.

3-Based on the diagram of determining the bending strength to add 3% of nano silica (p3), resistance increases for samples 7, 28 and 90 days samples with slope around 21, 20 and 25 percentages respectively and then reduces with a gentle slope for samples 7, 28 and 90 days around 0.18, 1.6 and 7.5 percentages.

4. Adding more than 3% of nano silica to light concrete due to the inadequate dispersion of nano particles and reducing the

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efficiency of manure concrete reduces compressive and flexural strength of light concrete samples.

5- Nanosilica containing samples have a large increase in 7-day resistance compared to non-nanosized samples, due to an increase in the speed of cement hydration and the production of c-s-h gel at an early age.

6- Water in pumice pulp aggregate, which has been added to concrete samples in saturated state during the processing of concrete, nanoSilica can provide the water needed for processing from aggregate and prevent the porosity of the concrete.

7- The effect of nano-silica on improving the compressive strength of concrete samples is more than its effect on improving the flexural strength of concrete samples.

8. The greatest difference between the compressive strength of the reference sample (p0) and the sample containing 3% nano silica (p3) in a compressed sample is 70kg / $cm^2$and in bending sample 27.9 kg / cm^2

9- The greatest difference between the sample containing 3% nano-silica (p3) and the reference sample (p0) in compressive strength for 7 days and for resistance bending occurred on 90 days.

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