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Effects of KCC-1/Ag Nanoparticles on the Mechanical Properties of Concrete

S. M. Ahmadi[a], A. Honarbakhsh*[b,c], R. Zhiani[d,e], D. Tavakoli[f]

[a] *Department of Civil Engineering, Toos Institute of Higher Education, Mashhad, Iran*
[b] *Department of Civil Engineering, Neyshabur Branch, Islamic Azad University, Neyshabur, Iran*
[c] *New Materials Technology and Processing Research Center, Department of Civil Engineering, Neyshabur Branch, Islamic Azad University, Neyshabur, Iran*
[d] *Department of Chemistry, Neyshabur Branch, Islamic Azad University, Neyshabur, Razavi-Khorasan, Iran*
[e] *New Materials Technology and Processing Research Center, Department of Chemistry, Neyshabur Branch, Islamic Azad University, Neyshabur, Iran*
[f] *Department of Civil Engineering, Shahrekord Branch, Islamic Azad University, Shahrekord, Iran*

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ABSTRACT

The effect of nano KCC-1/Ag and nano SiO_2 in concrete have been investigated in this study. Nano KCC-1/Ag and nano SiO_2 are synthesized and their characterization was investigated by FTIR, SEM, and TEM analysis. After that, these materials use as cement replacement in 1, 2, and 3 percent amounts. SEM images illustrate the denser structure of KCC-1/Ag nanoparticles. Furthermore, in the FTIR spectra 3640 cm^{-1} is related to C-S-H, which is sharper and more severe in samples with nano KCC-1/Ag and nano SiO_2. The results revealed that nano SiO_2 and nano KCC-1/Ag both improved the microstructure of cement paste and increased the concrete compressive and splitting tensile strength. For comparison the performance of nano KCC-1/Ag and nano SiO_2, the results indicated that nano KCC-1/Ag improved the microstructure of concrete better than nano SiO_2. Hence, it has a better performance in enhancing the strength of concrete. The study showed that the optimal percentage of using nano KCC-1/Ag was 2%.

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1. INTRUDUCTION

Improving the quality of concrete, as one of the most important building materials, has always been a concern. In recent years, it has been shown that using different pozzolanic materials has improved the quality of concrete [1-4]. After the advent of nanotechnology, their use in building industry was taken into consideration as it was thought that they can assist with the improvement of concrete quality. Building industry will be one of the main consumers of nanoproducts [5]. The impacts of nanomaterials on building materials have been specifically taken into account. Nano metal oxide such as Fe_2O_3, Al_2O_3, TiO_2 and etc were added to concrete separately. The authors nociced that addition of a small dosage of nanoparticles to the mix contributes not only to enhancing mechanical properties of SCC, but this also leads to significant improvements in the durability properties of SCC, in spite of the mprovement of concrete with w/c=0.4 was quite negligible [6]. They noticed tha although nanomaterials such as Au, Pd, Ag and etc. are rarely used in building materials (generally due to their high prices); while, they have strong potentials to remove concrete weaknesses such as high permeability, low compressive strength, cracking, weak ability, and low abrasion resistance. To reach this, SiO_2 is the most important material, which are used in concrete. It gained better compressive and tensile strength, to be more exact it could improve those features by 17% and nearly 15%, respectively [7]. Further, one of the most effective pozzolanic materials used extensively in concrete has been silica fume as it can improve most of concrete properties and also the micro structure of concrete [8]. Given this point, after imtroducing of nano-technology to building industry, attentions were drawn to nano SiO_2.

*Corresponding Author Email Address: amin_honarbakhsh@yahoo.com (A. Honarbakhsh)

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Studies on the effect of nano SiO_2 on concrete have remarkably increased and their results are being implemented in building industry. In fact, many researchers have produced new materials based on nano SiO_2. Most of these studies have reported beneficial results such as better setting time, slump, shrinkage and durability [7]. It has also been shown that adding nano SiO_2 might enhance the strength of concrete more than silica fume [9]. This improvement emerges from the pozzolanic activity of nano SiO_2 and improvement of the concrete micro structure. In fact, the pozzolanic activity of nano SiO_2 consumes CH and produces secondary CSH,which increases the quality of concrete [10]. In 2020, Alhawat et al. [11] conducted studies on concrete with different amount of nano SiO_2, diverse surface area and various w/b ratio, which revealed that the optimum amount of these factors could improved performance of concrete. Tavakoli et al. [12] also examined the properties of concrete produced with waste clay brick, as substitute of sand, in combination with nano SiO_2. Their results showed that, although the samples including just waste clay brick cause decreasing the mechanical properties of concrete, the sample containing 25% clay brick with only 1% nano SiO_2 could improve the compressive strength of concrete to around at 16%. Furthermore, Qing et al. [13] investigated the use of nano SiO_2 in cement mortar and compared it with Silica fume. They reported that, while the effectiveness of nano SiO_2 starts from early age, that of Silica fume is in the long term. Thus, to enhance the short-term strength, nano SiO_2 was recommended. It has also been reported that the pozzolanic activity of nano SiO_2 is more than that of Silica fume. Nazari and Riahi [14] examined the mechanical, microstructural and thermal behavior of self compacting concrete, which contains SiO_2 nanoparticles. They concluded that an increase in the ratio of nanoparticles led to increase of resistance against abrasion for the cured samples, which are saturated in water or lime-saturated water. They also argued that this situation was not observed for compressive strength in curing bath. In another study by Heidari and Tavakoli [15], the simultaneous effect of ceramic waste pozzolan and nano SiO_2 was investigated. They revealed that concrete, which was mixed with various percent of waste ceramic alone caused a considerable decrease. As a result, the beneficial mixture was the one with optimum amount of nano SiO_2 and ceramic waste, which improved the concrete features. In their study, the rate of improvement in compressive strength was nearly 12% at 28-days aged, which is lower than our article. Moreover,the results of this study supported the improvement of compressive strength and also water absorption of concrete containing nano SiO_2. Additionally, in other study, they compared impact of nano SiO_2 and Silica fume. It was shown that the effectiveness of nano SiO_2 on strength properties was more than that of silica fume [9]. Gunasekara et al. [16] investigated the effect of nano SiO_2 on high volume fly ash (HVFA) hydrated lime blended concrete. They noticed that utilizing of HVFA with appropriate percent of nano SiO_2 can improved mechanical properties of the mixtures in compared with the control sample. Said et al. [17] examined the effect of colloid nano SiO_2 on concrete incorporating ordinary cement and fly ash. They noticed that nano SiO_2 expedite the hydration process which, in turn, played an important role in achievement of strength at early ages. However, the mixture containing 3 to 6% nano SiO_2 along with 30% fly ash improved mechanical proprties of concrete only a negligible amount compared to control sample. Long et al. [18] showed that suitable or unsuitable dispersion of nano SiO_2 in cement paste plays an important role in its performance. Excessive substitution of nano SiO_2 can cause the agglomeration of particles in cement paste and creates a weak point in concrete, which in turn, reduces the concrete strength. They also revealed that 1% substitution of nano SiO_2 can lead to the maximum compressive strength. They observed that any substitution more than 1% decreases the compressive strength. Serag [19] studied the mechanical properties of high performance concrete with the presence of macro polymer fiber and nano SiO_2. Their result showed that nano SiO_2 increased the splitting tensile strength due to the improvement of the bond between cement paste and aggregates. In another study by Heidari et al. [20] the influence of nano SiO_2 and metakaolin on concrete containing ceramic waste materials was examined. This study revealed that nano metakaolin has a better effect in comparison with SiO_2, wchich could improve the compressive strength of concrete. Also, another research regarded the simultaneous effect of waste materials and nano SiO_2 on roller compactor concrete. This study also indicated that nano SiO_2 improved the compressive strength, splitting tensile strength, water absorption, and abrasion resistance of the concrete [21]. Ltifi et al. [22] also investigated the effect of nano silica on early age and durability properties of cement mortars. The study uncovered that mechanical properties of all the samples had increased compared with the controlvsample. Nazari and Riahi [14] studied the substitution effect of 0 to 5% nano SiO_2 on compressive strength of high performance concrete. They reported that adding nano SiO_2 up to 4% lead to an increase of compressive strength and adding nano SiO_2 more than 4% led to a decrease of compressive strength, which was due to inappropriate dispersion of nano SiO_2 and lack of enough CH for pozzolanic activity. Amin and el-Hassan [23] compared the compressive strength of high performance concrete by using nano Ferrite and SiO_2 with different aggregates including crushed dolomite and granite instead of natural ones. The study unveiled that resistance improved by adding nano ferrite 17% and SiO_2.

Zhang et al. [24] found that concrete mixture containing 15% coal fly ash and 3% NS improved compressive strength nearly15.5%.

Moreover, many researchers have improved the structure of nanomaterials specially nano SiO_2 for using in industries. These studies have also made it possible to obtain new properties in these materials by synthesizing nanomaterial with different shapes, textures, and structures [7].

A new type of nanoparticles Silica (KCC-1), which has a large number of positive aspects, has found by previous researches. The substance has nummerous sinalon groups on the surface of KCC-1, which can carry surface molecules well [25]. On the other hand, nanosilver is widely utilized due to its distinguish features. Including being antibacterial and having several surface active points. Some these materials such as nano KCC-1/Ag have pores in wrinkled forms and special center-radial pore structures with their pore sizes gradually increasing from the center to the surface [26]. These walls, which have been dispersed steadily in three dimensions. This unique structure not only increases the specific surface, but also increases the possibility of access to active sites and pores. Nano KCC-1/Ag was developed by Ouyang et al. [26]. The porous walls of it has expanded in wrinkled form from the center of particles toward outside along with radius. This has created a unique and dandelion-like shape for it. These walls, which have been distributed steadily in three dimensions, have created open pores on the structure. This peerless shape not only increases the specific surface area but also increases the possibility of access to the pores and active sites of it that, in turn, improves the efficiency of it in various applications. Given these points, the use of this nanomaterial in concrete has been under scrutiny.

Nano KCC-1/Ag has been employed in different industries [27]. It has been investigated that KCC-1 is definitely functional substance for producing new materials. For instance, it has high surface area, which could establish numerous connection with other particles, like Ag. In addition to this with regard to economy, the cost of Ag is relatively economic compare to other pricey metals, Such as Au and Pd [28].

Different studies have confirmed the high activity and performance of this material in comparison with nano SiO_2 [26]. However, no study has ever dealt with its application in construction materials such as cement and concrete. This study, aims to address such a gap by studying on the effect of nano KCC-1/Ag on concrete and comparing its effect with that of nano SiO_2. To do this, first, nano KCC-1/Ag and nano SiO_2 were synthesized and then replaced the cement of concrete in 1 to 3% of cement weight. Next, the identification tests such as compressive and splitting tensile strengths were implemented and obtained results were reported.

2. MATREIALS AND METHOD

2. 1. Materials

2. 1. 1. Cement ASTM type II cement was used in this study (Zaveh Torbat Company). Physical and chemical properties of this cement is summarized in Table 1.

2. 1. 2. Aggregates Aggregates were obtained from rock limestone aggregates from Neyshabur mine. All aggregate properties were in accordance with ASTM C33 standard. The physical properties of the aggregate are listed in Table 2.

2. 1. 3. Water In this study, Neyshabur drinking water has been used. The values of chloride, sulfate and pH of the solution are 25 mg/l, 17 m /l and 7, respectively.

2. 1. 4. Superplasticizer Due to the high water absorption of nanomaterials in this study, a suitable superplasticizer was used to maintain the workability of concrete. The superplasticizer is branded Glenium 55p and is based on polycarboxylate. The specifications of this superplasticizer are stated in Table 3.

2. 1. 5. Synthesis of Nano SiO_2 Nano SiO_2 used in this study was extracted via synthesis operation. To synthesize it, 2 ml of tetraethyl orthosilicate was mixed

TABLE 1. Properties of cement

Chemical Properties		Physical Properties	
% SiO_2	20.92	Specific surface area (cm^2/g)	3425
% Al_2O_3	4.61	Sieve Residue 90 µm	0.28
% Fe_2O_3	4.16	Sieve Residue 45 µm	9.24
% CaO	62.10	% Autoclave Expansion	0.10
% MgO	2.75	Initial Setting Time (min)	155
% Na_2O	0.30	Final Setting Time (min)	205
% K_2O	0.59	Specific Gravity (g/cm^3)	3.18
% SO_3	2.20	Free CaO	1.04
% LSF	94.24	3-day Compressive Strength	315
% CL	0.017	7-day Compressive Strength	386
% LOI	1.50	28-day Compressive Strength	520

TABLE 2. Physical properties of aggregate

Property	Sand	Gravel
Density (kg/m^3)	2.58	2.64
Water Absorption (%)	2.12	1.01
Bulk Density (kg/m^3)	1710	1530
Los Angeles (%)	-	21.34

TABLE 3. Properties of the superplasticizer admixture

Aspect	Relative Density	pH	Chloride Ion Content
Dark brown free-flowing liquid	1.20±0.02 at 25 °C	6-7	< 0.2%

with 5 ml ethanol. Then, it was put on the Stirrer and was exposed at 60 °C for reflux operation.

After half an hour, 2 ml ammonium was added to the solution and the reflux process restarted for two hours. Finally, after separation of sediments from the liquid by centrifuge machine and drying particles at 60 centigrade degrees in the oven, nano SiO_2 was obtained. To examine the synthesized nano particles, FTIR was utilized.

2. 1. 6. Synthesis of Nano KCC-1/Ag To synthesize Nano-Kcc-1/Ag, first, 0.3 g of Urea along with 30 ml deionized water was poured in a balloon and then was placed in the ultrasonic device for one hour so that the two materials would be mixed thoroughly. The ultrasonic device makes magnetic impacts in the nano scale and can mix the two particles completely. In the next stage, 0.5 g trimethyl hexadecyl ammonium bromide was combined with 0.75 ml 1-pentanol and 30 ml cyclohexane. Then, this mixture was added to the previous solution after one hour (solution 1). Then, 1.35 ml tetraethyl orthosilicate was added to the mixture of urea and deionized water and this new mixture was placed in the ultrasonic device once more (solution 2). Altogether , the mixture(solutions 1 and 2) was put into the stirrer device for reflux operation for two hours. The rotation speed of reflux was on 5 mod and the operation started at 120 °C for 5 hours. After 5 hours, the sedimentation was obtained. The precipitates washed and centrifuged several times. At the end, The sediments was put into the oven at 60 °C to dry to obtain KCC-1 nanoparticle. For increasing the density of dandelion branches and the specific surface of nano-KCC-1, silver cover was used. After preparation of nano-KCC-1, some experiment was done to place silver nitrate nanoparticles on it. For that, $AgNO_3$ was used. In this substance, nitrate was removed through a chemical process and only silver remains. To put silver on nano-KCC-1, 0.5 g nano-KCC-1 was mixed with 0.14 ml (3- aminopropyl) trimethoxysilane and 100 ml toluene and 0.1 g $AgNO_3$. Then, the mixture was stirrered at 45 °C for the reflux operation. The reflux was done in an environment incorporating nitrogen gas so that intended activities would be done ideally. After 12 hours, the sedimentation was obtained completely. In the next stage, the sedimentation separated from the solution by centrifugation. It should be pointed out that KCC-1 nanoparticles were in suspension and were changed to finer particles in the reflux process. After the separation stage, the sedimentation were put into an oven to dry at 60 °C. Finally, KCC-1/Ag nanoparticle was resulted.

2. 1. 7. Tests Compressive strength of samples based on BS 1881 standard and their splitting tensile strength based on ASTM C496 standard at 7, 28, and 90 days were estimated. Perkin-Elmer FTIR with resolution of 4 cm^{-1} in 64 scan mode was used to check the bending bands vibrational stretching. Moreover, to examine the nanomaterials structure with TEM, Philips CM10 at 100 KV was utilized. Finally, SEM was employed to study the microstructure of concrete and nanomaterials. The SEM image was given to confirm the formation of nano SiO_2 and KCC-1/Ag nanoparticles. Figure 1 represents the SEM image of synthesized nano SiO_2. As we can see, the produced nano SiO_2 has a steady and consistent structure with particles diameter of almost 40 nm. In Figure 2, apparently reveal the formation of the KCC-1/Ag nano material. As it is clear, the particles have a steady distribution and a dandelion sophere-shape. To compare, the KCC-1/Ag nanoparticles have steadier and denser structure than SiO_2 nanopaticles. Moreover, for higher resolution TEM image was taken as is shown in Figure 3. TEM image illustrates the Dandelion-shaped structure, which could provide a high amount of bonds because of so many branches. To know better about the performance of nano KCC-1/Ag, some tests were implemented on concrete microstructure. Since the

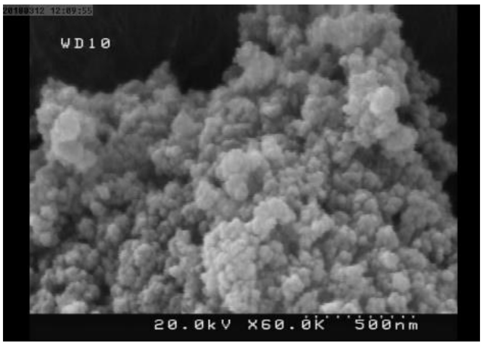

Figure 1. SEM image of nano SiO_2 ,at 500nm resolution

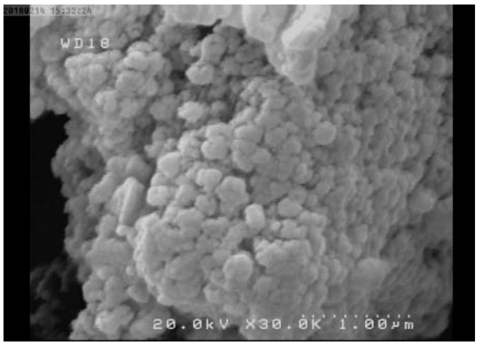

Figure 2. SEM image of nano KCC-1/Ag, at 1 µm resolution

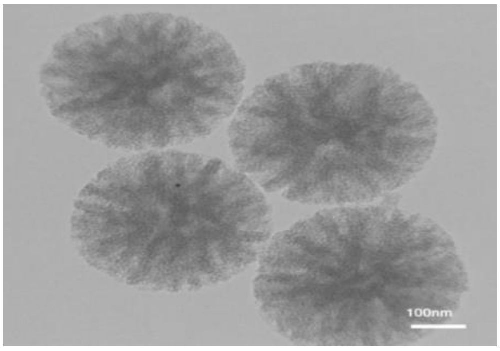

Figure 3. TEM image of nano KCC-1/Ag, at 100 nm resolution

optimal percentage was determined to be 2%, the identification tests of microstructure were done on the samples incorporating 2% nanomaterials at 28 days of age.

2. 2. Method In this study, nanomaterials replaced cement in 1, 2, and 3 percent. Moreover, seven mix designs with nano SiO_2 (CN), 3 ones with replacement of nano KCC-1A/g (CK), and one mix as the control sample (C) were prepared. Table 4 presents the mix designs.

For each mix design, 18 samples including 9 cylinder ones (30×15) and 9 cubic ones (10cm×10cm×10cm) were made. All the three ones were used to determine strength at one of the ages of 7, 28, and 90 days. Samples were created based on ASTMC42 standard and they were then cured in lime saturated water pool at 23±2 °C. It should be pointed out that given the high specific surface area of nanomaterials, the selected nanomaterial was mixed with part of the mix water using a stirrer at 120 RPM so that the agglomeration of materials in concrete would be hindered. In addition, in light of the high water absorption of nanomaterials and slump reduction of concrete, a superplasticizer was added to mixes.

3. RESULTS AND DISCUSSION

3. 1. Comperessive and Splitting Tensile Strengths Figure 4 represents compressive strength results at 7, 28, and 90 days. The compressive strength obtained in this study for 7 days was between

TABLE 4. Mix designs

Mix Name	Constituents (kg/m³)						
	Gravel	Sand	Water	Cement	Nano KCC-1/Ag	Nano SiO_2	Water reducer
C	525	1226	195	425	-	-	-
CN1	525	1226	195	420.75	-	4.25	2.5
CN2	525	1226	195	417	-	8.5	3.3
CN3	525	1226	195	412.25	-	12.75	4.3
CK1	525	1226	195	420.75	4.25	-	2.5
CK2	525	1226	195	417	8.5	-	3.3
CK3	525	1226	195	412.25	12.75	-	4.3

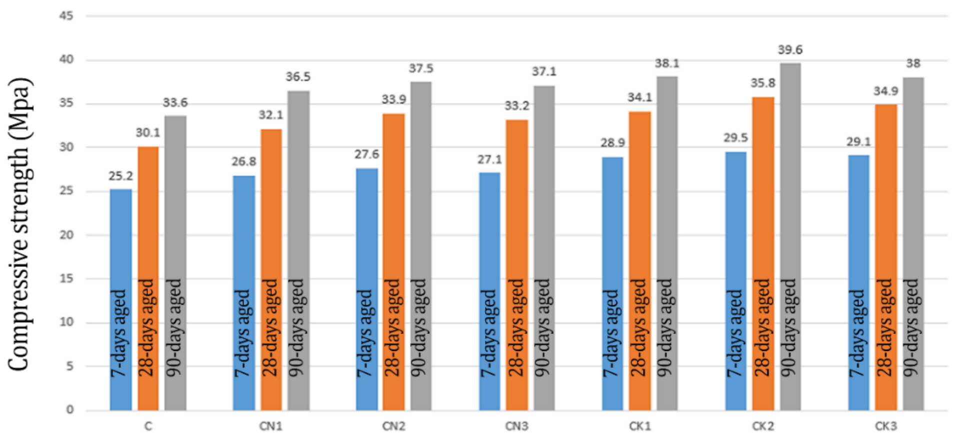

Figure 4. Compressive strength of mixes C: control sample, CN: (samples containing 1,2 and 3% nano SiO_2), CK: (samples containing1,2 and 3% nano KCC-1/Ag)

25.2MPa and 29.5MPa; for 28 days was between 30.1MPa and 35.8MPa; and for the 90 days was between 33.6MPa and 39.6MPa.

These results indicate that adding nano SiO_2 and nano KCC-1/Ag increased the compressive strength of concrete in all ages. However, this increase was more for nano KCC-1/Ag. Thus, this material had a better performance in comparison with nano SiO_2.

The highest increase of strength was observed in the sample incorporating 2% of nano KCC-1/Ag at 90 days (39.6 MP). The strength increased at 90 days for CN1, CN2, CN3, CK1, CK2, and CK3 in comparison with the control sample was 8.63%, 11.60%, 10.41%, 13.39%, 17.85%, and 13.09%, respectively. The same increase in nano SiO_2 samples was also reported in the previous studies. The reason for this increase is related to the pozzolanic activity of these materials as well as their filling effects. They can improve the microstructure of cement paste through their reaction with CH and production of secondary CSH. Because the compressive strength of samples containing 3% of nano SiO_2 and nano KCC-1/Ag showed a little reduction of strength compared with the ones with 2%, it can be concluded that the optimal percentage is 2%. This can be attributed to some reasons. First, adding high amount of nanomaterial causes CH to be used completely in hydration products. Thus, the extra nanomaterial remains in concrete as an inactive substance which, in turn, triggers defects and inconsistency in concrete. On the other hand, the high amount of nano material cannot be mixed in concrete very well (due to its high specific surface area) and some of the material may remain as agglomerate. This can damage the consistency of concrete.

Furthermore, the high water absorption of nanomaterial can create small cracks in concrete and negatively affect its strength. In samples with 2% of nano SiO_2, the increase rate of strength at 7, 28, and 90 days of age, in comparison with the control sample, was 6.34, 12.62%, and 11.60% respectively. This shows the suitable performance of nano SiO_2 at 28 days of age. In some previous studies, the suitable performance of nano SiO_2 was reported to be at 7 days of age. This might be due to the smaller size of nano SiO_2 and its higher specific surface area in those studies.

In addition, for the sample with 2% of nano KCC-1/Ag, the increase of strength at 7, 28, and 90 days of age was 17.06%, 18.93%, and 17.85%, respectively. In these samples, the best performance was also related to the age of 28 days. In comparison with Tavakoli et al. [12] paper,which investigated in the effect of adding waste clay brick and nano SiO_2 to concrete mixtures, our result is higher. In fact, they figured out that the sample containing 25% waste clay brick and only 1% nano SiO_2 could correct the compressive strength of concrete approximately 16%. In other works, Heidari et al. [15] studied the properties of concrete, which included ground ceramic powder and nano SiO_2. Their study indicated that, the samples containing only waste ceramic decreased the mechanical properties, while the sample including 10% waste ceramic and 1% nanoSiO_2 could increase the strength around 12% in comparison with control sample, which is fewer than our result.

Moreover, Heidari et al. [20] in another paper found that the concrete sample containing nano metakaolin have better influene on concrete strengths rather than the one containing nano SiO_2. However, the improvemen of ratio in comparison with our study is quite negligible.

Zhang et al. [24] showed that the concrete mixture containing 15% coal fly ash and only 3% nano SiO_2 improved compressive strength at around 15.5%.

The compressive strength of the 90 days sample containing 2% nano KCC-1/Ag in comparison with the same sample containing 2% of nano SiO_2 showed an almost 5.6% increase of strength.

In general, the samples with nano KCC-1/Ag performed better than those with nano SiO_2 and this was due to their higher contact surface because of their dandelion structure. Higher contact level leads to more activity and better dispersion of the cement paste microstructure. This can affect all properties of concrete positively.

Figure 5 shows the results pertaining to splitting tensile strength. This strength in samples of 7 days was from 2.21MPa to 2.58MPa; for those of 28 days was from 3.13MPa to 3.67MPa; and for those of 90 days was 3.52MPa to 4.12MPa. The highest splitting tensile strength was observed in the sample with CK2.

This increase of splitting tensile strength at 90 days for CN1, CN2, CN3, CK1, CK2, and CK3 in comparison with the control sample was 9.37%, 12.21%, 11.07%, 10.51%, 17.04%, and 13.92%, respectively. The trend of splitting tensile strength is the same of that for compressive strength. Moreover, Fallah et al. [29] tested the splitting tensile strength of nano-SiO_2 concrete. When 3% nano-SiO_2 replaced cement, the tensile strength of Nanosilica modified concrete was improved by 16% than that of ordinary concrete. While in our study the strengthening effect of adding nano KCC-1/Ag on the splitting tensile strength of concrete was 17.04%. Therefore, it proves that KCC-1/Ag is more effective than nano SiO_2. Moreover, Tavakoli et al. [21] investigated in effect of waste concrete and glass along with nano SiO_2 in roller-compacted concrete. They noticed that splitting tensile strength of the concrete, which contains 40% glass and 0.7% nano silica, increased around 12.67%. while the mixture, containing 40% waste concrete and 0.7% nano silica was approximately equal to that of control sample.

In the samples with nanomaterials, an increase of splitting tensile strength was observed compared with

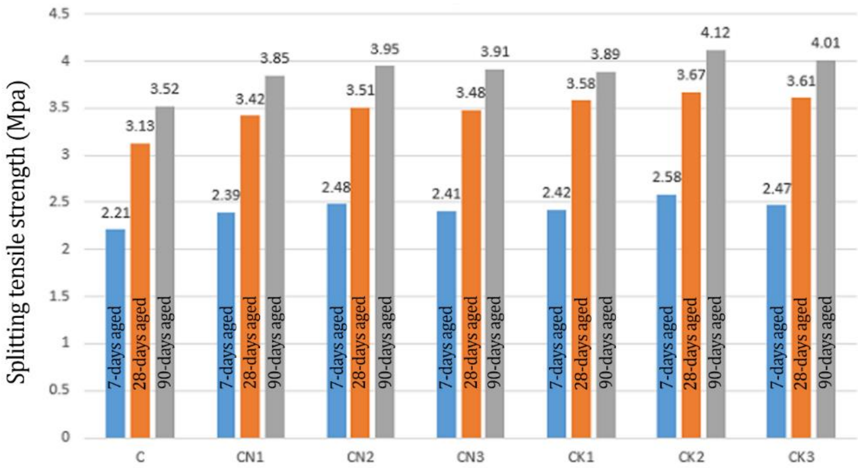

Figure 5. Splitting tensile strength of mixes C: control sample, CN: (samples containing 1,2 and 3% nano SiO_2), CK: (samples containing 1,2 and 3% nano KCC-1/Ag)

3. 2. SEM Image Analysis To examine the effect of nanomaterials on concrete, SEM was used. Figure 6 shows the images prepared from control samples with 2% of nano SiO_2 and 2% of nano KCC-1/Ag. As the photos show, in the control sample, porosity is easily observable.

Adding nanomaterials to concrete and implementation of pozzolanic activity leads to the production of secondary C-S-H and also more reduction in concrete pores. These, in turn, make the concrete structure denser, more steady, and with a higher quality. Comparing the samples with nano SiO_2 and nano KCC-1/Ag, it is noticed that the sample with nano KCC-1/Ag could produce a denser cement paste largely due to its higher activity. As Ouyang et al. [26] obtained the same structure in their research.

Consistency in concrete structure and reduction in pores in comparison with the sample containing nano SiO_2 is clearly observable in this sample. Using nano KCC-1/Ag made the concrete structure denser and as a result, pores, CH, and ettringite are not visible in the photo. In the figure, in fact, we can clearly observe the high activity of nano KCC-1/Ag and the reason for strength increase in samples incorporating nano KCC-1/Ag.

3. 3. FTIR Image Analysis Figure 7 shows a comparison of the three spectra of samples (a) of the control sample without nanoparticles (b) of the sample with SiO_2 nanoparticles and (c) of the sample with nanoparticles of KCC1 / Ag**.**

Figure 7(a, b and c) shows similar indexes for cement matrices as well. The pertinent peak is at 1425cm^{-1} limit and small ones between 800 and 790cm^{-1} are related to carbonate bonds. Bands related to the spectrum between 3434- 3430cm^{-1} are also connected with the hydrogen bond of OH in molecular and chemical water. Furthermore, the peak at 1090cm^{-1} limit belongs to the sulfate bonds in cement paste. But the most important peak that is related to hydrated silicate happens at almost 1000cm^{-1}.

As the Figure 7 indicate, the peak at 3640cm^{-1} related to C-S-H is sharper and more severe in samples with nano KCC-1/Ag and nano SiO_2.

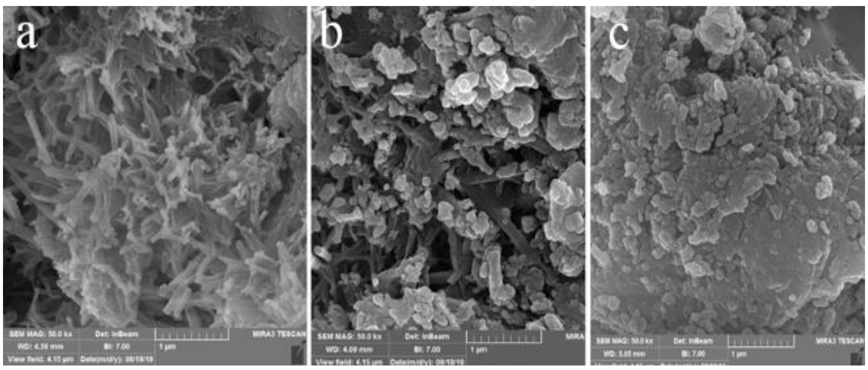

Figure 6. SEM: (a) Control concrete sample (b) nano SiO_2 concrete sample (c) nano KCC-1/Ag concrete sample

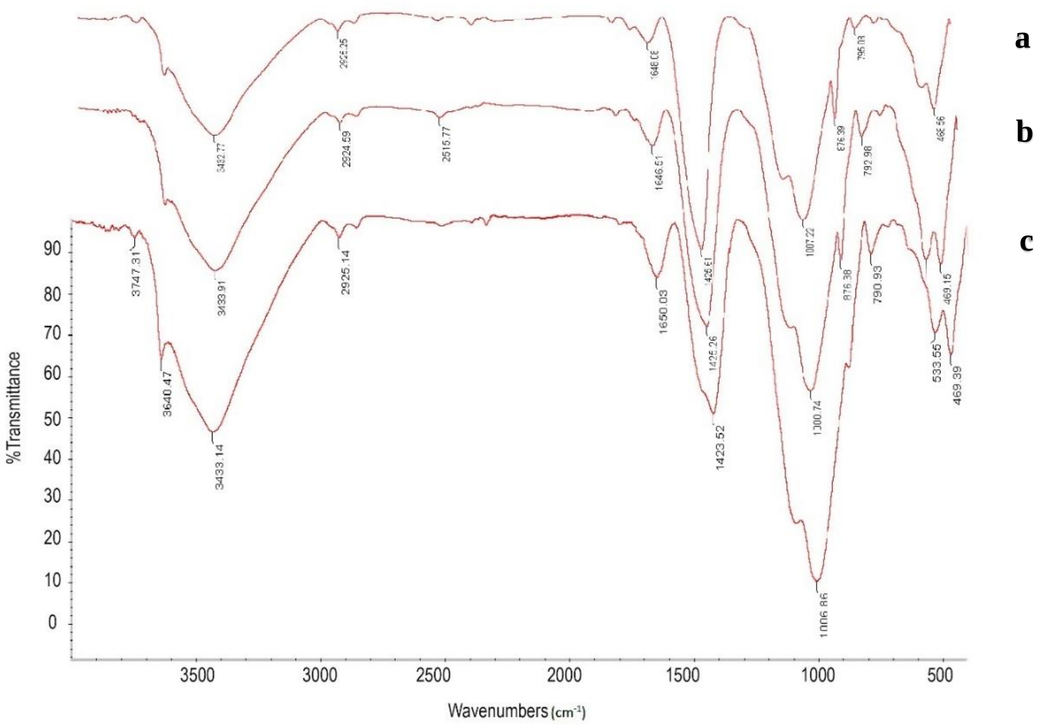

Figure 7. FTIR analysis: (a) Control concrete sample (b) nano SiO_2 concrete sample (c) nano KCC-1/Ag concrete sample

Additionally, the peak in the sample containing nano KCC-1/Ag is sharper than the peak in the sample containing nano SiO_2. This is related to the use of $Ca(OH)_2$ and its turn into C-S-H gel through the pozzolanic activity of nanomaterials in concrete. As it also observed, the C-S-H rate in samples with nano KCC-1/Ag is more than that in the samples with nano SiO_2 and also the control sample.

As it was already mentioned, more production of secondary C-S-H leads to the creation of a denser concrete and an increase of strength and other properties of concrete. This confirms the high activity of nano KCC-1/Ag and its desirable performance in concrete. No significant difference was observed in other peaks.

Additionally, the peak between 790-793cm^{-1} indicates the formation of Si-O-Si bond and the peak at 469cm^{-1} is related to the splitting tensile vibration of Si-O. The resulted spectrum is in line with that the previously conducted studies. This, in fact, confirms the accuracy and correctness of synthesis process [20].

4. CONCLUSION

While there are various researches about nano SiO_2 and KCC-1/Ag, this article has investigated the effects of them in concrete and compared them. To achieve this, nano KCC-1/Ag and nano SiO_2 were used as a cement replacement with 1 to 3 percent, then the compressive strength, splitting tensile strength, and the microstructure of concrete were examined.

The results uncovered that:

- Both Nano SiO_2 and nano KCC-1/Ag enhanced the microstructure of concrete as they can reduce the porosity and defects of concrete. However, the performance of nano KCC-1/Ag was better than that of nano SiO_2 largely due to its high activity and also its dandelion-like structure.
- In general, the Pozzolanic activity of nano KCC-1/Ag was more than that of nano SiO_2. The KCC-1/Ag nanoparticles increased the concrete compressive and splitting tensile strengths at 7 and 90-day of age. Also, an increase of compressive strength by 19% compared to the control sample was reported. This amount of increase was more than that of nano SiO_2. Hence, this material has a better performance in concrete compared with nano SiO_2.
- Observations of SEM images indicate the high activity of nano KCC-1/Ag. Denser and more steady structure of the samples containing nano KCC-1/Ag is apparent when compared with the control sample and the one containing nano SiO_2.
- The obtained optimal percentage for using nano KCC-1/Ag in concrete was 2% of replacement. Higher percentages showed weaker performance.

- Since one of the main positive aspects of KCC-1/Ag nanoparticles is being antibacterial, it could use mostly in medical buildings.
- In compare with other pricey metals, Ag is nearly economic to use in construction industry.
- Due to having dandelion-shape, KCC-1/Ag nanoparticles are able to establish numerous connection, wchich result better density in mixtures.

Given these findings related to nano KCC-1/Ag and its high activity in concrete, it may be contended that the use of this material in concrete is desirable and further studies need to be conducted in this regard.

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Persian Abstract

چکیده

اثر نانو KCC-1/Ag و مقایسه آن با نانو SiO_2 در بتن در این مطالعه بررسی شده است. برای این منظور ابتدا نانو KCC-1/Ag و نانو SiO_2 در آزمایشگاه سنتز شده و سپس تست‌های شناسایی مانند FTIR، SEM و TEM بر روی نمونه‌های سنتز شده اجرا شده اند. پس از آن، این مواد به عنوان جایگزین سیمان در مقادیر ۱، ۲ و ۳ درصد استفاده گردیده است. مقاومت فشاری، مقاومت کششی شکست، FTIR و SEM بر روی نمونه‌ها انجام شده تا اثربخشی نانو KCC-1/Ag و نانو SiO_2 بر خواص بتن بررسی شود. نتایج نشان داد که نانو SiO_2 و نانو KCC-1/Ag هر دو ریزساختار خمیر سیمان را بهبود بخشیدند و مقاومت کششی فشاری و کششی بتن را افزایش دادند. با مقایسه عملکرد نانو KCC-1/Ag و نانو SiO_2، نتایج به‌دست‌آمده نشان داد که نانو KCC-1/Ag ریزساختار بتن را بهتر از نانو SiO_2 بهبود می‌بخشد. از این رو عملکرد بهتری در افزایش مقاومت بتن دارد. این مطالعه نشان داد که درصد بهینه استفاده از نانو KCC-1/Ag ۲درصد است.