

## Research Article

# Application and Microstructure Properties of Nanomaterials in New Concrete Materials

Jialu Zhang <sup>1,2</sup>, Cheng Shen,<sup>3</sup> and Guangfen Diao<sup>1,4</sup>

<sup>1</sup>Nanjing Forestry University, Nanjing, 210000 Jiangsu, China

<sup>2</sup>Nanjing Jiangbei New Area Railway Construction Investment Co., Ltd, Nanjing, 210000 Jiangsu, China

<sup>3</sup>Jiangsu Testing Center for Quality of Construction Engineering Co., Ltd, Nanjing, 210000 Jiangsu, China

<sup>4</sup>Nantong Jiarun Holding Group Co., Ltd, Nantong, 226311 Jiangsu, China

Correspondence should be addressed to Jialu Zhang; [gracezhang@njfu.edu.cn](mailto:gracezhang@njfu.edu.cn)

Received 9 March 2022; Revised 26 April 2022; Accepted 7 May 2022; Published 29 May 2022

Academic Editor: Awais Ahmed

Copyright © 2022 Jialu Zhang et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

This article takes the application of nanomaterials in new concrete materials as the research object and explores the defects of nanomaterials in improving the toughness and tensile capacity of traditional concrete by analyzing the effects of nanomaterials on the structure and properties of new concrete. This article takes the application of nano-SiO<sub>2</sub> in new concrete materials as an example. Firstly, the experiment of preparing nanoconcrete was carried out, and then, aiming at the experimental results, a detailed analysis and discussion on the effects of nano-SiO<sub>2</sub> on the shrinkage, mechanical properties, and microstructure of the new concrete materials were carried out. The research results show that the cement paste with nano-SiO<sub>2</sub> is much better in chemical shrinkage than the cement paste without admixture, and the chemical shrinkage value of the cement paste with nano-SiO<sub>2</sub> increases significantly in the early setting stage. The chemical shrinkage values are 11.4%, 26.7%, 53.9%, and 94.2%, respectively, according to the amount of nano-SiO<sub>2</sub> added. With the extension of the setting period, the growth rate of the shrinkage value of cement paste slows down; nano-SiO<sub>2</sub> can improve the compressive capacity and strength of concrete, and with the increase of the amount of compressive strength, the value of compressive strength is also increasing. In the early stage of coagulation, when the nano-SiO<sub>2</sub> dosage is 1.6%, the compressive strength of the coagulation for 3 days is 39.02%. With the prolongation of the setting period, the increase in compressive strength continues to increase, but the growth rate slows down; the addition of nano-SiO<sub>2</sub> has changed the microstructure of concrete. Nano-SiO<sub>2</sub> has high pozzolanic activity, which can promote the hydration process of cement, and because of the small particles, it can fill the voids of concrete, thereby improving its compactness and mechanical strength.

## 1. Introduction

**1.1. Background and Significance.** In recent years, with the rapid development of the social economy, the process of industrialization and urbanization has also been accelerating, which is manifested in the construction and improvement of various infrastructures. Concrete, as the most widely used construction material in the construction industry, has also been used in the largest amount. In recent years, its demand has also increased exponentially. However, due to the problems of insufficient toughness and tensile resistance caused by the components of concrete materials, many projects have collapsed and damaged, which has a major

impact on casualties and property losses. Seeking new building materials and improving the quality of building materials are the demands of many parties.

Nanomaterials were born in the 1960s and have been widely used since the 21st century. For example, it has played a huge application value in medical, chemical, electronic industry, and biochemical fields. It is a new type of material with excellent physical and chemical properties, which is different from the atomic and molecular characteristics of microscopic particles and different from macroscopic objects. Nanomaterials are mesoscopic structural materials with singular characteristics [1]. Because of their small size, they exhibit strange properties that neither

microscopic particles nor macroscopic objects possess. The development of nanomaterial technology is a revolution in the history of materials science and construction engineering [2]. Its unique properties of light, electricity, heat, and magnetism have had a huge impact on the development of the construction industry and civil engineering. Adding nanomaterial into traditional concrete and other building materials to change the composition structure of traditional concrete can greatly improve the mechanical properties and durability of new concrete, thereby improving its toughness and tensile capacity [3].

*1.2. Related Work.* Since the advent of nanomaterials in the 1960s, more and more experts and scholars have paid attention to it due to its special properties. Huang and Lovell pointed out that nanomaterials have been widely used as reagents for therapeutic and diagnostic (therapeutic) applications. They note that research efforts in nanomaterials have changed beyond the *in vitro* investigation of emerging substances to the conception of substances that work on more contextually relevant patterns of animal disorders, thus multiplying the opportunity for therapeutic clinical conversion. Common categories of nanoscale biomaterials, consisting of magneto nanoparticles as well as volume particles, upswitched granules, dielectric silica granules, charcoal-based granules, and organochromatic dye-based granules, exhibit the diagnostic and therapy applications of biomaterials. Changes like dimensional manipulation and process surface modification allow for regulation of ecological compatibility and interaction from the intended organization. Demands for better treatment for testing disorders and intensified chemical therapies, as well as practical thoughts on the need for climatologically scalable nanomaterials, are set to be crucial drivers [4]. Xiangzhen et al. have also stated that temporary structural failures frequently occur in dynamic tension (e.g., spalling) when reinforced structures are loaded by detonating and impact velocity charges. The precise forecast of structural failure due to static forces is known to be a competitive issue. In their study, they suggest a nonlocal damage-dependent modelling to forecast temporary elastic failure of specific concrete material building on the relatively recently developed localized porous square product model. In this nonlocal pattern, the interference fields diminish as the extent of insolation grows, and this results in an ideal characterization of the total damage area and the free surface localization, i.e., the lack of localization disappears in such areas. The statistical illustrations of one-dimensional peel tests and two-dimensional dynamic tension tests on concrete slabs show that a less damage-dependent nonlocal model can address the full range of restrictions of the primal nonlocal market. A general model predicated on nonlocal injuries was then validated on the basis of two experiments, the divided Hopkinson extension lever test and the adapted divided Hopkinson lever (scattered) trial. Mathematical demonstrations indicate that the suggested nonlocal induction model can provide a sensible estimate of the location of mechanical dynamic tension failure. However, the topographic example does not properly forecast dynamic tension failure, while the primitive nonto-

pographic model does not forecast several cracks at high load rates [5]. The advantages of nanomaterials in construction have only emerged in recent years. Therefore, there is not much research on nanomaterials in the construction industry. Based on this, it is very meaningful to study the application of nanomaterials in new concrete materials.

*1.3. Innovation in This Article.* The innovations in this article are mainly reflected in the following aspects: (1) It is proposed to apply nanomaterials to new types of concrete. The excellent properties of nanomaterials can effectively improve the defects of traditional concrete toughness, tensile strength, compression, and insufficient durability. (2) Take nano-SiO<sub>2</sub> as an example through experiments to specifically explore the influence of nanomaterials on the performance and structure of concrete, turn abstraction into concrete, and make the article easy to understand. The article provides a suggestion for optimization and improvement of concrete materials in the construction industry and can also provide new ideas for the research of nanomaterials.

## 2. Nanomaterial and Their Application in New Concrete Materials

*2.1. Nanomaterials.* Nanomaterials are a new and hot new material science in the past two years and have received extensive attention and research from all walks of life since its inception. It refers to a material that is at least one-dimensional in the three-dimensional space at the nanometer level. Because of its small size, it exhibits singular characteristics that are very different from the atoms and molecules of microscopic particles and macroscopic objects. The form of particles between microscopic atoms and macroscopic individuals. The size of nanomaterials is in the range of 1-100 nm, which is equivalent to the scale of 10-1000 atoms closely packed together [6, 7].

*2.1.1. Characteristics and Effects of Nanomaterials.* Nanomaterial particles are small and larger than the surface volume. When the diameter of the nanoparticle is 10 nanometers, the body of the nanoparticle contains more than 4000 atoms, and the atoms on the surface account for 40%; when the diameter of the particle drops to 1 nanometer, the particle body contains 30 atoms, and the body surface atoms will account for 99%, which means that almost all the atoms are concentrated on the surface of the particle [8, 9]. The number of atoms on the surface of the nanoparticles and the total number of atoms increase dramatically with the reduction of the diameter of the nanoparticles. This strange characteristic has led to the nanomaterials having many special properties that are not available in general materials, manifested in various effects, as follows:

*First: surface and interface effects.* The so-called surface and interface effects are manifested in the phenomenon that the number and total number of surface atoms of nanomaterial particles will increase sharply and violently as the diameter of nanoparticles becomes smaller. When the diameter of the nanoparticle is 10 nanometers, the number of atoms on the surface of the particle will occupy 40%, and as the

diameter of the particle continues to decrease, the percentage of its surface atoms will increase significantly; when the diameter of the nanoparticle continues to decrease to about 1 nanometer, the percentage of atoms on the surface will increase to more than 90%, and then, all the atoms contained in the particles will be concentrated on the surface. Due to the violent increase in the number of surface atoms, particles will have extremely high surface energy, easily combine with other atoms, and will have high stability and chemical activity [10].

*Second: small size effect.* The external morphology of nanomaterials is a tiny crystalline particle. In terms of individual particle morphology, nanomaterials are similar to atoms and molecules in the microscopic world, but from the surface of the entire nanomaterial, it has the ability to be compared with macroscopic objects. It has a huge body surface area. Therefore, nanomaterial is a kind of special material body which is different from microscopic particles and macroscopic individuals. For ultrafine particles such as nanomaterials, the size becomes smaller and the body surface area increases, which produces various peculiar properties and also significantly improves its strength, toughness, and hardness, showing greater than other materials. The advantages are reflected in its acoustic, optical, electrical, thermal, and magnetic properties. For example, the combination of nanomaterials and metal materials makes the nanometals much harder than normal normal metals; the combination of calcium fluoride and nanomaterials can bend flexibly at room temperature without breaking, etc. [11, 12].

*Third: quantum size effect.* When a nanomaterial with a large specific surface area is split into discrete energy levels from the continuous energy band, the spacing between energy levels will increase as the particle size decreases. When the spacing between energy levels is greater than thermal energy, electrical energy, or magnetic field energy, nanomaterial particles will produce a series of anomalous properties that are different from macroscopic and microscopic particles, that is, the quantum size effect of nanomaterials [13].

*Fourth: macro quantum tunnel effect.* The ability of microscopic particles to penetrate the barrier is called tunneling. And for ultrafine particles such as nanomaterials, due to their special magnetization, it also has this kind of tunneling effect. The ability of nanomaterials to penetrate the barriers of the macroscopic system but change their own special properties is called the macroscopic quantum tunneling effect of nanoparticles [14].

*Fifth: volume effect.* The volume of nanomaterial particles is very small, and the number of atoms contained in the body is very small. Therefore, it is impossible to describe many phenomena with the mass of infinite atoms. This is the volume effect of nanomaterials [15].

**2.1.2. Classification of Nanomaterials.** With the deepening of research, nanomaterials are now mainly divided into the following categories:

*First: nanoceramics.* Nanoceramics use nanotechnology to incorporate nanopowder into ordinary engineering

ceramics to change the properties of ordinary ceramic materials, so that the finished ceramic products have higher flexibility, hardness, and strength and overcome the problems of traditional ceramics that are brittle and fragile [16, 17].

*Second: nanopowder.* Nanopowder refers to powder or particles with a diameter of less than 100 nm and is a solid particulate material between microscopic particles and macroscopic objects.

*Third: nanofibers.* Nanofiber is a linear material with a diameter between 1 and 100 nm and a long length. It is mainly used for the manufacture of components of quantum computers and photonic computers in the future.

*Fourth: nanofilm.* Nanofilm is divided into granular film and dense film. A particle film is a thin film that sticks to nanoparticles with a small gap in the middle; a dense film refers to a film with a tight film layer and a particle size of nanometers.

*Fifth: nanoblock.* Nanoblocks are nanocrystalline materials that are shaped by nanopowder by high pressure or crystallized by metal liquid. It is mainly used for ultrahigh strength materials and smart metal materials [18, 19].

**2.2. New Concrete Materials.** It is the most widely used and most used building material in the construction industry. The traditional concrete is mainly made of cement, with the addition of aggregates such as water, stones, and sand. If necessary, chemical admixtures and mineral admixtures (such as fly ash and mineral powder) are added, and they are evenly distributed according to the appropriate ratio. The condensed artificial stone made of agitation is a basic building material. For a long time in the past, concrete has been used for the construction of housing infrastructure projects due to its fire resistance, compression resistance, and extremely convenient characteristics in production and use. It has also been used to this day. However, with the development of social technology and the continuous improvement of people's requirements for the quality of building materials, some problems of traditional concrete, such as poor toughness and weak tensile capacity, have gradually been exposed. Traditional concrete can no longer meet the needs of the current society. Looking for new energy materials or new technologies to improve the performance of traditional concrete has become an important research direction in the construction industry and civil engineering and other fields [20, 21].

New concrete is based on traditional concrete materials using modern technological means or adding new material energy, so that the structural composition and performance of traditional concrete can be changed, and its aspects such as toughness, tensile strength, mechanical properties, and durability are improved. Performance of an improved building material [22]: compared with traditional concrete, the new type of concrete shows more powerful performance advantages. At present, new concrete is mainly made of nanotechnology and nanomaterials to improve traditional concrete [23].

**2.3. Application of Nanomaterials in New Concrete Materials.** Due to its small particle size and large body

surface area, nanomaterials can show strong hardness, strength, and toughness when combined with other atoms. The combination of concrete and nanomaterials can well solve its lack of toughness and tensile strength problem. As mentioned earlier, there are different classifications of nanomaterials, and nanomaterials used in concrete materials are also diverse. The main applications are mainly the following:

*First: the application of nanometer ore powder in new concrete materials.* Nanomaterials have special properties such as surface and interface effects, small size effects, quantum size effects, macroscopic quantum tunneling effects, and volume effects. Therefore, when combined with other materials, they can give the combined materials different properties from traditional materials. The nanometer ore powder added to the new concrete mainly includes nanometer  $\text{SiO}_2$ , nanometer  $\text{CaCO}_3$ , and nanometer silicon powder. Using nanotechnology to add nanometer ore powder to the concrete makes its atomic structure into nanometer level, which can greatly improve the strength and hardness of the concrete, toughness, and durability [24].

*Second: the application of nanometal powder in new concrete.* Nanometal powder has the characteristics of high strength, high hardness, and good plasticity. At the same time, because of its surface effect and good activity, it can be added to concrete to produce functional electromagnetic shielding concrete. However, since there are many types of nanometal powders, to make the best electromagnetic shielding concrete, the appropriate nanometal nonpowder must be selected [25, 26].

*Third: the application of nanometal oxides in new concrete materials.* The use of nanometal oxides can make smart cement concrete, such as self-alarm devices. The addition of nanometal oxides can make the concrete have a strong conductive function. If a sensor made of nanometal oxides is inserted into the concrete, then the concrete will be able to realize the alarm and monitoring functions of the outside world [27, 28].

*Fourth: the application of nanocomposites in new concrete materials.* Nanocomposite is a new type of material developed based on the combination of basic nanomaterials and other materials. Adding nanocomposites to concrete can not only improve the compressive strength, tensile strength, and ductility of concrete but also improve durability of concrete [29, 30].

### 3. Preparation Experiment of Nanoconcrete

Nanomaterials are widely used in new concrete materials. Based on the different types of nanomaterials, the nanoadditives mixed in concrete materials are also different, and different nanoadditives have shown to improve the performance of concrete materials. In order to specifically analyze the improved performance of nanomaterials on concrete properties, this paper selected nano- $\text{SiO}_2$  as a nanoadditive added to new concrete materials for experimental research.

*3.1. Experimental Object and Purpose.* In this experiment, the application of nano- $\text{SiO}_2$  in new concrete materials was

taken as the research object and theme of the experiment, and the purpose was to explore the effects of nano- $\text{SiO}_2$  on the shrinkage performance, mechanical properties, internal structure, durability, and other aspects of the new concrete materials.

#### 3.2. Raw Materials Used in the Experiment

*3.2.1. Cement.* Cement is the basic material of concrete, accounting for the largest proportion. The cement used in this experiment is ordinary Portland cement, and its main components and properties are shown in Tables 1 and 2.

*3.2.2. Aggregate.* The aggregate of concrete is composed of coarse aggregate and fine aggregate. The coarse aggregate used in this experiment is broken limestone, and the fine aggregate is siliceous natural river sand.

*3.2.3. Chemical Admixture.* The chemical admixture is added to improve the performance of the concrete and make it more suitable for the external service environment. Commonly used chemical admixtures are water reducing agents, which are divided into fatty acid salt series, naphthalene sulfonate series, melamine resin series, sulfamate series, and polycarboxylate series. The naphthalene sulfonic acid is used in this experiment. Water reducer, swelling agent, and UEA swelling agent are also used in this experiment.

*3.2.4. Mineral Admixture.* Whether the concrete has good tensile strength, durability and corrosion resistance has a decisive relationship with its mineral admixture. The performance of the mineral admixture can directly affect the performance of the concrete, so the mineral admixture added to the concrete is selected. Mixing is very important. The mineral admixtures used in this experiment are ore powder and fly ash, and their chemical composition is shown in Table 3.

*3.2.5. Nanomaterial.* The nanomaterial used in this experiment is nano- $\text{SiO}_2$  in nanoore powder. Its example diameter is between 6 and 50 nm, the specific surface area is  $250\text{ m}^2/\text{g}$ , and the purity is greater than 99%.

*3.2.6. Water.* It is general civilian tap water.

#### 3.3. Experimental Steps and Methods

*3.3.1. Measuring the Density and Specific Surface Area of Cement, Mineral Powder, and Fly Ash. Step 1.* Place the cement, ore powder, and fly ash samples in an oven to dry, and then, put them in a desiccator to cool to room temperature.

*Step 2.* Pour appropriate amount of anhydrous kerosene into the pycnometer, the volume is between 0 and 1 ml, then close the lid tightly and place it in a constant temperature water bath, and take out the recorded reading  $V_1$  after 20 minutes.

*Step 3.* Wipe the upper part of the pycnometer not in contact with kerosene, then pour 60g of cement, mineral powder, and fly ash samples, and use ultrasonic vibration until there are no more air bubbles in the bottle.



TABLE 1: Chemical composition of cement.

Chemical composition (%)	SiO <sub>2</sub>	CaO <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	MgO3	Fe <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>
Content	21.3	52.14	6.52	3.18	3.77	4.98

TABLE 2: Properties of cement.

Setting time		Stability	Compressive strength (MPa)		Flexural strength (MPa)	
Initial setting	Final setting	Qualified	4D	27D	4D	27D
2.5 h	3.5 h		25.7	50.0	5.5	8.7

TABLE 3: Chemical composition of mineral powder and fly ash.

Chemical composition (%)	SiO <sub>2</sub>	CaO <sub>3</sub>	Al <sub>2</sub> O <sub>3</sub>	MgO3	Fe <sub>2</sub> O <sub>3</sub>	SO <sub>3</sub>
Mineral powder	31.12	34.45	14.23	11.45	0.31	2.47
Fly ash	61.34	2.13	28.12	0.82	5.04	0.36

*Step 4.* Put the pycnometer in the constant temperature water bath again, read V<sub>2</sub> after 20 minutes, and then use formula (1) to calculate the density of cement, mineral powder, and fly ash.

$$\rho = \frac{P}{V_2 - V_1}, \quad (1)$$

where  $\rho$  stands for density,  $P$  stands for mass,  $V_1$  stands for the first reading, and  $V_2$  stands for the second reading.

*Step 5.* Use the density of cement, mineral powder, and fly ash calculated in the above steps and formula (2) to calculate the quality of the sample, and then, place the sample in the automatic specific surface area measuring instrument to measure the specific surface area, a total of three measurements. Then, go to the average.

$$W = \rho V(1 - \varepsilon), \quad (2)$$

where  $W$  represents the sample mass of cement, mineral powder, and fly ash,  $\rho$  represents the sample density,  $V$  represents the volume of the particle film layer, and  $\varepsilon$  represents the porosity of the film layer.

**3.3.2. Measuring the Packing Density and Porosity of Sand and Gravel.** *Step 1.* Take a 3 L sample of sand and stone in an oven and dry it; then, cool to room temperature.

*Step 2.* Remove the excessively large sand and gravel, and then, divide the rest into two parts of the same quality.

*Step 3.* Take one of them and put it into the volume cylinder twice before and after. Each time it is installed, a cylindrical steel pipe with a diameter of 10 mm is put into the cylinder to hit the ground. The steel pipe is perpendicular to the ground during the impact, about 20-25 hits.

*Step 4.* After the impact is completed, load another sample into the cylinder until it exceeds the mouth of the cylinder, and smooth the cylinder mouth with a ruler.

*Step 5.* Weigh the total weight of the sample and the volumetric cylinder to calculate the packing density and porosity of the gravel.

**3.3.3. Mixing Cement.** *Step 1.* Nano-SiO<sub>2</sub> is placed in water and dispersed with ultrasound for 5 minutes.

*Step 2.* Put cement, mineral powder, fly ash, and chemical admixture weighed according to a certain proportion into the pure paste mixing pot and stir slowly for 3 minutes.

*Step 3.* Put the ultrasonically treated nano-SiO<sub>2</sub> into the stirring pot, stir slowly for 1 minute and a half, then let it stand for 10 s, and then stir quickly for 1 minute.

*Step 4.* Put the well-mixed clean mud into the mold, and let it stand after setting.

*Step 5.* To prepare concrete, first, put nano-SiO<sub>2</sub> into water and disperse it with ultrasonic wave for 5 minutes.

*Step 6.* Put cement, mineral powder, fly ash, chemical admixture, and coarse and fine aggregate weighed according to a certain proportion into the concrete mixing pot and mix slowly for 6 minutes.

*Step 7.* Pour in nano-SiO<sub>2</sub> treated with ultrasonic wave and stir for 5 minutes.

*Step 8.* Pour the mixed concrete into the mold and set it under high pressure and then let it stand for curing.

## 4. Analysis of the Influence of Nanomaterials on the Performance of New Concrete Materials

In the third part of the article, we used nano-SiO<sub>2</sub> as a specific example to conduct the preparation experiment of nanoconcrete. The experimental results show that the addition of nano-SiO<sub>2</sub> changed the chemical composition of the original traditional concrete, greatly improved its chemical and physical properties, and showed the excellent performance that traditional concrete does not have. In this chapter, we will make a specific analysis and discussion on

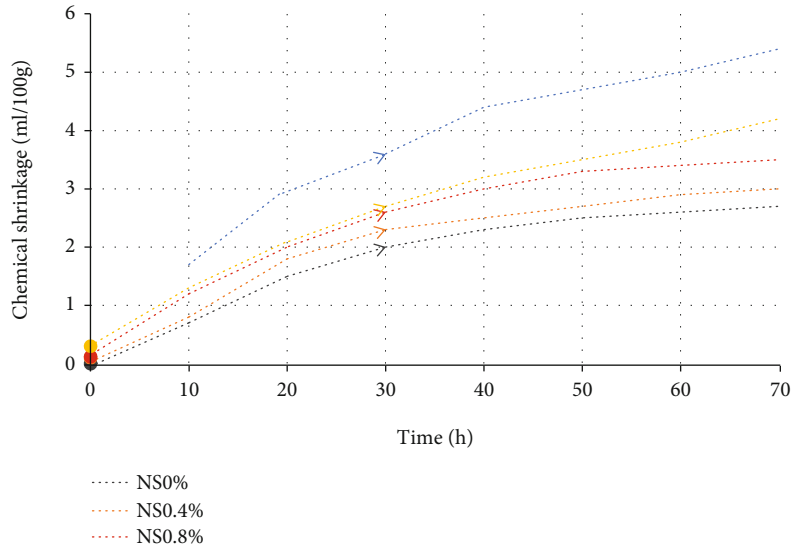


FIGURE 1: Chemical shrinkage of cement paste after 4 days of setting.

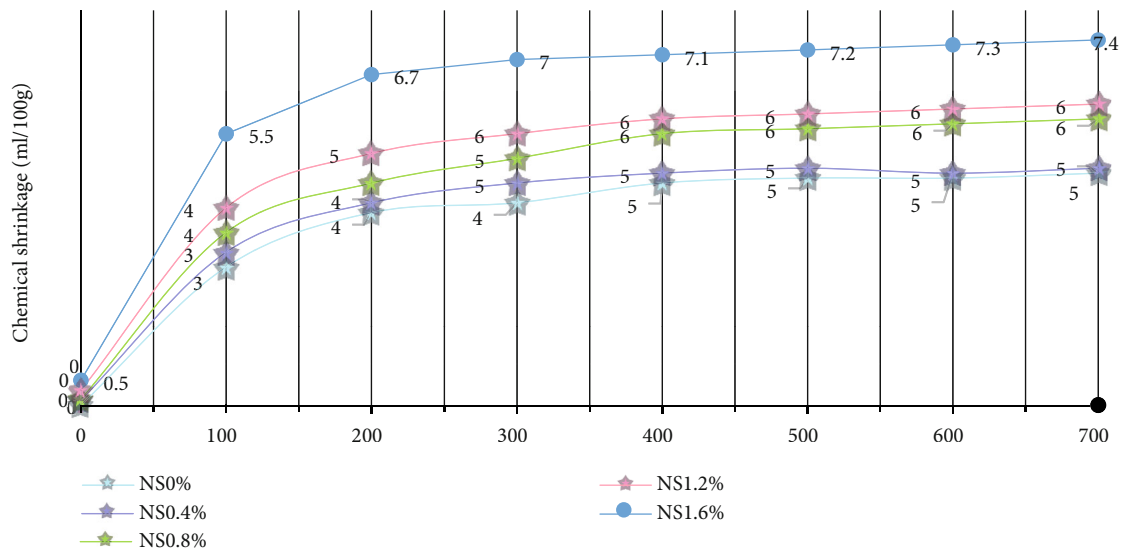


FIGURE 2: Chemical shrinkage of cement paste after 27 days of condensation.

TABLE 4: Concrete mix ratio.

NS content	Water	Cement	Gravel	Water reducer and swelling agent	Mineral powder and fly ash
NS0%	165	623	650	12.65	114
NS0.4%	165	621.7	650	12.65	114
NS0.8%	165	617.8	650	12.65	114
NS1.2%	165	624	650	12.65	114
NS1.6%	165	619.55	650	12.65	114

the improvement of nano-SiO<sub>2</sub> on the performance of new concrete materials.

**4.1. Effect of Nano-SiO<sub>2</sub> on Chemical Shrinkage of Cement Paste.** Nano-SiO<sub>2</sub> has high pozzolanic activity. Adding it to cement paste can shorten the setting time of cement paste and reduce its fluidity, which is very helpful for improving the strength of cement. In order to deeply analyze the effect of nano-SiO<sub>2</sub> on the chemical shrinkage of cement paste, we mixed four different amounts of nano-SiO<sub>2</sub> (0.4%, 0.8%, 1.2%, and 1.6%) into the preparation of cement paste and record the chemical shrinkage value of each setting period and compare it with the cement paste without nano-SiO<sub>2</sub>. The results are shown in Figures 1 and 2.

From Figure 1, we can see that the cement paste added with nano-SiO<sub>2</sub> has a much faster chemical shrinkage value than the cement paste without nano-SiO<sub>2</sub>, and the chemical shrinkage effect is significant. The chemical shrinkage value of cement paste of SiO<sub>2</sub> increases rapidly, and the chemical shrinkage value gradually increases with the increase of the amount of nano-SiO<sub>2</sub> added. When the cement paste was set for 3 days, the amount of nano-SiO<sub>2</sub> added was 0.4%, 0.8%, 1.2%, and 1.6%. The corresponding chemical shrinkage values increased by 11.4%, 26.7%, 53.9%, and 94.2%, respectively. From Figure 2, we can see that the chemical shrinkage value of the cement paste doped with nano-SiO<sub>2</sub> increased significantly in the early stage, but with the increase of the setting time, the growth rate of the chemical shrinkage value slowed down, but it was still increasing. At 27 days of coagulation, the chemical shrinkage values of the cement pastes with nano-SiO<sub>2</sub> dosages of 0.4%, 0.8%, 1.2%, and 1.6% increased by 3.5%, 17.6%, 31.2%, and 58.9%, respectively. The cement paste doped with nano-SiO<sub>2</sub> has a significantly increased chemical shrinkage value than the undoped cement paste, and its chemical shrinkage value continues to increase with the increase of the added amount. This shows that nano-SiO<sub>2</sub> can affect the chemical shrinkage effect of cement paste and reduce its setting time, and because of its high pozzolanic activity, it is also conducive to improving the compactness and uniformity of cement paste.

**4.2. Effect of Nano-SiO<sub>2</sub> on the Compressive Capacity of New Concrete.** In order to study the effect of nano-SiO<sub>2</sub> on the compressive capacity and strength of new concrete, after keeping the water, aggregate, chemical admixture, and mineral admixture constantly, we make four kinds of nano-SiO<sub>2</sub> (0.4%, 0.8%, 1.2%, and 1.6%) instead of cement to add to concrete, the compressive strength of the setting time on the 3rd, 7th, 28th, and 60th days was tested, and at the same time, it is compared with the compressive strength of concrete without nano-SiO<sub>2</sub>. The combination of concrete with different amounts is shown in Table 4, and the compressive strength of concrete in each setting period is shown in Table 5 and Figure 3.

It can be seen from Table 5 and Figure 3 that the addition of nano-SiO<sub>2</sub> can significantly improve the compressive strength of concrete in the early setting stage, and as the amount of admixture increases, the compressive strength

TABLE 5: Increased value of nano-SiO<sub>2</sub> content in concrete compressive strength.

NS content	3D	7D	28D	60D
NS0.4%	9.67	5.67	5.75	5.60
NS0.8%	18.25	11.25	12.13	12.11
NS1.2%	37.88	18.04	12.5	12.34
NS1.6%	39.02	20.19	13.01	12.86

increase value also continues to increase. When nano-SiO<sub>2</sub> is added, the amount is 1.6%, the compressive strength of the coagulation period is 3 days and 7 days, respectively, increased by 39.02% and 20.19%, but with the extension of the coagulation period, the increase in compressive strength is not large, and when the coagulation period is on the 60th day, its compressive strength increased by only 12.86%. This shows that nano-SiO<sub>2</sub> can improve the early resistance of concrete, but with the extension of time, its compressive performance becomes less obvious. The reason is that the nano-SiO<sub>2</sub> particles have a small volume and a large specific surface area, have high pozzolanic activity, and can react with calcium hydroxide produced by the hydration of cement in concrete to promote the hydration process of cement, thereby improving its coagulation. Because of its small volume, nano-SiO<sub>2</sub> can fill the voids in the concrete, improve the density of rice concrete, and thus improve the early compressive capacity and strength of concrete. However, as the amount of nano-SiO<sub>2</sub> added increases, its chemical shrinkage value will also increase, which slows the cement water process of the concrete, resulting in a decrease in the growth rate of the compressive strength of the concrete in the later period.

**4.3. Effect of Nano-SiO<sub>2</sub> on the Microstructure of New Concrete.** Nano-SiO<sub>2</sub> has a variety of specific properties, and it can change the internal structure and composition of concrete materials when combined with new concrete materials. In order to explore the microstructure changes of concrete doped with nano-SiO<sub>2</sub>, we have drawn the XRD pattern of the concrete before and after nano-SiO<sub>2</sub> is added, as shown in Figure 4.

Figure 4 is the XRD pattern of the concrete before and after the nano-SiO<sub>2</sub> is added. From the figure, it can be seen that the diffraction peak of the internal structural components of the concrete changes greatly, which shows that after the nano-SiO<sub>2</sub> is added, the microstructure of the concrete has changed a lot. It promotes the hydration process of concrete cement, narrows the pores between concrete systems, makes the concrete components more closely connected, and is conducive to improving its mechanical strength.

## 5. Conclusions

In recent years, econoour has developed rapidly. Various real estate industries and infrastructure construction units have developed rapidly. Concrete, as the largest and most extensive building material, has become a very promising project. However, in today's modernized society, the

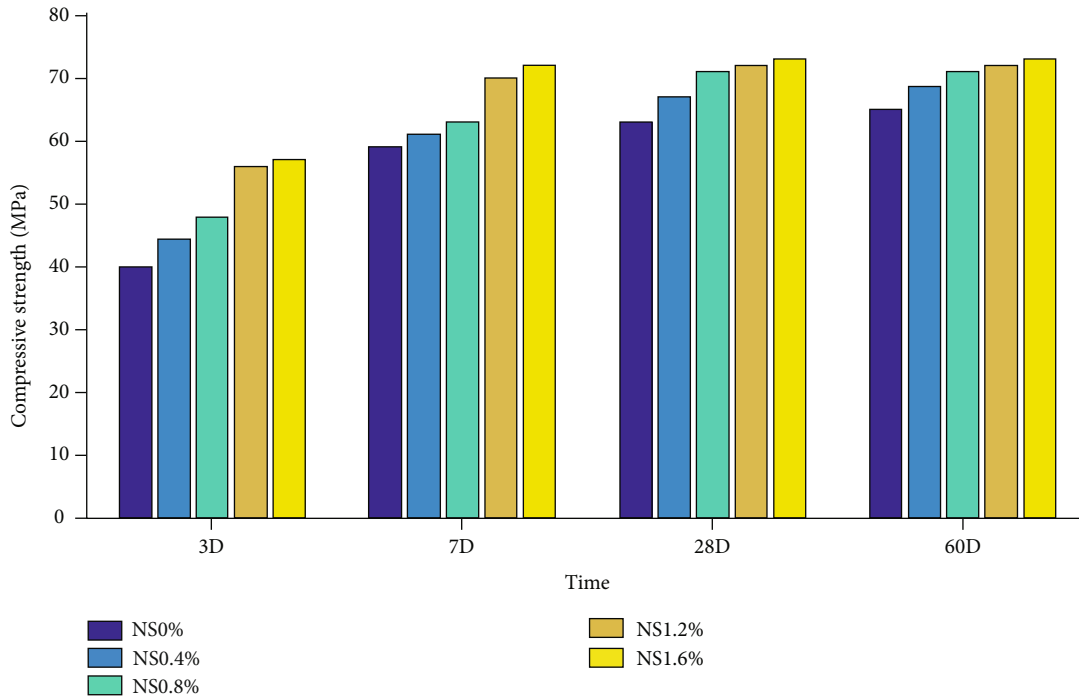


FIGURE 3: Compressive strength of concrete with different nano-SiO<sub>2</sub> content at each setting time.

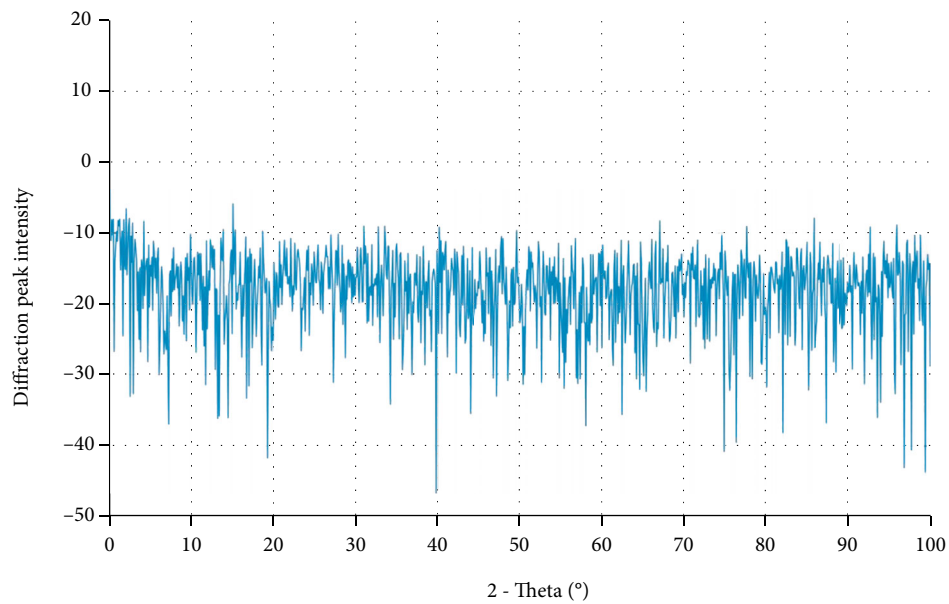


FIGURE 4: XRD pattern of concrete before and after incorporation of nano-SiO<sub>2</sub>.

application requirements of concrete are getting higher and higher. Due to its structural composition, traditional concrete often shows poor toughness, insufficient compression and tensile capacity, and poor endurance in engineering construction. Unable to adapt to more severe service environment and other issues, it is particularly important to strengthen the improvement of the traditional concrete performance structure.

Nanomaterials are a new type of high-tech materials. Because of their small particle size and large specific surface area, they have special properties that many other materials do not have. The combination of nanomaterial and new concrete materials on the market can produce concrete materials with better performance effects, which have a great influence and help to improve the mechanical, chemical, and physical properties of concrete.



This study obtained through experimental analysis that nano-SiO<sub>2</sub> can significantly improve the chemical shrinkage value and compressive strength of concrete. Due to its high pozzolanic activity and small particle volume, it can fill the pores of concrete, improve its interface structure, and promote the compactness and compressive capacity of the concrete system. In short, the addition of nano-SiO<sub>2</sub> has greatly improved the performance of concrete and obviously improved its previous defects. Although the optimization of traditional concrete materials has been deeply studied in this paper by using nanomaterials, there are still many deficiencies. The depth and breadth of the research in this paper are not enough. In the process of this research, the selection and acquisition of experimental data are absolutely ideal. The completeness and effectiveness are not enough. Some interference factors involved in the experimental process are not considered. My academic level research is also limited. The research on the application of nanomaterials is still in the preliminary stage. In the future, in our work, we will study appropriate methods and means from more perspectives based on the existing technology and level and continuously improve the research content.

## Data Availability

No data were used to support this study.

## Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

## References

- [1] P. Wang, S. Wang, X. Zhang et al., "Rational construction of CoO/CoF<sub>2</sub> coating on burnt-pot inspired 2D CNs as the battery-like electrode for supercapacitors," *Journal of Alloys and Compounds*, vol. 819, article 153374, 2019.
- [2] J. Zhao, J. Huang, Y. Xiang et al., "Effect of a protective coating on the surface integrity of a microchannel produced by micro-ultrasonic machining," *Journal of Manufacturing Processes*, vol. 61, pp. 280–295, 2021.
- [3] Y. Tang, Z. Chen, W. Feng, Y. Nong, C. Li, and J. Chen, "Combined effects of nano-silica and silica fume on the mechanical behavior of recycled aggregate concrete," *Nanotechnology Reviews*, vol. 10, no. 1, pp. 819–838, 2021.
- [4] H. Huang and J. F. Lovell, "Advanced functional nanomaterials for heranostics," *Advanced Functional Materials*, vol. 27, no. 2, p. 1603524, 2017.
- [5] K. Xiangzhen, F. Qin, and H. Jian, "A new damage-based non-local model for dynamic tensile failure of concrete material," *International Journal of Impact Engineering*, vol. 132, no. - OCT., article 103336, 2019.
- [6] Y. Shi and B. Zhang, "Correction: recent advances in transition metal phosphide nano-materials: synthesis and applications in hydrogen evolution reaction," *Chemical Society Reviews*, vol. 45, no. 6, pp. 1781–1781, 2016.
- [7] L. Canesi and I. Corsi, "Effects of nano-materials on marine invertebrates. ence of the Total," *Environment*, vol. 565, no. - sep. 15, pp. 933–940, 2016.
- [8] D. Bozyigit, N. Yazdani, M. Yarema et al., "Soft surfaces of nano-materials enable strong phonon interactions," *Nature*, vol. 531, no. 7596, pp. 618–622, 2016.
- [9] T. Sun, N. A. Bornhöft, K. Hungerbühler, and B. Nowack, "Dynamic probabilistic Modeling of environmental emissions of engineered Nanomaterials," *Environmental Science & Technology*, vol. 50, no. 9, pp. 4701–4711, 2016.
- [10] G. M. Deloid, J. M. Cohen, G. Pyrgiotakis, and P. Demokritou, "Preparation, characterization, and *in vitro* dosimetry of dispersed, engineered nanomaterials," *Nature Protocols*, vol. 12, no. 2, pp. 355–371, 2017.
- [11] S. Choi, H. Lee, R. Ghaffari, T. Hyeon, and D. H. Kim, "Recent advances in flexible and stretchable bio-electronic devices integrated with nano-materials," *Advanced Materials*, vol. 28, no. 22, pp. 4203–4218, 2016.
- [12] L. Jiang, Y. Liu, S. Liu et al., "Adsorption of estrogen contaminants by graphene nano-materials under NOM preloading: comparison with carbon nanotube, biochar, and activated carbon," *Environmental ence & Technology*, vol. 51, no. 11, pp. 6352–6359, 2017.
- [13] K. Zheng, M. I. Setyawati, D. T. Leong, and J. Xie, "Antimicrobial silver nano-materials," *Coordination Chemistry Reviews*, vol. 357, no. FEB., pp. 1–17, 2018.
- [14] P. Liu, R. Qin, G. Fu, and N. Zheng, "Surface coordination chemistry of metal nano-materials," *Journal of the American Chemical Society*, vol. 139, no. 6, pp. 2122–2131, 2017.
- [15] A. H. Khan, S. Ghosh, B. Pradhan et al., "Two-dimensional (2D) nano-materials towards electrochemical nanoarchitectonics in energy-related applications," *Bulletin of the Chemical Society of Japan*, vol. 90, no. 6, pp. 627–648, 2017.
- [16] G. Bo, L. Chang, H. Chenglong et al., "Effect of Mg and RE on the surface properties of hot dipped Zn–23Al–0.3 Si coatings," *Science of Advanced Materials*, vol. 11, no. 4, pp. 580–587, 2019.
- [17] E. J. Hong, D. G. Choi, and M. S. Shim, "Targeted and effective photodynamic therapy for cancer using functionalized nanomaterials," *Acta Pharmaceutica Sinica B*, vol. 6, no. 4, pp. 297–307, 2016.
- [18] X. Cao, C. Tan, X. Zhang, W. Zhao, and H. Zhang, "Solution-processed two-dimensional metal dichalcogenide-based nanomaterials for energy storage and conversion," *Advanced Materials*, vol. 28, no. 29, pp. 6167–6196, 2016.
- [19] R. J. Moon, G. T. Schueneman, and J. Simonsen, "Overview of cellulose nano-materials, their capabilities and applications," *JOM*, vol. 68, no. 9, pp. 2383–2394, 2016.
- [20] D. Elieh-Ali-Komi and M. R. Hamblin, "Chitin and chitosan: production and application of versatile biomedical nanomaterials," *International journal of Advanced Research*, vol. 4, no. 3, p. 411, 2016.
- [21] H. Ying, G. Xiang, and Y. Xinshun, "Defect repairs by new materials and new technology of marine wharf concrete," *Building Materials World*, vol. 38, no. 3, pp. 13–15, 2017.
- [22] B. Gutarowska, R. Kotynia, D. Bielinski et al., "New sulfur organic polymer-concrete composites containing waste materials: mechanical characteristics and resistance to biocorrosion," *Materials*, vol. 12, no. 16, p. 2602, 2019.
- [23] B. Körber, D. Stephan, and W. U. WiTraBau, "New materials developments for concrete pipes: opportunities and obstacles for industrial application," *Betonwerk + Fertigteil Technik*, vol. 83, no. 2, pp. 36–36, 2017.
- [24] S. Fei, "The discussion on a new type of ultra high strength concrete materials to improve the bearing capacity of the

- groove-shaped beam,” *Shanxi Transportation Science & Technology*, no. 6, pp. 48–51, 2016.
- [25] N. Beuntner and K. C. Thienel, “Calcined clays as alternative supplementary cementitious materials: new aspects of concrete technology pertaining to their use,” *Betonwerk + Fertigteil Technik*, vol. 83, no. 2, pp. 50–50, 2017.
- [26] Y. Ju, L. Wang, H. Xie et al., “Visualization of the three-dimensional structure and stress field of aggregated concrete materials through 3D printing and frozen-stress techniques,” *Construction & Building Materials*, vol. 143, no. JUL.15, pp. 121–137, 2017.
- [27] T. Xu, Q. Chen, Z. Zhang, X. Gao, and G. Huang, “Investigation on the properties of a new type of concrete blocks incorporated with PEG/SiO<sub>2</sub> composite phase change material,” *Building and Environment*, vol. 104, no. aug., pp. 172–177, 2016.
- [28] L. Kaiqing, X. Duotian, Y. Shijue, Z. Qiuhong, Z. Qingfeng, and Y. Xing, “Experimental study on the mix ratio of new ceramsite concrete materials,” *Concrete*, no. 4, pp. 147–150, 2017.
- [29] M. A. A. Aldandooh, N. M. Bunnori, M. A. M. Johari, A. Jamrah, and A. Alnuaimi, “Retrofitting of damaged reinforced concrete beams with a new green cementitious composites material,” *Composite Structures*, vol. 142, no. May, pp. 27–34, 2016.
- [30] X. Kong, Q. Fang, L. Chen, and H. Wu, “A new material model for concrete subjected to intense dynamic loadings,” *International Journal of Impact Engineering*, vol. 120, no. OCT., pp. 60–78, 2018.