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Effect of Nano SiO2 Enhanced Polyurethane Road Grouting Material on Folding Strength and Durability of Road Concrete

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Abstract: Concrete pavement is one of the most important forms of highway pavement because it requires less maintenance, consumes less energy, has a simple structure and is highly adaptable to the environment. However, ordinary cement concrete has shortcomings such as high brittleness and low strength, and its application in road construction is limited. This article aims to study the influence of nano-SiO2 reinforced polyurethane road grouting materials on the flexural strength and durability of road concrete, and analyze the properties of commonly used polymer chemical grouting materials, nano-materials, the application of nano-materials in concrete, and the characteristics of nano-SiO2. Based on the damage of concrete joints and the common shrinkage in concrete engineering, the influence of nano-SiO2 materials mixed into concrete at different dosages was studied from the perspective of mechanical properties and durability. The test proves that when the content of nano-SiO2 reaches 2%, the compressive and flexural strengths of 3d, 7d and 28d reach the maximum. Nano-SiO2 reinforced polyurethane road grouting material improves the strength of road concrete and improves the early strength of concrete.

1. Introduction

Since the 1990s, bottlenecks in the transportation industries such as building materials, highways, and railways have affected the rapid, stable and sustainable growth of the Chinese economy. Concrete is widely used in roads, bridges and buildings with its excellent strength and economy [1-2]. Due to the increase in domestic cars and the impact of environmental factors such as rain and moderate erosion, roads are vulnerable to damage or destruction, including cracks and dents on the road and damage to the road slab [3-4]. These diseases lead to a reduction in the carrying capacity of road construction, seriously affecting road performance, road traffic capacity and structural safety, and reducing construction service life.

At present, in addition to physical reinforcement, chemical grouting technology is widely used. Chemical grouting is slurry made of certain chemical materials, which is poured into the stratum or crevices with pressure feeding equipment to make it diffuse gel or solidify, so as to achieve reinforcement or anti-seepage plugging, to ensure the smooth progress of the project or in order to improve the quality of the project.

In order to obtain better concrete material properties, inspired by the application of silica fume to cement-based materials, experts and designers began to study the incorporation of nanomaterials into concrete. With the development of society and science and technology, nanomaterials and nanotechnology are receiving extensive attention from other industries. A scholar designed a comparative experiment, combined with XRD and SEM experiments, discussed and analyzed the difference in the degree of interaction between the two and hydrogen, which led to the mechanism of high-strength concrete producing a variety of silica fume and nano-SiO2. The conclusion was reached through comparative experiments and analysis. The nano-SiO2 in the cement reacts quickly and completely with calcium hydroxide, resulting in a significant reduction in the initial curing time and an increase in the initial strength [5-6]. Another scholar used a combination of basic mechanical performance testing and microstructure testing to comprehensively discuss and analyze the significant impact of nano-SiO2 on fly ash concrete, and combined with the test results to analyze its reinforcement mechanism. The result is nanoSiO2. It reacts with calcium hydroxide in the cement to enhance the composition of the interface between the aggregate and the matrix to a certain extent, thereby enhancing the bonding strength and macro-mechanical properties between the two, and the flexural strength of concrete increases significantly [7-8]. Some researchers have initially studied the effect of nano-SiO2 on the initial strength of concrete, and the results show that the addition of nano-SiO2 helps to increase the initial strength of concrete, and there is an optimal dosage [9-10]. Some researchers have conducted related experiments and found that adding an appropriate amount of nano-SiO2 can significantly improve the air-tightness of the corresponding concrete [11-12]. Some scholars have conducted related studies on the effect of nano-SiO2 on the anti-segregation performance of lightweight aggregate concrete. They believe that a proper amount of nano-SiO2 can improve and improve the performance of concrete slump and other properties. The results show that it inhibits the impact of lightweight aggregate concrete and greatly increases the float [13-14]. Some scholars have carried out a mix ratio test for concrete with a single addition of steel powder. By changing the amount of steel powder added, various mechanical indexes of the concrete were tested, and the best mix ratio of steel powder was 20%~30%[15-16]. In addition, some experts also carried out related experiments based on the effects of various nano-SiO2 surfaces on high-performance concrete. Studies have shown that nano-SiO2 has the best specific surface area and can significantly improve the corresponding mechanical properties [17-18]. Based on the results of the above existing experimental research on nano-SiO2 in concrete, at this stage, we can find literature on the use of nano-materials, most of which focus on the impact on the physical and mechanical properties of concrete. The effects of early hydration, rheology and durability are limited to relative. The shallow research shows that nanomaterials still have a large research field.

On the basis of consulting a large number of domestic and foreign references, this article combines the properties of polymer chemical grouting materials, nanomaterials, the application of nanomaterials in concrete, the characteristics of nano SiO2, the damage of concrete joints and the common shrinkage in concrete engineering. The effect of nano-SiO2 reinforced polyurethane road grouting material in road concrete was studied.

2. Effect of Nano SiO2 Enhanced Polyurethane Road Grouting Material on Folding Strength and Durability of Road Concrete

2.1. Commonly Used Polymer Chemical Grouting Materials

(1) Epoxy resin grouting material

Epoxy resin has a series of advantages such as high hardness, strong adhesion, low thermal shrinkage, and excellent chemical stability, and it can be stable at room temperature. During the operation period of the 1950s, the country began to use epoxy resin to repair previously unsolvable cracks in cement. Since then, many countries have conducted extensive research and application of epoxy resin grouting materials [19-20]. Epoxy resin is used as a grouting material. First, the grouting must have a low viscosity before it can be poured into small cracks or pores. However, since the viscosity of the epoxy resin itself is relatively high, it is important to reduce the viscosity as much as possible, and it is also necessary to give the cured product all the necessary properties.

(2) Acrylic ammonium grouting material

Acrylamide grouting is made of acrylamide as the main component, methylene bisacrylamide as the cross-linking agent, and grouting made of other materials. The characteristics of acrylamide grouting material are as follows:

1) The slurry is fixed in nature, and the two components can be separated and stored for a long time. The slurry with a content of more than 5% will produce 0.5 transparent gel when it solidifies. It is insoluble in water, kerosene, gasoline and other solutions, and is not corroded by dilute acids, gases and bacteria. And the gel material can continue to swell after drying, which is considered as a semi-permanent material [21].

2) The slurry viscosity is very low, close to water, and has excellent injection characteristics. It can penetrate very small cracks and pores, and "quickly" polymerize to stop or solidify water.

3) The gel time can be adjusted arbitrarily by adjusting the same amount of polymerization inhibitor, and the slurry will thicken within a few seconds or hours. The viscosity of the mud before the blending process will not change basically. Since the gelatinization process is carried out instantaneously, it is easier to use when grouting the material.

(3) Polyurethane grouting material

Polyurethane grouting is a kind of mortar material whose main components are isocyanate and polyol. It is a relatively advanced type of mortar material with a wide range of applications. Depending on the raw materials and processes used, the pulp characteristics, uses, curing characteristics and results obtained are also different. Because there are still unreacted isocyanate groups in the mud, it can chemically react with the aqueous solution to cross-link to form a water-insoluble synthetic polymer, which can achieve the purpose of anti-seepage engineering, plugging and plugging. Because the supercritical carbon dioxide gas produced during the chemical reaction increases the volume ratio, the solidification volume ratio is increased, and a higher expansion pressure is generated, which also increases the secondary dispersion of the mud, thereby increasing the dispersion range [22-23]. Because the slurry reacts with the aqueous solution and is stable under all conditions, it is not washed away by water when diluted with the solution. Another feature is through different materials and polymerization methods. When the slurry is cured, it may be low-density foam or maximum-density polyurethane rubber, or it may be soft, semi-soft or hard. Therefore, it can be used not only as a sealing connection material, but also as a corrosion-resistant and waterproof connection material, or as a caulking material that deforms in response to expansion and contraction.

2.2. Performance of Nanomaterials

(1) Mechanical properties Nano materials have high hardness and strong plasticity. Nanowires have a hardening effect and have higher fracture toughness than ordinary coarse-grained materials. At the same time, nanomaterials also have excellent creep resistance and fatigue resistance, as well as excellent superplasticity.

(2) Optical characteristics. Bulk metal has its own color, and when the particle length is reduced to nanometers, the entire metal surface becomes dark, and the smaller the particle size, the deeper the color. In other words, it is the largest size of nanocrystalline grains and has strong light absorption. In addition to linear optical properties, nanomaterials also possess nonlinear optical properties.

(3) Electromagnetic characteristics. Nanomaterials have electromagnetic properties such as high electrical conductivity and high magnetic permeability, as well as nonlinear volt-ampere characteristics. In addition, nanomaterials also have better electromagnetic shielding capabilities.

(4) Catalytic performance. Nanocrystalline catalysts are used to avoid the slow diffusion of reactants into the catalyst due to the widespread use of conventional catalysts to form specific harmful reaction products, and to ensure that no catalytic structure is produced. Due to local overheating, it is destroyed and loses its activity.

(5) Photocatalytic efficiency. Some nanomaterials can convert light energy into chemical energy under visible light or ultraviolet light, thereby promoting the synthesis of organic matter or the decomposition of organic matter. This process is called photocatalyst material. The atomic size and acceptor concentration of nanomaterials are very small, so most of the electrons and holes can smoothly reach the surface of the nanoparticle. This is the main prerequisite for high photocatalytic efficiency and fast chemical reaction speed in the application of nanomaterials.

(6) High sensitivity characteristics. For the application of nanomaterials, it has the advantages of small particle size, large atomic surface area, high electron absorption capacity, and high surface reaction activity. Inorganic nanomaterials exposed to the atmosphere absorb the gas to produce an absorption layer. Using this feature, people have produced various gas sensors to measure various gases.

2.3. Application of Nanomaterials in Concrete

(1) The application of nano mineral powder in concrete

Nano mineral powder mainly includes nano SiO2, nano CaCO3, and nano silicon powder. Nano mineral dust can effectively fill the voids in the cement stone, improve the interface structure of the cement stone and its aggregate in the concrete, and improve the mechanical properties and durability of the concrete. The pozzolanic activity of nano-SiO2 is much higher than that of silicon fume, making nano-SiO2 the most widely used nanomaterial in nano-concrete.

(2) Application of nano metal oxides in concrete

Anatase nano-titanium dioxide is a chemically stable nano-material. It has strong redox ability under the influence of visible light and ultraviolet light. It can destroy the chemical structure of organic matter, kill bacteria and viruses, and eliminate particles in the air. Harmful gases such as formaldehyde, benzyl mercaptan and ammonia purify organic pollutants in water. When making concrete blocks or cement blocks, by adding an appropriate amount of nano-titanium dioxide into the cement mortar on the surface, concrete blocks or cement blocks with photocatalytic function can be made.

(3) Application of nano metal powder in concrete.

Rice metal powder is an excellent absorbent material. Under the irradiation of the microwave field, the mutual movement between atoms and electrons is enhanced, which converts the kinetic energy of electrons into heat, thereby enhancing the absorption rate of electromagnetic waves, and has the function of radar detection and avoidance. Using these unique properties of nano metal powder, an appropriate amount of nano metal powder can be added to concrete to form a special concrete with electromagnetic barrier. Because these concrete bodies have excellent confidentiality functions, they can reduce the chance of being discovered by the enemy and achieve military goals, and have very broad development potential in the construction of military bases.

(4) Application of polymer/inorganic nanomaterials in concrete

The physical, chemical and mechanical properties of polymer/inorganic nanocomposite materials are significantly higher than traditional composite materials, and they have good heat resistance and electrical conductivity. Based on the characteristics of polymer/inorganic nanocomposites, the application of polymer/inorganic nanocomposites to cement can not only enhance the tensile strength of cement, but also use excellent thermal conductivity materials to resist and load cement preparations.

2.4. Characteristics of Nano SiO2

Nanomaterials are generally divided into three categories: nanoparticles, bulk nanomaterials, and nano-assembly systems according to their internal existence. This material is a material with a particle size of 1-100nm. Nanomaterials are small in size, and the size is between the atomic level and the macroscopic level of matter, and the mesoscopic system is in the transition zone between the microscopic system and the macroscopic system. Due to its special structural characteristics, it has special effects different from macroscopic systems: surface effects, volume effects, quantum effects, and macroscopic quantum tunneling effects. Compared with other materials, the superior structural characteristics of nanomaterials give them many unique physical and chemical properties:

(1) Mechanical properties

The advantages of nanomaterials are that the strength, hardness, specific strength and other indicators are significantly higher than other materials, and the creep resistance, fatigue strength, heat resistance and fracture safety are significantly higher than other materials, which are excellent.

(2) Chemical activity

Due to the extremely small scale of nanomaterials, the atomic order and the ratio of all atomic weights scattered on the surface of the particles are relatively large, so these molecules have a large surface activity. These individuals can easily fuse with other individuals and form chemical effects.

(3) Electrical performance

The macroscopic quantum tunneling effect makes the charge transfer of nanoparticles to the surface abnormal, leading to continuous changes in their conductivity and diffusivity.

(4) Thermal performance

Based on the small-scale effect and surface effect of nanoparticles, nanomaterials have the characteristics of high activity and high surface energy. Like other metal materials, the kinetic energy required to melt it is quite small. Therefore, it is possible to compare nanoparticles with other materials. They not only have the advantages of lower melting point temperature, sintering high temperature and crystallization temperature, but also have a large specific heat capacity and thermal expansion coefficient.

The special properties of nanomaterials have greatly enriched the application of nanotechnology in building materials, resulting in many nano products such as nano paint, nano glass, nano cement, and nano waterproof materials. As "the most widely used material in the new century", nanomaterials have countless practical application values and huge development prospects.

2.5. Diseases of Cement Concrete Pavement

2.5.1. Damaged Concrete Panels

(1) Mesh cracks appear on the surface of the panel

Crack diseases account for the largest proportion of all concrete pavement diseases. Due to the inherent defects of cement concrete, almost all cement mortars have microcracks. The concrete pavement is initially micro-cracked, which is less harmful to the performance and structure of the pavement, depending on factors such as vehicle load and external environment. In addition, improper design of road concrete mix ratio and poor quality of raw materials such as cement and aggregate used in the manufacturing process can lead to insufficient concrete strength. Excessive vibration or leakage during concrete slab construction, too short curing time for concrete slabs, improper maintenance, uneven subgrade subsidence, etc., are all likely to cause more serious network cracking diseases.

(2) The road slab is broken

As the pavement layer is not resistant to water corrosion, the high-pressure water between the surface layer and the base layer will produce mud pumping, and the load stress and temperature stress action panel will be damaged. Due to the large size of the concrete pavement, the cutting time after hardening and forming is relatively slow, and the concrete is prone to deformation and initial hidden dangers under the action of high temperature stress. In addition, the concrete pavement is too thin to reach the design thickness, causing the floor slab to fracture under vehicle load and temperature stress.

(3) Large area damage to road slab

The main reasons are the poor quality of selected raw materials, high sludge content, insufficient concrete strength, unreasonable design of road concrete mix ratio, and low level of construction technology. High-speed vehicle impact and wheel friction will also accelerate the damage of the concrete frame.

2.5.2. Damaged Concrete Joints

(1) Damaged joints

It usually appears in the area of tens of centimeters on both sides of the cutting edge of the panel. The main reason is that the power transmission rod of the joint is not adjusted well or the concrete frame is not cut to a certain depth. Therefore, the interior of the concrete is subject to thermal stress. If hard objects such as stones fall onto the joints at the joints, the concrete frame will not be able to stretch freely. During the expansion process, the concrete panel will receive a lot of compression force. If the strength of the frame is exceeded, the concrete will be damaged.

(2) Arching

The concrete slab has obvious effects of thermal expansion and contraction. If blocked during thermal expansion, the concrete frame on the hinge side will bend upward. The main reason is that the joints of the filler are of poor quality or broken, the concrete frame expands and shrinks too much, or there are hard objects such as stones falling at the joints. The concrete frame increases the concentration of tension during the expansion process, resulting in unstable longitudinal bending.

(3) Misplacement

Vertical displacement occurs on both sides of the seam. The water resistance of the road surface is poor. External water seeps into the pavement through the cracks and softens the pavement. The medium and high pressure water generated under the action of the vehicle load continuously cleans the roadbed and evacuates the bottom of the slab.

(4) Mud

External water seeps into the bottom of the concrete frame through the joints. It sprays along the joints. The mud can help the grassroots evacuate to the bottom of the concrete frame, causing cracks and fractures in the concrete frame, affecting the normal use of the road.

2.6. Common Shrinkage in Concrete Engineering

(1) Dry shrinkage

The shrinkage of concrete is one of the most common types of deterioration in concrete, and it is a very common and inevitable physical or chemical behavior. Dry shrinkage is the most common form and main cause of concrete cracks. The occurrence of dry shrinkage cracks is mainly due to the different volatilization degree of water inside the cement, so different shapes are formed. The external structure of concrete is greatly affected by the change of moisture content. The surface loses water faster. The greater the change, the slower the internal water diffusion and the smaller the change. The deformed surface is bound by internal water, causing stress and cracks to increase. The internal shrinkage of concrete is mainly based on the multi-layer combination of monohydrate calcium silicate, in which water molecules diffusely enter the hydrogel layer of the adjacent two layers to expand the lattice structure. When water is lost, the layer shrinks and the concrete shrinks accordingly. The formation process is shown in Figure 1:

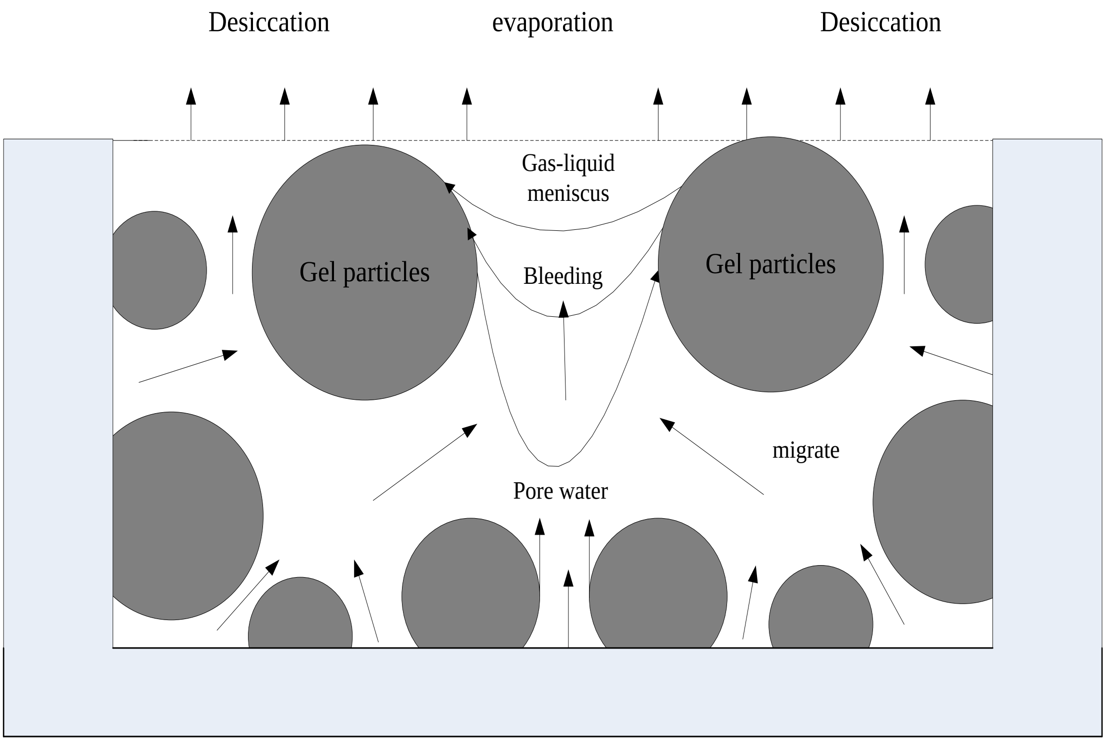


Figure 1. Concrete shrinkage process

(2) Temperature shrinkage

Temperature shrinkage refers to the normal state of the building structure. The main cause of temperature shrinkage is that during the hardening process of commercially available cement, the hydration heat, temperature difference and solar radiation of the cement harden the cement, so the temperature after hardening decreases. The concrete component has undergone a rapid high temperature drop in a short period of time. However, due to the cold wave attack and the flooding of the dam under construction, the temperature difference between the upper and lower sides changed greatly. When the temperature rose rapidly, the concrete components cracked. According to the different widths of temperature cracks, it is obviously affected by temperature fluctuations. It is wider in winter and narrower in summer. The temperature variation of temperature cracks is generally irregular, and the cracks of larger surface structure often intersect. For slender beams and plates, the cracks are basically parallel to the short sides. However, deep penetration temperature cracks are usually parallel or nearly parallel to the short side, and partly crack along the long side, and the middle is denser. The high-temperature cracks formed by cement due to high-temperature expansion are generally thicker in the center and thinner on the edges, while the thickness difference of cold shrinkage cracks is not obvious. The existence of such cracks causes corrosion of steel bars and carbonization of cement, thereby reducing the ability of cement to resist freezing and thawing, fatigue and air tightness.

(3) Plastic shrinkage

Plastic shrinkage refers to the shrinkage of the concrete surface due to the rapid loss of water before it sets. Plastic shrinkage cracks are usually caused by dry heat or wind. Most of the cracks are wide in the center, thin at both ends, different in length, and non-adhesive. Most of the reason is that the tensile strength of the concrete before it finally hardens is very low or even not, even when the concrete has just hardened and is still very soft. The concrete surface will lose water under the influence of high temperature and wind. When the negative air pressure is high, the volume of cement decreases sharply. At this time, the strength of commercially available cement cannot withstand air compression, and cracks are formed. The main factors affecting cement compression and cracks are water-cement ratio, cement setting time, temperature, wind speed and relative humidity.

(4) Carbonization shrinkage

A carbonization reaction occurs between carbon dioxide in the atmosphere and concrete hydrate, and the resulting compression deformation is called carbonization shrinkage. Carbonation only occurs at moderate temperatures, and it gradually deepens inward from the surface of the cement. Carbon dioxide gasification occurs most intensely in an environment with high carbon dioxide content and a dry and wet environment. Carbon shrinkage is not considered under normal circumstances, but it should be considered in some environments or projects that require higher strength. Because carbonization can reduce the air tightness of cement and neutralize the alkalinity of cement, while also reducing the pH value. When the cement protective layer of the steel bar is fully carbonized, the steel bar will corrode if water and oxygen can penetrate. The following chemical reactions occur during the carbonization of concrete:

$$Ca(OH)_2 + H_2O + CO_2 \rightarrow CaCO_3 + 2H_2O \quad (1)$$

In the formula, $Ca(OH)_2$ is calcium hydroxide; $CaCO_3$ is calcium carbonate.

$$3CaO \cdot 2SiO_2 \cdot 3H_2O + 3H_2O + 3CO_2 \rightarrow 3CaCO_3 + 2H_2O + 2SiO_2 + 6H_2O \quad (2)$$

Among them, CaO stands for calcium oxide.

$$2CaO \cdot SiO_2 + \lambda H_2O + 2CO_2 \rightarrow 2CaCO_3 + SiO_2 \cdot \lambda H_2O \quad (3)$$

$$3CaO \cdot SiO_2 + \lambda H_2O + 3CO_2 \rightarrow 3CaCO_3 + SiO_2 \cdot \lambda H_2O \quad (4)$$

3. Experiment

3.1. Experimental Raw Materials

3.1.1. Cement

The cement used in this paper is ordinary Portland cement, and its performance meets the specification requirements. The cement was scrubbed through a 325 mesh sieve to create a sample and used for XRF analysis. The composition of the cement is shown in Table 1, and the basic properties of the cement are shown in Table 2.

Table 1. Components of cement

chemical components	cement(%)
CaO	55.8
SiO_2	19.68
Al_2O_3	6.47
Fe_2O_3	3.2
SO_3	3.51
TiO_2	0.31
MgO	3.25
K_2O	0.96
Na_2O	0.18
P_2O_5	0.12
SrO	0.07
ZrO_2	0.03

Table 2. Basic properties of cement

Ignition loss (%)	Water consumption for standard consistency (%)	Setting time (min)		Flexural strength (MPa)		Flexural strength (MPa)	
		Initial setting	Final set	3d	28d	3d	28d
3.25%	29%	196	261	4.4	6.8	22	45.2

3.1.2. Fine Aggregate

The fine aggregate is natural river sand. Before forming concrete, the fine aggregate is sieved to remove large sand particles, washed with water and dried to remove dirt and other harmful impurities in the fine aggregate. Weigh a sample of fine aggregate and dry it at a constant weight for 48 hours in an oven at 105±5 ℃, and perform a screening test on the dried sample. The test results are shown in Table 3:

Table 3. Fine aggregate screening test

Sieve/mm	Remaining mass/g	Screening rate/%	Cumulative screening rate/%
4.76	35.6	7.09	8.91
2.37	69.4	13.87	22.79
1.19	107.4	21.44	44.22
0.61	112.9	22.57	66.8
0.31	115.7	23.11	89.9
0.16	41.7	8.33	98.24

The calculation formula of sand fineness modulus is:

$$M_X = \frac{(A_{0.16} + A_{0.31} + A_{0.61} + A_{1.19} + A_{2.37}) - 5A_{4.76}}{100 - A_{4.76}} \quad (5)$$

According to the above formula, the fineness modulus of the fine aggregate used in the test is 2.97, which is relatively coarse medium sand.

3.1.3. Coarse Aggregate

The coarse aggregate is basalt crushed stone. Before pouring the concrete, the coarse aggregate is sieved, and then the large pieces of crushed stone are sieved to remove the coarse aggregates with poor performance such as needle-like flakes and long strips. Take a 20kg sample of coarse aggregate and dry it in an oven at 105±5 ℃ for 48 hours to a constant weight. The test adopts the dry sieving method, and the test is divided into two groups of parallel tests. The sieve residual results are shown in Figure 1:

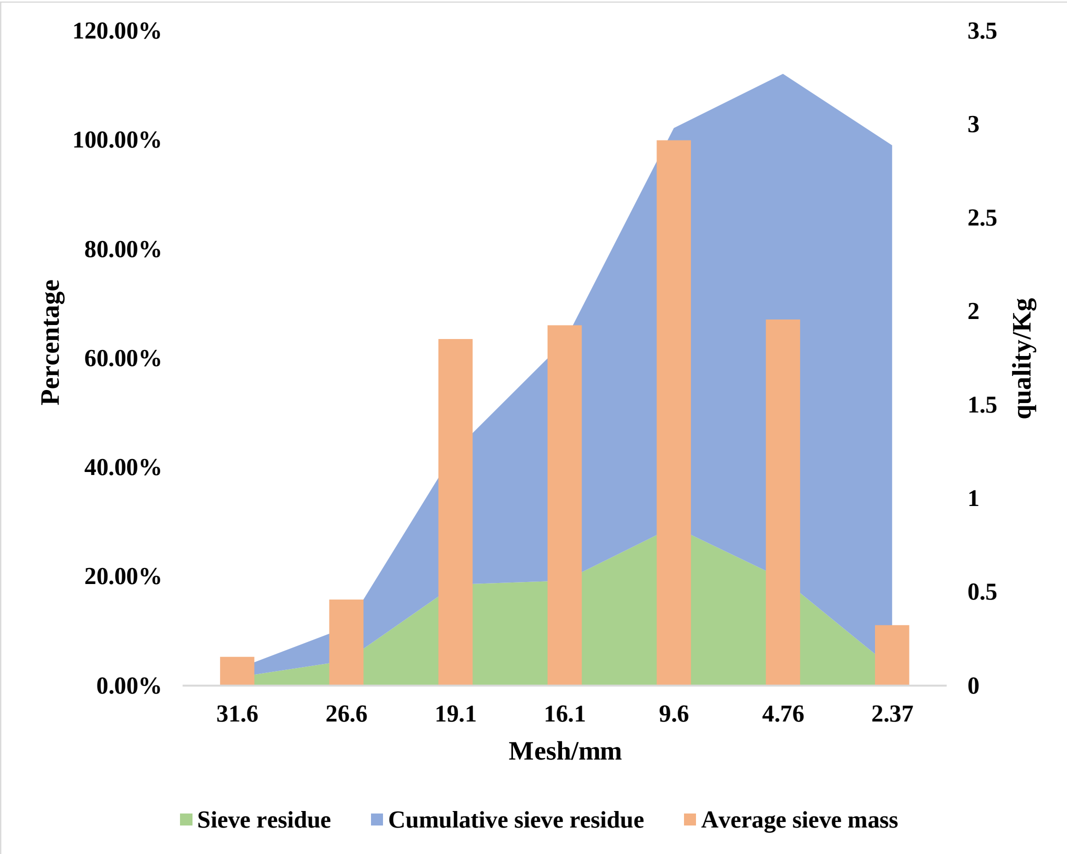


Figure 2. Coarse aggregate screening test sieve residue rate

According to the comparison of related coarse aggregate test rules, the gradation of the coarse aggregate used in the concrete form is 5-25 continuous gradations, and the gradation state meets the requirements of the test mixed concrete.

3.1.4. Water Reducing Agent

The water reducing agent is a polycarboxylic acid superplasticizer, and the theoretical water reducing rate under different cement mass fractions is shown in Table 4:

Table 4. Theoretical water reducing rate of water reducing agent

Water reducing agent parameters	Theoretical water reduction rate/%
1.5	20
2.0	30
2.5	35

3.2. Design of Nano-concrete Mix Ratio

High-performance concrete is the main direction for the development of concrete technology in the future. It has the advantages of high strength, high strength, and convenient structure, which greatly improves the uniformity and compactness of concrete. The mix ratio design is also better than ordinary concrete, and the design strength is C60. According to the specification, if the design strength of concrete is C60 or higher, the formwork strength should be calculated as follows:

$$f_{cu,o} = 1.15 f_{cu,k} \tag{6}$$

The calculation formulas of concrete water-cement ratio, water consumption and sand ratio are as follows:

$$\frac{m(w)}{m(c+f)} = \frac{1}{\frac{f_{cup}}{Af_{ce}} + B} \tag{7}$$

$$V_w = \frac{V_e - V_a}{1 + \frac{1}{\rho_c(1-\varphi) + \varphi\rho_f}\left[\frac{f_{cup}}{Af_{ce}} + B\right]} \tag{8}$$

$$S_P = \frac{(V_{es} - V_e + V_w)\cdot\rho_s}{(V_{es} - V_e + V_w)\cdot\rho_s + (1000 - V_{es} - V_w)\rho_g} \times 100\% \tag{9}$$

In the formula, S_P means sand ratio; V_e means cement slurry volume; V_w means water consumption; ρ_s means sand density; ρ_g means gravel density; ρ_c means cement density.

3.3. Experimental Method

(1) The flexural strength is tested by the three-point bending method, as shown in Figure 3.

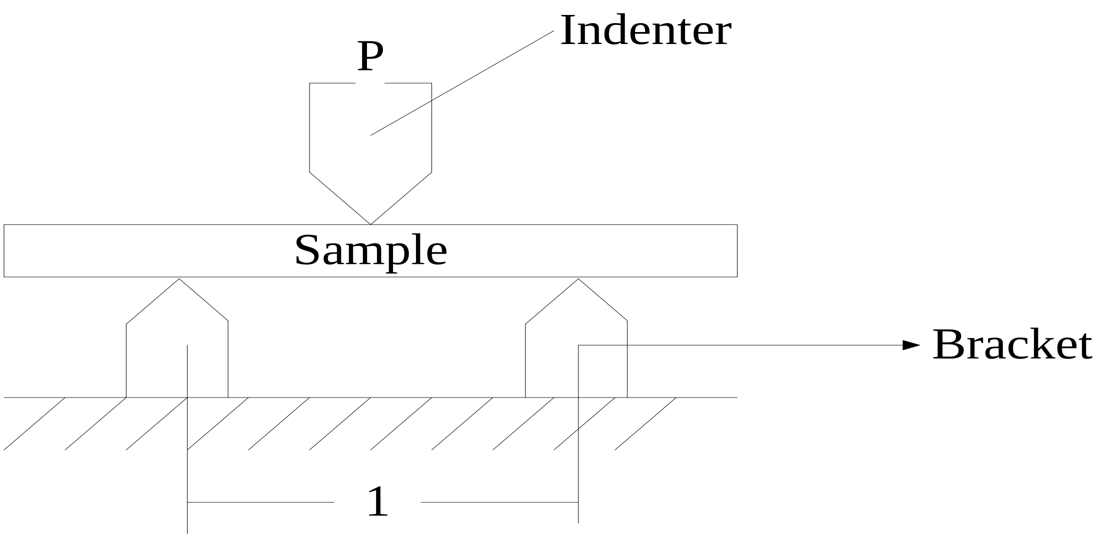


Figure 3. Schematic diagram of three-point bending test method for flexural strength

The formula for calculating the flexural strength of concrete is as follows:

$$f_f = \frac{0.85 F_f L}{bh^2} \tag{10}$$

(2)After the compressive strength is tested with a folding and pressing integrated testing machine, take the test block out of the standard curing box and store it for about 15 minutes, then smooth the surface of the test block and install it on the clean indenter of the testing machine, and place the concrete test block in the middle of the indenter. Start the experiment machine, first select the computer's compressive strength test program, and delete the initial data, and then start running. As the pressure gradually increases, the structure of the test block's compressive strength is broken and changes rapidly. If the maximum load cannot be accepted, the test machine will be shut down and the maximum load when the test block's compressive strength ruptures is recorded. Measure the flexural strength as follows:

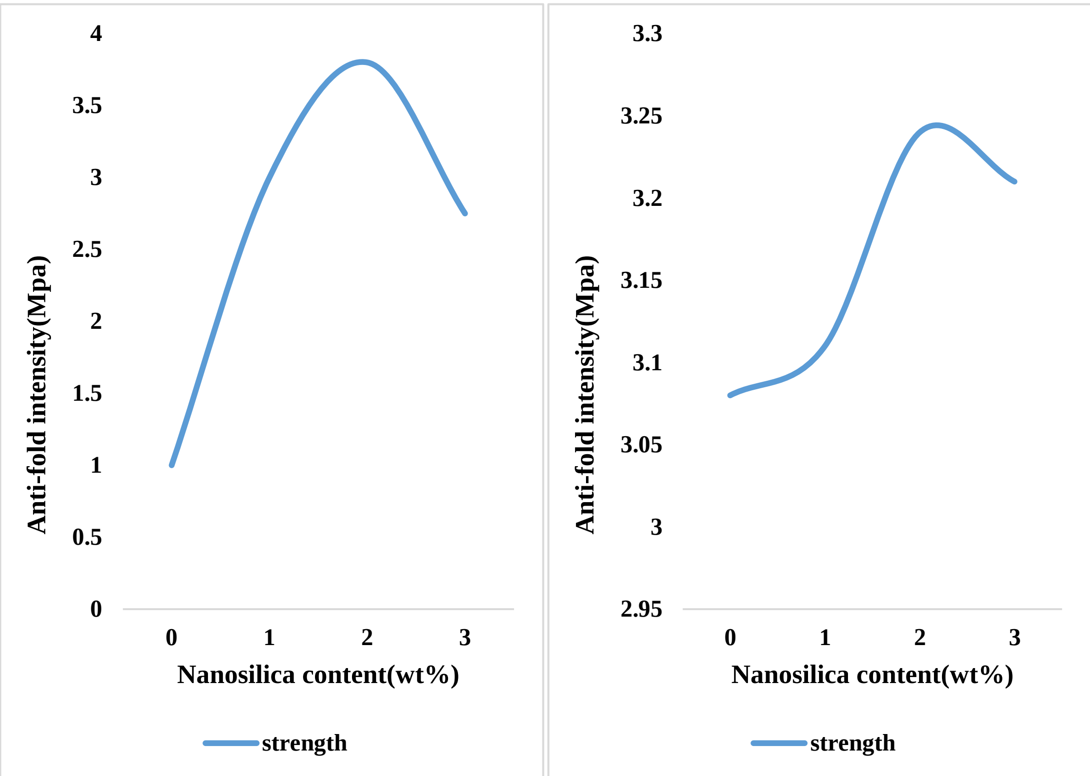
$$f_{cc} = \frac{F_{cc}}{A_{cc}} \tag{11}$$

$$f_{cp} = \frac{F_{cp}}{A_{cp}} \tag{12}$$

In the formula: f_{cc}, F_{cc}, A_{cc} represents the failure load, bearing area, and concrete compressive strength of the specimen respectively.

4. Discussion

4.1. Nano SiO2 Enhances the Performance of Polyurethane Road Grouting Material

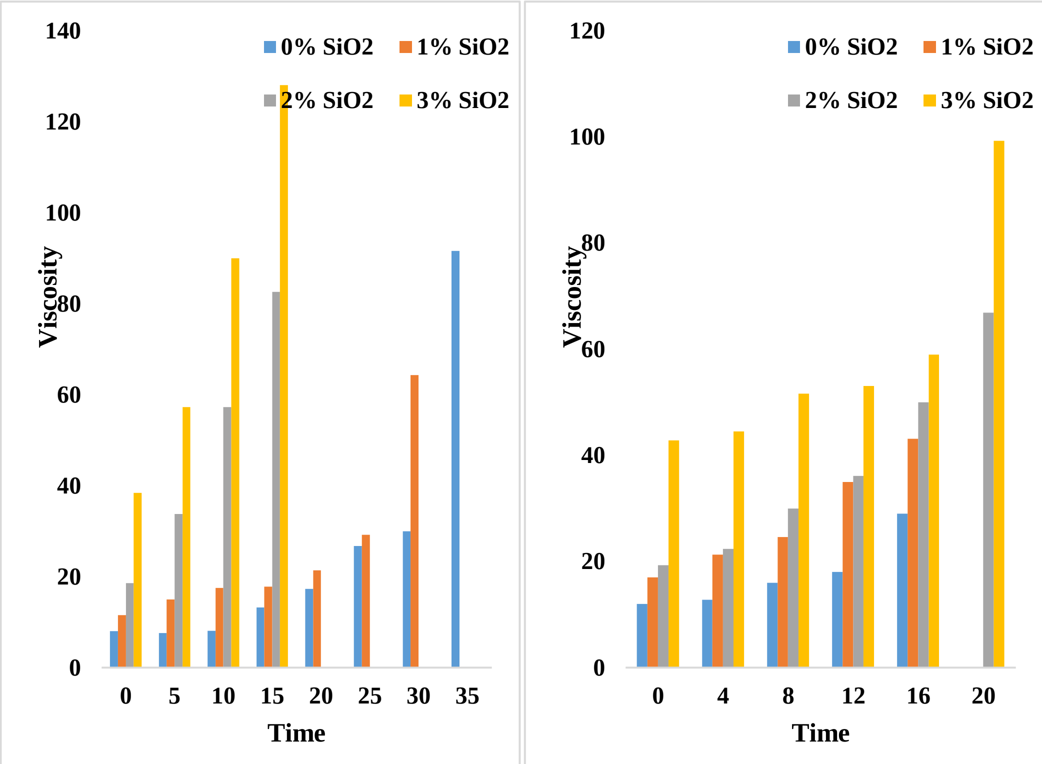


a) Chain extension factor=100% b) Chain extension factor=70%

Figure 4. Effect of nanosilica content on the anti-fold intensity

Figure 4 shows the bond strength relationship of the slurry solidification to the concrete mortar when SiO2 particles are added when the chain extension coefficient is 100% and 70%. It can be seen that the bonding strength also increases first and then decreases with the increase in the amount of SiO2 particles. When the amount of SiO2 particles is 1%, the bond strength with a chain extension coefficient of 100% is 3MPa, and the bond strength with a chain extension coefficient of 100% is 3.11MPa; when the amount of SiO2 particles is 2%, the maximum value is reached.

Figure 5 shows the relationship between the viscosity of the slurry and the amount of SiO2 particles when the chain extension coefficient is 100% and 70%.



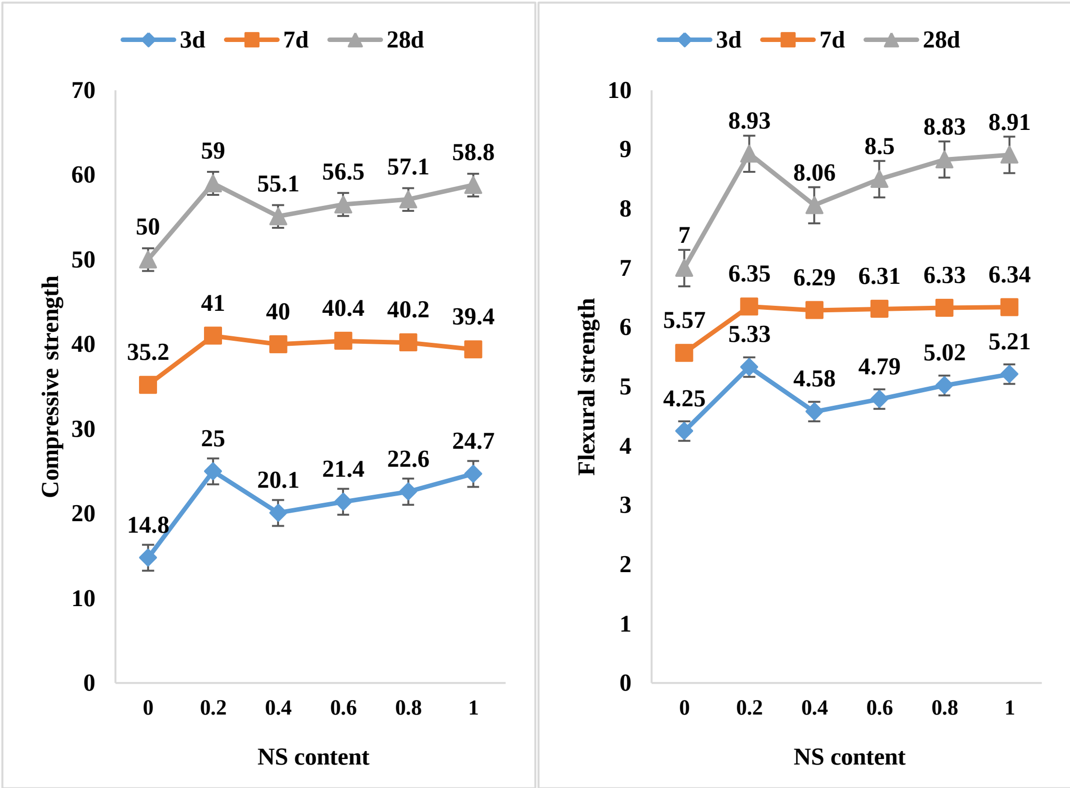
a) Chain extension factor=100% b) Chain extension factor=70%

Figure 5. Effect of nanosilica content on the viscosity of the grouts

It can be clearly seen from Figure 5 that for a 100% chain extension system, increasing the amount of SiO2 particles will increase the initial viscosity of the system, and increasing the amount of SiO2 particles will increase the viscosity of the slurry. This is because as the amount of SiO2 particles increases, the friction between the nanoparticles and the polymer chain increases, and the viscosity increases. For the 70% chain extension system, the change rule is basically the same as the previous 100% chain extension system, but for the pulp system with 1% and 2% nano-SiO2 content, there is no significant difference in viscosity.

4.2. Mechanical Properties of Concrete

In this paper, the 3d, 7d, 28d compressive performance and flexural strength of nano-modified concrete were tested. The compressive performance and flexural strength of nano-SiO2 modified concrete are shown in Figure 6.



a) Compressive strength b) Flexural strength

Figure 6. Compressive and flexural strength of nano-SiO_2 modified concrete

It can be seen from Figure 6 that as the content of nano-SiO2 increases, the compressive and flexural strength of concrete increases. When the content of nano-SiO2 reaches 2%, the compressive and flexural strengths of 3d, 7d, and 28d reach the maximum, the compressive and flexural strengths of 3d are 25 and 5.33MPa, respectively, and the compressive and flexural strengths of 7d are 41, respectively. And 6.35MPa, the compressive and flexural strengths of 28d are 59 and 8.93, respectively.

5. Conclusion

As a material with excellent properties, nanomaterials have been applied in many fields, as well as in concrete. Nanomaterials are used to modify concrete. This article focuses on the two starting points of nanomaterials and concrete, combining nanomaterials. In the research progress and results in concrete, the difference in flexural performance and durability of concrete with different content of nano-SiO2 was explored through experiments. Nanomaterials have become a key issue in the field of civil engineering and building materials. The study of nano-material modified concrete not only has great scientific research significance for the working principle and characteristics of nano-modulated concrete, but also creates the possibility for the application of nano-modulated concrete in actual construction.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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