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Numerical Simulation of Influence of Nano Materials on Mechanical Properties of Asphalt Concrete for Dam Based on Neural Network

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Abstract Conventional concrete has higher stiffness and lower flexibility. At the same time, due to some inherent defects, it is easy to crack in use, which may cause damage to the structure seriously. At present, composite materials have been used to improve the performance of concrete, which is a widely used method. Nanostructure refers to the structure with the size of 1-100 nm or above, which has attracted people's attention due to its unique and attractive characteristics, and its use exceeds that of most complexes. In this paper, the mechanical properties of dam asphalt concrete were analyzed, and the theory of concrete mechanical properties was introduced. Then, academic research was carried out and summarized on the two key sentences of mechanical properties of dam asphalt concrete and the impact of nano materials on the mechanical properties of dam asphalt concrete. The preparation, characterization, properties and applications of one-dimensional nanostructured materials were summarized. After establishing the algorithm model, various algorithms were proposed as the numerical simulation analysis of the effect of nanomaterials on the mechanical performance of dam asphalt concrete based on neural networks. Then, the related concepts were proposed. At the end of the article, a simulation experiment was carried out. The results such as the superiority of nanomaterials over conventional materials and the average modulus of elasticity of concrete with nanomaterials of about 33416.3 N/mm2 were obtained from the cubic compressive resistance, axial compressive resistance, modulus of elasticity, and flexural strength. Therefore, this paper has practical significance for this kind of research, which can help this kind of academic advancement and give reference. At the same time, the application of electronic imaging in media requires comprehensive consideration of various factors. Therefore, it has become the focus of academic research.

Index Terms Concrete Mechanical Properties, Nanomaterials Tpye, Neural Networks, Nanostructure Analysis

I. Introduction

Due to the development of various factors and the rapid expansion of the concrete material field, the requirements for concrete structures are getting higher and higher. By adding nanomaterials, the mechanical toughness, intelligent sensing, impermeability, and durability of concrete can be improved. Nanotechnology breaks through the limitation of traditional concrete and endows concrete with new vitality.

Many scholars have conducted in-depth analysis on the mechanical properties of dam asphalt concrete. Benemaran Reza Sarkhani tested the performance of asphalt, coarse aggregate and filler, the main raw materials of asphalt concrete. He studied the performance of asphalt mixture and gave the corresponding mixing parameters [1]. Shaikh Faiz Uddin Ahmed evaluated the residual compressive strength of recycled aggregate concrete after exposure to high temperature and compared it with the compressive strength measured during heating [2]. Bilal Mehvish mixed with biomedical waste ash to partially replace cement to improve the mechanical performance of concrete and compared with conventional concrete [3]. Owczarek Mariusz measured the physical properties and thermal parameters of concrete, and proved that the milled corncob reduced the final mechanical properties of the studied concrete [4]. Bheel Naraindas found an increase in the application of basalt fibers for enhancing the hardening performance of concrete. These fibers were incorporated into concrete leading to changes in the hardening state of concrete. However, these fibers had an effect on the correspondent new characteristics of the concrete, especially the compatibility in it [5]. The purpose of Lee Kyung-Ho's research was to examine the compatibility and diverse mechanical performance of concrete using artificial lightweight aggregates made from expanded bottom ash and dredged soil [6]. Daneshfar M concluded that concrete was one of the most widely used construction materials and was friable. The addition of different kinds and contents of fibers affected the ductile behavior and mechanical performance of concrete [7]. The above research has achieved good results. However, with the continuous updating of technology, there are still some problems.

Many scholars have investigated the effect of nanomaterials on the mechanical performance of dam asphalt concrete. Abdul-Hamead Alaa A believed that nanoparticles had unique properties and had received more attention in all fields and civil engineering. The growth of the construction industry requires the development of low-cost and more efficient concrete types while maintaining sustainability [8]. Gowda Raje found that after adding nano alumina, the compressive strength of cement mortar was improved to a certain extent and its fire resistance was significantly improved, but its workability was reduced [9]. Liu Rui compared the infiltration-related properties of nano-SiO2-filled cement slurry with those of a reference cement slurry composed of diverse water and cement ratios in order to find the appropriate conditions under which nano-SiO2 can exhibit remarkable impermeability enhancement and the potential mechanism for this effectiveness [10]. Yoo Doo-Yeol investigated the effect of nanomaterials on the piezoresistive sensing ability of cementitious composites. Three different nanomaterials, multi-walled carbon nanotubes, graphite nanofibers and graphene oxide, were regarded and subjected to cyclic compression tests along with ordinary mortar [11]. Serag Mohamed I considered bond as the interference between the reinforcement and the peripheral concrete, allowing the transfer of tensile stresses from the reinforcement to the concrete. The best way to improve the bond intensity of concrete was to improve the interfacial transition zone between the aggregates and the mortar between the aggregates and the reinforcement. It was concluded that because of the enhancement of mechanical properties, nano-silica had improved the bond intensity in two modes of failure, namely pull-out and splitting [12]. Hosseini Payam tested the results according to the microstructure. The lower enhancement of the mechanical properties of SCC (Stress Corrosion Cracking) samples at higher dosage might be related to the lower efficiency caused by the higher risk of nano montmorillonite particle agglomeration [13]. Murthi P ascertained the intensity performance of high performance concrete made using a ternary blended cement based upon nano-silica and bagasse ash added to Portland cement. Depending on the substitution of the constituent materials, several mixing ratios based on stochastic mixing design were contemplated [14]. The above research shows that the application of nanomaterials based on neural networks has a positive effect, but there are still some problems.

In this paper, the numerical simulation of the effect of nano-materials on the mechanical performance of dam asphalt concrete based on neural network was studied. First, the related principles were described. In the method part, the mechanical performance of concrete and the preparation, characterization, performance and application of nano structured materials were studied. Finally, the experimental analysis was carried out.

II. Principle of Influence of Nano Materials on Mechanical Properties of Concrete

Because nano-materials are composed of many small molecules, and their molecular size and even atomic size are the same, they are very different from other materials with the same chemical composition in terms of mechanics, electricity, magnetism, heat, etc. The nano effect is shown in Figure 1.

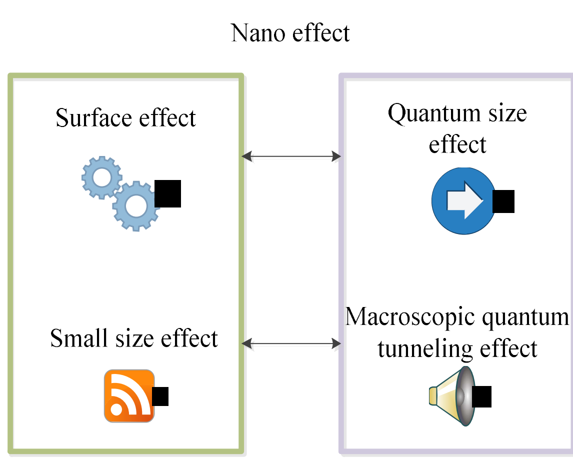

Figure 1: Classification of nanometer effects

(1) Surface effect

Nanomaterials have low size and high surface energy, and they occupy a large proportion in atoms. Smaller particles increase the number of atoms on the surface, largely because of the particle size and larger surface area.

The increase in the amount of surface atoms and insufficient coordination of atoms leads to high surface energy, high surface atomic content, instability, and easy chemical reaction with other atoms.

Due to the dramatic changes in particle size and the proportion of total particles, the surface of nano-particles is greatly affected. The atomic proportion increases with the decrease of particle size. When the diameter of the nano particle is 1 nm, the number of atoms on its surface exceeds 89% and a large number of atoms gather on its surface.

(2) Small size effect

If the size of the ultrafine particle is consistent with the physical properties such as the wavelength of light wave, de Broglie wavelength, the coherent length of superconducting state, and the penetration depth, the periodic boundary condition of the crystal is changed. The concentration of amorphous nanoparticles on the particle surface decreases, resulting in some new micro effects. These phenomena show that the absorption spectrum is obviously improved, and the frequency of plasma harmonics is changed. The transition from magnetic order to magnetic disorder and from superconductivity to normal are also changed. Micro scale effect is caused by small size effect. As the volume and surface of the ultrafine particles become larger, a new set of features are generated, as shown in Figure 2.

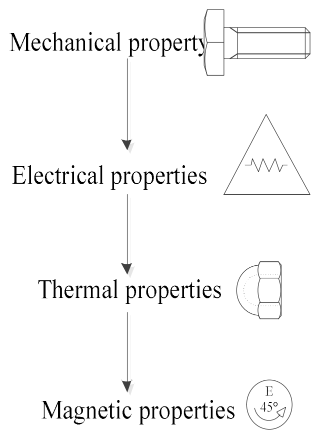

Figure 2: Classification of micro-scale effects

a) Mechanical properties

Because nanoparticles have better dispersion and more interfaces, they can improve their creep, superplasticity, solid solution, sintering temperature, chemical activity and corrosion resistance. The mechanical, thermal, acoustic, optical and electromagnetic properties of nanomaterials are very different from their rough crystals. This material has high hardness, elastic modulus, resistance, specific heat and thermal expansion coefficient, low thermal conductivity, good ductility and soft magnetic properties.

b) Thermal properties

The specific heat and thermal expansion coefficients of nanoparticles are higher than other coarse-crystalline, amorphous materials due to their unreasonable interfacial structure, lower density, and poor interfacial coupling ability. Therefore, it is a very promising technology to use it in the field of thermal storage and nanocomposites.

c) Electrical properties

As the number of atoms on the grain boundary interface increases, its resistivity increases, which leads to the size effect of metals. Therefore, the quantum channel and coulomb retardation of nanoparticles can be used to develop a kind of ultrahigh speed, ultrahigh capacity, ultramicro, ultra-low power consumption nano device.

d) Magnetic properties

Superparamagnetism is the obvious difference between ultrafine particles and large particles in magnetism. Magnetic super particles have high coercivity and are widely used in magnetic tape, magnetic disc, magnetic card and other fields. Superparamagnetic force can make ultra-fine magnetic particles into various types of magnetic fluids.

(3) Quantum size effect

Because the maximum occupancy and minimum orbital energy level of nano semiconductor particles are discontinuous, this phenomenon is called quantum level effect. Quantum level effects can well explain a series of properties that are completely different from macroscopic properties.

(4) Macroscopic quantum tunneling effect

The movement of microscopic particles in the barrier is called a tunnel. Tunneling effect exists in the magnetization and magnetic flux of quantum coherent devices. Therefore, the macroscopic quantum tunneling phenomenon is deeply studied, which lays the foundation for the foundation and engineering application. It specifies the time limit for storing information on magnetic tape. Quantum size effect and tunneling effect have become the basis for the development of microelectronic technology, and have also brought new restrictions to the precision manufacturing of current microelectronic products.

III. Methods of Nano Materials in Concrete Mechanical Properties Based on Neural Network

(1) Mechanical properties of concrete with nano materials

Some materials about nano materials are summarized for analysis, as shown in Figure 3.

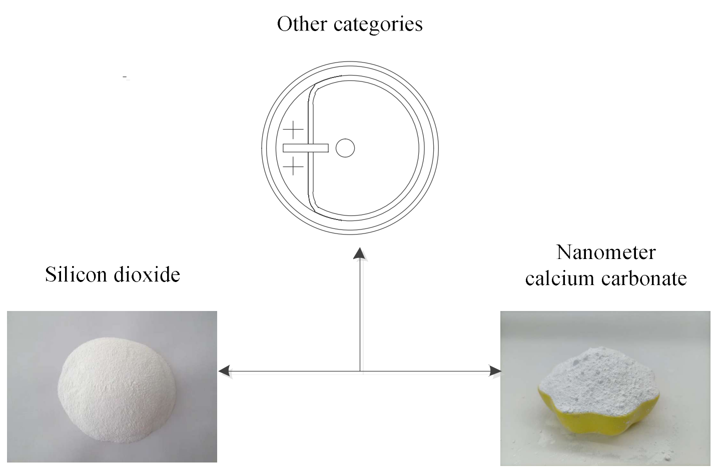

Figure 3: Material analysis of nanomaterials types

a) NSD

Nano-silicon dioxide (NSD) can promote the hydration reaction to increase the hydration rate, and its crystal and filling properties are good. Therefore, it has attracted much attention.

When NSD is added to concrete, its good filling capacity increases its density. NSD has high activity and combines with hydration products to form a new type of hydrated calcium silicate gel. To some extent, NSD can use calcium hydroxide to accelerate hydration and improve its mechanical properties. The compressive strength and splitting tensile strength of NSD cement are tested. The results show that the compressive strength of NSD is obviously improved when the content of NSD is 0~1.5%.

The compressive strength of NSD treated concrete and steel fiber concrete under high temperature has been significantly improved. However, the mechanism of NSD in concrete, such as the rational application of NSD, has not yet been unified.

b) NPCC

Nanometer Precipitated Calcium Car-bonate (NPCC) has been widely used in plastic and paint industries. Although the activity of NPCC is very low, its nanostructures are still comparable to nanomaterials. Moreover, because its cost is very low, many construction projects have chosen it.

Some experiments show that NPCC has an effect in the microstructure of concrete and greatly promotes its hydration rate and compressive strength. After adding NPCC, the compressive intensity and splitting intensity of concrete are obviously improved.

c) Other categories

With the development of nanotechnology, there are more and more kinds of nano-materials, such as nano titanium dioxide, $Fe2O3$ nano, $Al2O3$ nano materials, etc. Many scholars have discussed its influence on the mechanical performance of concrete.

The findings suggest that nano materials has accelerated the formation of cement matrix and improved its flexural capacity. $TiO2$ nano powder also plays a role in improving the microstructure of concrete. In addition, some scholars have conducted experiments on the influence of $Fe2O3$ nanoparticles in concrete. It is found that $Fe2O3$ nanoparticles can form a new cylindrical structure on the surface of concrete, thus significantly improving the compactness of concrete. Others have studied the mechanical properties of nano Al2O3 in concrete through experiments. It is found that nano Al2O3 has significantly increased the compactness of concrete. The interface transition zone has been significantly increased, and its intensity and toughness have been significantly improved. The mechanical performance of concrete mixed with modified carbon nanotubes are tested. The fingdings show that when the cement content is the same, the compressive intensity and cracking intensity increase with the increase of carbon nanotubes content. However, the compressive intensity and cracking intensity decrease when the cement content exceeds 0.3%.

In the dispersion process, there are still many problems in the aspects of dispersant, ultrasonic dispersion and addition of dispersants. At present, there is no unified dispersion system and no better dispersion method. In practical engineering, concrete has high fluidity. Therefore, how to coordinate the relationship between them is very necessary. The effect of the particle size of nanoparticles on their mechanical properties cannot be ignored. However, the size of nanoparticles selected in the existing research is different, and there is no relevant research at present. Different nano materials have little effect on the mechanical performance of concrete. Others have studied the mechanical performance of nano concrete under high temperature.

(2) Preparation, characterization, properties and applications of nanostructured materials

a) Mechanical

After adding nano materials, the mechanical performance of cement concrete are increased and the corresponding internal deformation and cracks are reduced. In addition, the mechanical performance of cement concrete can be significantly enhanced, such as wear resistance, conductivity, thermal conductivity, piezoresistive intelligence, self reinforced damping, etc. However, at present, the performance of different types of concrete nano materials has not been fully understood, and the research on the composite technology and performance of different types of nano composites is even less. However, with the rapid development of nanotechnology, there are more opportunities to apply it to all parts of the world, thus promoting the healthy development of the concrete industry.

b) Sensitivity

Nanomaterials are macromolecular substances that are very sensitive to the external environment [15]. These characteristics make it have a very bright development path in sensors, electrochemistry, gas adsorption and photocatalysis. As an excellent semiconductor and photocatalyst material, TiO2 can absorb nitrogen oxides and sulfides in the air on the cement floor. It is suitable for cement walls to decompose formaldehyde in indoor organic coatings. Therefore, anatase is the most suitable one in terms of cost, efficiency and environment. Nano-TiO2 can not only play the role of photocatalysis, but also improve the microstructure, permeability resistance, wear resistance and other physical properties of concrete.

IV. Related Utilization Algorithm of Simulation

(1) Neural network algorithm

$$F = \frac{1}{1+\overline{E}} \tag{1}$$

$$\overline{E} = \frac{1}{m}\sum_{j=1}^{m}\frac{(d_n - y_n)^2}{2} \tag{2}$$

Among them, m is the corresponding network output node d_n. y_n is the required output and actual output of the output layer.

Each weight of the network is determined randomly according to the following formula:

$$\omega + e^{1-\partial} \tag{3}$$

(2) Material mechanical property algorithm

It is assumed that the nanoscale solid phase is expressed by the strength standard:

$$F = \sigma_d + T(\sigma_m - h) < 0 \tag{4}$$

The parameter T represents the friction force, and h represents the static tensile strength of the nano solid phase. The third-order nonlinear homogenization and modified secant method are adopted to obtain an approximate macroscopic strength criterion:

$$F = \frac{A + \frac{2\rho}{3}}{1 + \frac{2\rho}{3}} \sum 2d + B \sum 2m + C \sum m \tag{5}$$

The coefficients are as follows:

$$A = \frac{1 + \frac{2f}{3}}{T^2} \tag{6}$$

$$B = \frac{\frac{3}{2} + f}{T^2} \varphi + \frac{3f}{2T^2} - 1 \tag{7}$$

$$C = 2(1 - f)(1 - \varphi)h \tag{8}$$

φ is large porosity, and f is small porosity of nanometer scale. T is the failure intensity that can be measured by the relationship.

V. Numerical Simulation Experiment on the Influence of Concrete Mechanical Properties

The experiment shows that the numerical simulation analysis of the effect of nano-materials on the mechanical performance of asphalt concrete dam based on neural network is carried out in this paper. The water conservancy dam in a city is selected as the experimental target. Four samples of asphalt concrete used in the dam are collected and compared with traditional fusion and nano material fusion. Asphaltic concrete takes prism of 150mm×150mm×300mm as the standard specimen. The experiments are summarized and discussed from four aspects: cube compressive intensity, axial compressive intensity, elastic modulus and flexural intensity. Table 1 shows the strength experimental analysis of C45 concrete for experimental reference.

Table 1: Strength experimental analysis of C 45 concrete concrete

/	Code	Type	Strength	
			3d	7d
C45 concrete	First copy	River sand	21.8	24.8
	Second copy	Artificial sand (content: 11%)	25.8	26.1
	Third copy	Artificial sand (14%)	27.3	28.1
	Fourth copy	Nanoparticles+river sand	30.1	30.5

(1) Cube compressive intensity

The standard compressive intensity of concrete cube is 30N/mm2 or 30MPa. The first asphalt concrete is used to compare the cube compressive intensity of concrete mixed with traditional materials and concrete added with nano materials in the dam, as shown in Figure 4.

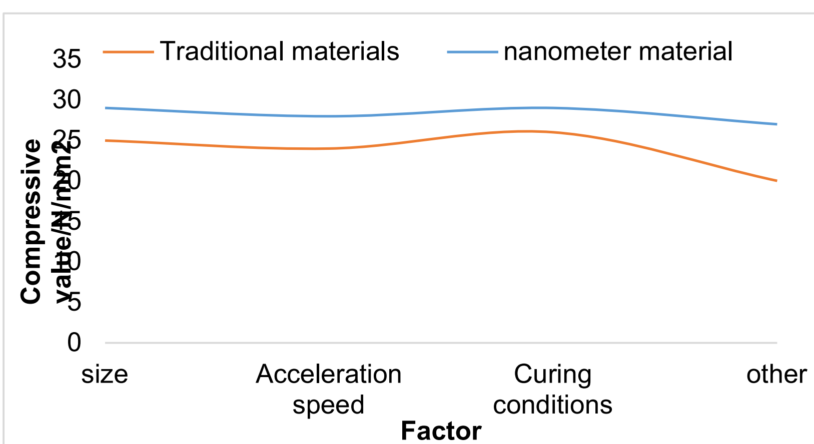

Figure 4: Comparative analysis of the cube compressive intensity of the concrete under the two materials

According to Figure 4, four factors that can affect the compressive intensity of the cube are listed. In traditional materials, the cube compressive strength under the influence of size on concrete is 25. The cube compressive strength is 24 under the influence of accelerated speed on concrete. Under the influence of curing conditions on concrete, the cube compressive intensity is 26. The cube compressive intensity under the influence of other factors on concrete is 20. Through simple calculation, it is concluded that the average compressive intensity of concrete cube under the influence of these four factors is 23.75. After adding nano materials, the cube compressive intensity is 29 under the effect of size on concrete. The cube compressive intensity is 28 under the influence of accelerated speed on concrete. Under the influence of curing conditions on concrete, the cube compressive intensity is 29. The cube compressive intensity under the influence of other factors on concrete is 27. Through simple calculation, the average compressive intensity of concrete cube under the influence of these four factors is 28.25. It can be seen that the cube compressive intensity of concrete with nano materials is the closest to the standard. Therefore, it can be seen that the cube compressive intensity is improved after adding nano materials.

(2) Axial compressive intensity

The axial compressive intensity of concrete is also called prism compressive intensity. The manufacturing and maintenance of standard prisms are basically the same as those of standard cubes, but their axial compressive intensity is obviously inferior to that of the cube. The standard value is 50 MPA to 55 MPA. The second asphalt concrete is used to compare the axial compressive intensity of concrete mixed with traditional materials and concrete added with nano materials in the dam, as shown in Figure 5.

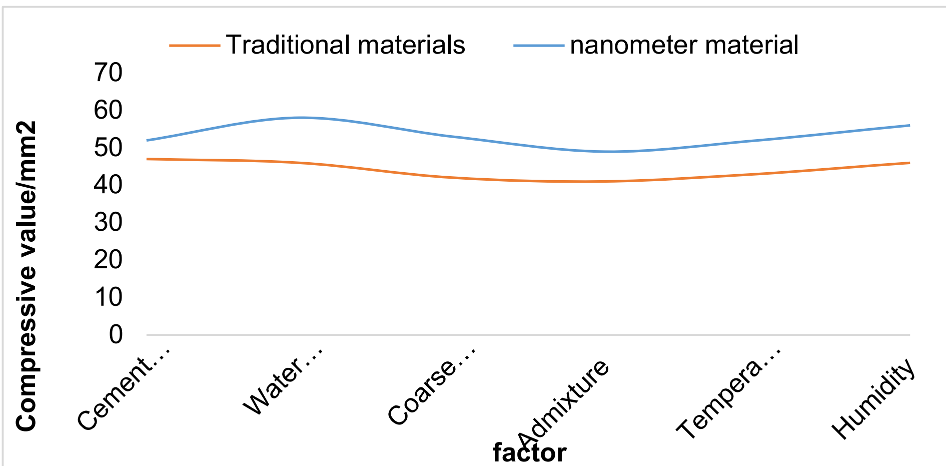

Figure 5: Comparison of the axial compressive strength of the two materials in the dam

From Figure 5, a total of six factors that can affect the axial compressive strength are cited. Among the conventional materials, the axial compressive strength is 47 under the condition of cement strength, 46 under the condition of water-cement ratio, 42 under the condition of coarse aggregates, 41 under the condition of admixtures, 43 under the condition of humidity, and 41 under the condition of humidity. The axial compressive strength is 41 under the effect of temperature on concrete, 43 under the effect of humidity on concrete, and 46 under the effect of humidity on concrete. The axial compressive strength is 52 under the influence of cement strength, 58 under the influence of water-cement ratio, 53 under the influence of coarse aggregates, 49 under the influence of admixtures, 52 under the influence of temperature, and 52 under the influence of humidity. The average compressive strength of the cube of concrete under the influence of these four factors is 44.2. It can be seen that the cube compressive strength of concrete with the addition of nanomaterials is closest to the standard. Therefore, it can be learned that the axial compressive strength has increased after the addition of nanomaterials.

(3) Elastic modulus

It is known that the type of concrete used for this dam is C45 concrete, and the standard value is 33500N/mm2. The third asphalt concrete is used to analyze the elastic modulus of concrete of the two materials, as shown in Figure 6.

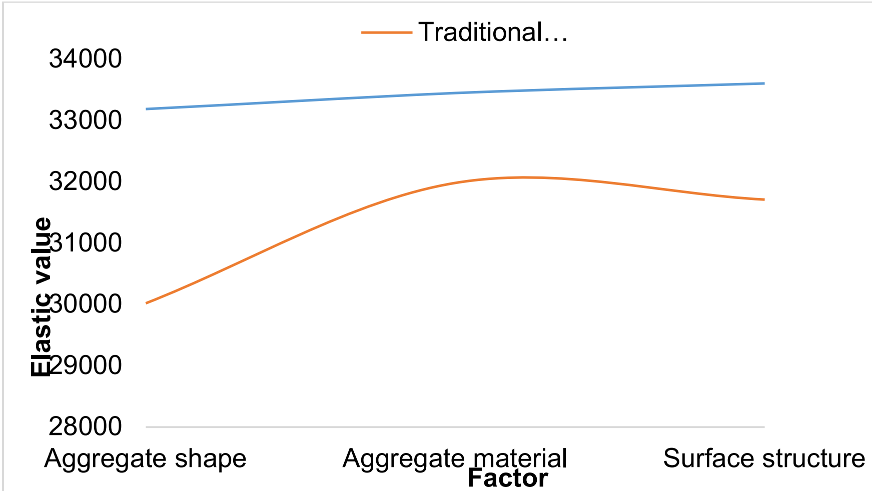

Figure 6: Flexible modulus of concrete of two materials

It can be learned from Figure 6 that the trend of the two curves in the broken line chart is: the curve of traditional materials rises first and then decreases, and the curve of nano materials rises in a straight line. Among them, the surface structure has the greatest impact on the elastic modulus of concrete under the two materials, and the maximum impact on the elastic modulus of concrete under the traditional materials is 31710N/mm2. The maximum influence of elastic modulus of concrete with nano materials is 33610N/mm2. Through calculation, the average elastic modulus of these three factors for concrete made of traditional materials is 31,239N/mm2, and the average elastic modulus for concrete made of nano materials is about 33,416.3N/mm2. Therefore, it can be learned that the elastic value increases after adding nano materials.

(4) Flexural intensity

The flexural intensity of concrete refers to the maximum bending moment that concrete can withstand under the action of bending moment. Generally, the flexural intensity of concrete is about 20% of its cube. 150mm×150mm×300mm small beam is took as the standard test piece. The fourth asphalt concrete is used to compare the flexural intensity of concrete under the two materials, as shown in Figure 7.

The bending intensity is calculated as follows:

$$f_f = \frac{FL}{bh^2} * 1.5 \tag{9}$$

In the formula, f is the bending strength. F is the failure load in bending. L is the distance between two fulcrums. b is the cross-sectional width of the specimen. h is the cross-sectional height of the specimen.

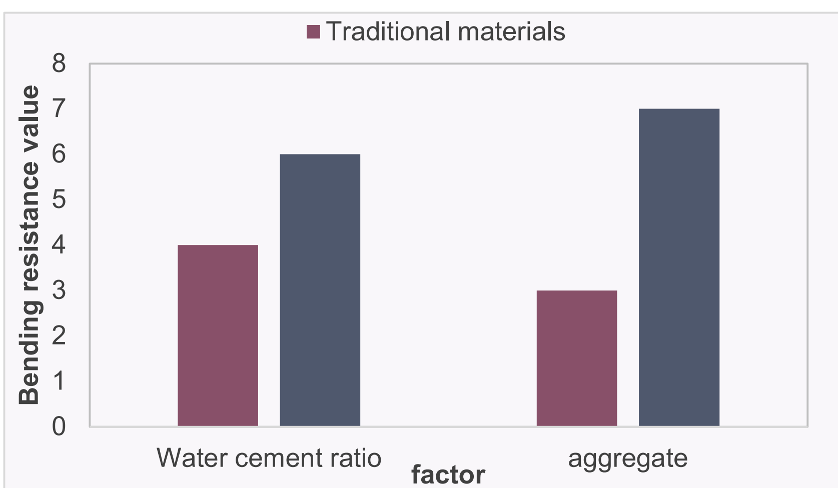

Figure 7: Comparison of the antifolding strength of the concrete under the two materials

It can be learned from Figure 7 that in traditional materials, the flexural intensity is 4 under the effect of water-cement ratio on concrete and 3 under the influence of aggregate on concrete. Among nanomaterials, the flexural strength is 6 under the effect of water cement ratio on concrete and 7 under the influence of aggregate on concrete. In combination with the concrete cube compressive strength standard of 30N/mm2 or 30MPa in Experiment 1, the average flexural strength of concrete under the effect of two factors of traditional materials can be calculated as 3.5. The average flexural strength of concrete under the effect of two factors under nano materials is 6.5, and the average value of combined flexural strength is 6. It is not difficult to find that the flexural strength of concrete with nano materials is close to the average value.

To sum up, the influence of nanomaterials based on neural network on the mechanical properties of asphalt concrete of dam is numerically simulated and analyzed in this paper. By discussing the influencing factors of the above four concrete characteristics, it is concluded that nano materials are better than traditional materials in all aspects.

VI. Conclusion

In this paper, the influence of nano materials of neural network on the mechanical performance of dam asphalt concrete was analyzed by numerical simulation, and the corresponding method was proposed. At the same time, 150mm×150mm×300mm prisms was used as standard specimens for simulation experiment analysis. Four concrete raw materials, cube compressive intensity, axial compressive intensity, elastic modulus and flexural intensity, were studied in combination with relevant factors. It was concluded that cube compressive strength, axial compressive strength, elastic modulus and flexural strength have been improved after adding nano materials. Therefore, the concrete with nano materials has advantages over the concrete with traditional materials in many aspects, which is worth considering in many construction industries.

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