Research Article

The Application of Nano-Calcium Carbonate in the Technology of Improving Road Petroleum Asphalt

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Nano-calcium carbonate is a new type of nanomaterial, which has great influence in many fields. In order to explore the influence of nano-calcium carbonate on petroleum asphalt, an experiment was designed to analyze the application of nano-calcium carbonate in improving road petroleum asphalt technology. This article explores the methods of preparing nano-calcium carbonate and petroleum pitch, understands the characteristics of the two materials, and then draws two methods of mixing nano-calcium carbonate and petroleum pitch: one is freezing and disintegrating, and the other is stepwise mixing fusion. In this paper, the fusion-modified asphalt is subjected to grouping experiments on the prediction model and "three indicators." The experimental results show that with the increase in nano-calcium carbonate, the ductility of the modified asphalt decreases, the softening point increases, and the penetration is 15% reaching the maximum value. Nano-calcium carbonate is very suitable for improving road petroleum asphalt.

1. Introduction

As an inorganic functional filler, nano-calcium carbonate is widely used in all fields, but various industries have different requirements for the performance indicators of nano-calcium carbonate. With the widespread application of modified asphalt, the international community’s evaluation methods for high-temperature performance of asphalt have become the focus of controversy and the focus of research. To develop high-quality asphalt products, it is necessary to study the chemical composition of the asphalt itself. Petroleum asphalt is the most complex part of crude oil and the most important part of crude oil, for the development level of science and technology. Due to technical limitations, people still cannot fully understand the chemical structure of asphalt, all the inherent properties of asphalt roads, and the relationship between physical and chemical characteristics and road performance. Therefore, the limitation of the scope of professional research and the influence of cross-professional scope are restricted. In order to study the influence of nano-calcium carbonate on petroleum asphalt and to better improve the road environment, this article has launched a study on it.

Barrett et al. found that the electron optics in both technologies provide a spatial resolution of tens of nanometers. And he introduced the application examples of ferroelectric thin film and single crystal research [1]. He studies the structure of ferroelectric materials, which is different from the applications of ferroelectric materials studied in this paper. In order to improve the efficiency of next-generation ferroelectric (FE) electronic devices, new technologies for controlling ferroelectric polarization switching are required. Although most previous studies have attempted to induce polarization switching through the excitation of phonons, these experimental techniques require complex and expensive terahertz sources and have not been completely successful. Lian et al. proposed a new mechanism to switch FE polarization quickly and efficiently through laser tuning of the underlying dynamic potential surface. Using time-dependent density functional calculations, he observed ultra-fast switching of FE polarization within 200 fs in BaTiO3 [2]. The new mechanism proposed by Lian has greatly improved the efficiency of ferroelectric electronic equipment, but it has little effect on the research and application of ferroelectric materials in this paper. Xi
et al. studied the effects of filler content and operating conditions on the microstructure and morphology of iPP and iPP/nano-CaCO₃ microporous samples. The results show that the iPP/nano-CaCO₃ composite material can effectively reduce the bubble size of the microporous sample while increasing the pore density, especially in the case of high CO₂ concentration and back pressure, low mold temperature and injection speed, and high filler content [3]. The main research is polypropylene/nano-calcium carbonate composite materials, and this article mainly studies the influence of nano-calcium carbonate in petroleum asphalt. Liu has established a new type of nano-platform (GNS@CaCO₃/ICG), which is composed of gold nanostars coated with calcium carbonate loaded with ICG to combine the photothermal properties of gold nanostars (GNSs) with indocyanine green (ICG) and the photodynamic properties are combined [4]. This platform is very helpful in reducing the side effects of drug inactivation. Although it is based on the research of nano-calcium carbonate, it is mainly aimed at drug inactivation. Sadeghi Ghari and Jalali Arani use different amounts (0, 5, 10, and 15 parts per 100 parts rubber, phr) of nano-CaCO₃ (nano-CaCO₃) and organo-clay (OC) to prepare nanocomposites based on natural rubber (NR) by the melt mixing process [5]. Some people want to analyze the reasons for the formation of asphalt-resin-paraffin deposits in high-viscosity oil well casings and tubing. Bogdanovich et al. proposed the electrochemical concept of technology for removing sediments through highly concentrated induction heating of pipelines without interrupting oil production and described the necessary set of equipment [6]. Research on petroleum asphalt is very in-depth, and it will be better if the influence of nano-calcium carbonate on petroleum asphalt is studied. Warm mix asphalt (WMA) is widely used in pavement engineering due to its economic and environmental protection characteristics. Due to the lack of microscopic research on WMA, it is difficult to understand its mechanical behavior and mechanism on a macro scale, which ultimately hinders the improvement of WMA performance. Yang et al. used atomic force microscopy (AFM), a promising microscopy technique, to study the influence of wax-based warm mix agents on the microstructure and micromechanical properties of asphalt at different temperatures [7]. They studied the effect of warm-mix asphalt on the performance at different temperatures. It would be more in line with the theme if nano-calcium carbonate can be added to it. In view of the problems of high oil viscosity, slow steam chamber expansion, low oil production rate, and low oil-to-gas ratio in the super-heavy oil block developed by using dual horizontal well steam-assisted gravity drainage (SAGD) at high temperature in China, Wu et al. adopted a solvent-assisted method. A crude oil viscosity reduction test was carried out, and on this basis, the analytical equation and similar laws of solvent swelling SAGD (ES-SAGD) were derived [8]. Its research is related to crude oil experiments, but this article mainly studies the influence of nano-calcium carbonate on petroleum pitch.

The innovation of this article is to explore two methods of fusing nano-calcium carbonate and petroleum asphalt, one is freezing and disintegrating and the other is stepwise mixing and fusion, and the improvement is made through predictive models and “three major indicators.”

2. Fusion Method of Nano-Calcium Carbonate and Petroleum Pitch

2.1. Application of Nano-Calcium Carbonate. The particle size of nano-scale calcium carbonate [9] is between 0.01 and 0.1 μm, and it has become a new type of ultrafine solid material. The main production process is shown in Figure 1. Due to the ultrafine particles, the electronic structure of the crystal and the surface has changed. Ordinary calcium carbonate is different in quantum size, small size, surface, and macroscopic quantum effects. It is better than previous materials in terms of magnetism and catalyst. The main purpose is shown in Figure 2.

2.1.1. Application of Nano-Calcium Carbonate in Plastics. In terms of plastic processing and manufacturing [10], ordinary calcium carbonate products can only be used as general fillers, but in addition to being used as fillers, modified calcium carbonate also functions as an active agent [11] and a strengthening agent [12]. At the same time, the amount of plastic products should be increased, the hardness and strength of the products should be improved, the plastic processing performance should be improved, and the heat resistance, bending strength, elastic modulus, and other performance indicators of plastic products should be improved.

2.1.2. Application of Nano-Calcium Carbonate in Rubber. Nano-calcium carbonate is mainly used in tires, wires, cables, rubber products in the rubber industry [13], etc., which can increase the amount of rubber, cut costs, and improve processing performance. At present, the calcium carbonate used in rubber is mainly heavy calcium carbonate and ordinary light calcium carbonate. The application field and scope of nano-calcium carbonate are also expanding. Compared with ordinary calcium carbonate, it has stronger surrender resistance and crack resistance [14]. The nano-calcium carbonate treated by a special process has high surface activity and can freely move electrons under ultraviolet light. It easily reacts with oxygen and organic matter and can kill viruses and bacteria. Therefore, nano-calcium carbonate has a bactericidal effect.

2.1.3. Application of Nano-Calcium Carbonate in Adhesive. Roughly speaking, the adhesive also belongs to the category of rubber [15], and the adhesive is mainly composed of basic rubber, hardener, filler, coupling agent, catalyst, and so on. With the rapid development of China’s real estate, packaging materials, building materials, etc., the amount of glue has increased sharply. As one of the important fillers for glue, nano-calcium carbonate is not only low in price but also compatible. At present, the technology of applying nano-calcium carbonate to polysiloxane is relatively mature, but the technology of applying urethane adhesive has just begun. Polyurethane adhesives not only have excellent adhesion and aging resistance but also have better surface finish than silicone adhesives. Moreover, polyurethane adhesives have...
obvious advantages in the application of pollution-free, good adhesion, and weather resistance.

2.1.4. Application of Nano-Calcium Carbonate in Coatings. Heavy calcium carbonate, light calcium carbonate, and nano-calcium carbonate are widely used in coatings. Compared with heavy calcium and ordinary light calcium, nano-calcium carbonate has a weak coating effect [16]. It can improve concealment, gloss transparency, quick-drying, and coating stability. In some industries, such as automobile coating and construction coating, in order to reduce commercial costs, it is possible to partially or completely replace the expensive titanium dioxide of nano-calcium carbonate. The PVC plastic system mentioned in this article consists of PVC resin, plasticizers, fillers, and other additives. Nano-calcium carbonate can greatly improve the rheology, reinforcement, and impact resistance of the system.

2.1.5. Application of Nano-Calcium Carbonate in Printing Ink. Ink is mainly composed of pigments, binders, fillers, additives, and so on [17]. The modified nano-calcium carbonate has high compatibility with the binder, high gloss, stability, and adaptability, and does not affect the ink factor and drying. According to the performance and other advantages, the quality of the ink can be comprehensively improved and the manufacturing cost can be reduced.

2.1.6. Application of Nano-Calcium Carbonate in Papermaking. As a filler for papermaking, nano-calcium carbonate has a small and uniform particle size and less equipment
wear. While making paper products small and uniform, the particle size is small, the oil absorption and the surface area are large, which contributes to the hardness of the pigment.

On roll paper, nano-calcium carbonate has a high refractive index and high opacity. The cigarette in the roll paper is invisible from the outside, so the amount of nano-calcium carbonate added is about 45%–50% [18]. The CO₂ released by calcium carbonate controls the burning speed to a certain extent and does not extinguish the smoke. At the same time, calcium carbonate can keep the burned ash in its original position and improve the transparency of the air. The content of tar made from paper and cigarettes is reduced.

High-grade physiology products, especially baby products, such as physiology products, napkins, diapers, etc., have a large amount of nano-calcium carbonate, which is mainly used to make polyethylene film with good air permeability. In addition, due to the small particle size of nano-calcium carbonate, it is not sensitive. It hurts the skin and does not give the human body an unpleasant sensation.

2.2. Petroleum Bitumen. The economic development and activation of most countries and regions in the world is first to build convenient roads and secondly to promote sustainable and healthy economic development in the region. The main application areas of petroleum asphalt are shown in Figure 3.

At present, China’s highway paving is divided into two types: asphalt roads and cement roads. The advantages and disadvantages of these two paving properties are different. Compared with cement paving, asphalt paving [19] has the advantages of smooth and seamless surface, less noise, less vibration during driving, convenient maintenance, and suitable for phased road paving. It is used in high-performance highways and cities. Figure 4 shows a manufacturing process that is widely used at home and abroad. Therefore, research on low-cost and high-performance asphalt materials is very important in practice.

2.2.1. The Composition of Petroleum Asphalt. The elemental composition of petroleum pitch is a very important basic data for the composition of heavy crude oil such as petroleum pitch [20]. In light-weight images of petroleum, the content of carbon and hydrogen is generally about 98%–99%. There are only 95 barren hydrocarbon elements in pitch. Except for hydrocarbons and hydrogen, the content of heterogeneous atoms, such as sulfur, nitrogen, and oxygen, is about 5% and the maximum is even 14%. Although the content of heteroatoms is small, the relative molecular
weight of the asphalt road is relatively large and it occupies most of the compounds containing heteroatoms on the asphalt road. In fact, only a small amount of hydrocarbons are composed of carbon and hydrogen. The components of petroleum asphalt are asphalt and solutes, and solutes can be divided into chewing gum, oil, and wax:

1. Asphalt is a dark brown or dark fragile solid, usually in powder form [21]. The solubility of asphalt in benzene solution gradually decreases with the extension of storage time. It can be inferred that the aging cracks produced during the operation of the asphalt road are closely related to the aging process of the asphalt road. At the same time, bitumen may affect the temperature sensitivity of bitumen, and bitumen also exhibits good viscosity at high temperatures. From the above reasons, it can be judged that asphalt is one of the components that should be included on high-quality asphalt.

2. The chewing gum of petroleum pitch is a black or dark brown viscous substance, which is solid or semisolid at room temperature [22]. There are many condensed ring aromatics and heteroatom compounds in colloidal molecules. When using asphalt, in order to make the asphalt fully adhere, the ingredients of chewing gum are indispensable. Moreover, chewing gum also plays an important role in forming the excellent viscoelasticity of petroleum pitch.

3. The oil content in petroleum asphalt is about 40%–50%. Although it can make asphalt have a soft and lubricating effect, the oil content is very sensitive to temperature and is not an ideal component of petroleum asphalt.

4. Wax in petroleum pitch is a solid component that crystallizes out of the distillate oil formed after petroleum pitch is pyrolyzed and distilled under limited conditions. Petroleum asphalt produced in many areas of China generally contains a lot of wax. The content of chewing gum and bitumen in petroleum containing four components is closely related to the depth and generation age of crude oil. The content of chewing gum and asphalt decreases with the depth of the formation. The results show that the older the formation, the more obvious the reduction.

2.2.2. Conventional Performance of Petroleum Asphalt. Petroleum bitumen is the residue after distillation of crude oil, which is generally based on the difference in the degree of refining of the petroleum bitumen components. At room temperature, there are several forms of liquid, semisolid, or solid. The bitter taste of petroleum is generally black and shiny, and, at the same time, it has strong temperature sensitivity:

1. Thermal performance
   As a pavement, road asphalt has to withstand the four seasons, day and night temperature changes. People often hope that the asphalt will not soften in summer to avoid rutting; the road will not be brittle in winter to avoid road asphalt cracking. But in fact, road asphalt will always soften in summer and harden in winter, but the degree of change is different. It can be seen that the performance of road asphalt with temperature changes is its temperature-sensitive performance. China’s highway asphalt roads have many commonly used indicators to characterize their temperature-sensitive performance. For example, penetration-viscosity index, penetration-temperature index, viscosity-temperature index, etc. Molten gel asphalt is a kind of asphalt road with high viscoelasticity and high quality [23].

2. High-temperature performance
At present, in China, the highest temperature in summer can reach 35~40°C, and the highest temperature of road asphalt can reach 60~65°C, which is 25°C higher than the highest temperature. At the same time, continuous high temperature for a long time may cause heavy asphalt pavement. It is quickly destroyed or even deformed under the load of traffic pressure. Road asphalt is a material with greater viscosity and elasticity. However, long-term high-temperature irradiation will also deteriorate the elasticity and increase the plasticity, resulting in a significant decrease in the resistance to deformation. The high-temperature performance of asphalt pavement is not good, so in the high-temperature season in summer, there will be deformation marks such as crowding and rutting. As a result, the service life of the pavement will be shortened, and the driving comfort will also be affected.

(3) Low-temperature performance

Generally speaking, the index reflecting the low-temperature performance of asphalt roads includes Fuller's brittleness point and low-temperature ductility. The temperature at which cracks occur on the asphalt surface is the temperature at which the asphalt pavement causes brittle failure at low temperatures, and is the brittle point of wear. Generally speaking, the low-temperature brittleness of asphalt is determined by the grade of brittleness point. Experiments show that the lower the brittle point,
the better the low-temperature brittleness of the asphalt pavement. Ductility and low-temperature ductility test the cohesion and uniformity of asphalt, and essentially control the wax content of asphalt. Therefore, the low-temperature crack resistance of asphalt roads can be judged based on low-temperature ductility.

### 2.3. Fusion Methods and Prediction Models

#### 2.3.1. Fusion Method

This paper proposes two possible processes for preparing nano-calcium carbonate-modified asphalt, the principle of which is shown in Figure 5. Method 1: firstly, the asphalt is crushed into block particles with a larger specific surface area in a certain form, such as frozen and sheared, and then, a suitable amount of nanomaterial is mixed with the asphalt to prepare nanomaterial-modified asphalt. The principle is to reduce the size of the asphalt matrix and increase the surface area of the petroleum asphalt, so that the modifier and the asphalt form a more effective synergistic system. Method 2: a certain amount of nanomaterials is placed in a container, the flow state of the asphalt is controlled, the asphalt is added while stirring the mixed system, and finally the nanomaterial-modified asphalt is obtained. The principle of this process is to eliminate the difference in content between adjacent areas of the mixture and make it more uniform. Compared with traditional stirring and shearing preparation methods, the two methods proposed in this article have the following advantages:

1. Taking full account of the easy agglomeration characteristics of nanomaterials, it can not only reduce the difference in size between asphalt and nanomaterials but also reduce the difference in content of asphalt and nanomaterials, making it easier to obtain the dispersion and phase of nanomaterials in asphalt. Modified asphalt with good capacity;
2. The mixing method is simple to operate and can be used in combination with the previous polymer processing and molding processes. This is the easiest way to make nanocomposites and is suitable for various forms of nanoparticles.

#### 2.3.2. Forecast Model

**1. Perfect Interface Situation.** To analyze and optimize the structure of composite materials [24], it is first necessary to establish the correlation between the effective properties of the composite material and the microstructure parameters. First, a two-layer embedded model is established. In other words, inclusions of each particle size are wrapped by a matrix of a specific thickness and are regarded as circular inclusions embedded in an infinitely large composite medium.

According to the meso-mechanical model [25], based on the two-layer embedded model [26], as shown in Figure 6, by applying uniform normal stress \( \sigma_r \) and shear stress \( \tau \) on the boundary of \( r=x, r=y, \) and \( r=z \), the stress \( \lambda_{\alpha\beta} \) can deduce the effective shear modulus \( a_0(x) \).

According to the Chinese mechanical model, based on the two-layer embedding model, as shown in Figure 6, the uniform vertical stress \( \sigma_r \) and shear stress \( \lambda_{\alpha\beta} \) are effectively sheared on the boundary of \( r=x, r=y, \) and \( r=z \). The modulus of elasticity \( a_0(x) \) calculation formula is as follows:

\[
\alpha_0 \left( \frac{a_0(x)}{a_1} \right)^2 \mathbf{X} + \left( \frac{a_0(x)}{a_2} \right) \mathbf{Y} + D = 0. \tag{1}
\]

\[
\alpha_0, \alpha_1, \text{ and } \alpha_2 \text{ are the shear modulus of the same medium, matrix, and inclusions, respectively. } x \text{ is the radius of the inclusions, } y \text{ is the sum of the radii of the matrix and the inclusions, } f \text{ is the volume percentage of the inclusions, } f \text{ is the boundary and matrix outside the inclusions, which is the volume fraction of the composite material. If it is a two-dimensional problem, there is the following formula:}
\]

\[
f = \frac{x^2}{y}. \tag{2}
\]

Solving formula (1) can obtain the effective shear modulus and effective elastic modulus \( a_0 \) of the composite material.

Li and Metcalf apply uniform radial stresses \( P, P_0, \) and \( P_1 \) on the boundaries of \( r=x, r=y, \) and \( r=z \) (refer to Figure 7). Based on the principle of total deformation energy equal to Timoshenko’s elastic theory, composite materials can be obtained. The effective modulus of elasticity \( Q_0(x) \) of the material:

\[
Q_0(x) = \frac{Q_1(1-f)(1-y)}{t_1-4Q_2f/Q_1(1-f)(1-y)+Q_1t_2}. \tag{3}
\]

We have:

\[
t_1 = f(1+y)+1-y1, \quad t_2 = (1+y)+f(1-y). \tag{4}
\]

Among them, \( v_0, v_1, \) and \( v_2 \) are the equivalent Poisson’s ratio of the composite material, the Poisson’s ratio of the matrix, and the inclusions, respectively. \( Q_0, Q_1, \text{ and } Q_2 \) are the elastic modulus of equivalent medium, matrix, and inclusions.

According to the relationship between elastic constants,

\[
Q_0(x) = 2(y_1+1)\alpha_0(x). \tag{5}
\]

Combining (3) and (4), we get

\[
Q_0(x) = \frac{2Q_1(1-f)}{t_1-4Q_2f/Q_1(1-f)(1-y)+Q_1t_2+Q_1(1-f)/2a_0}. \tag{6}
\]

Taking the effective shear modulus \( a_0 \) obtained in formula (1) into formula (9), the effective elastic modulus \( Q_0(x) \) of the single-inclusion composite material can be obtained.

**2. The Situation of Imperfect Interface.** Composite materials have a complex mesoscopic structure, and their macroscopic performance is also very different due to the different factors such as the composition, shape, and performance of the
The interface between the matrix and the reinforcement is also one of the main factors that determine the macroscopic properties of the composite material. As a composite material composed of multiphase materials such as blending, aggregate, and fiber, the macroscopic properties of the green mixture are also affected. We view the influence of interface characteristics. In general, the interface between the matrix and the reinforcement is somewhat weakened, and there is no perfectly strangled interface. Therefore, it is very important to take the weak interface into consideration when analyzing the macroscopic characteristics of the green mixture. De Almeida [28] established a mesomechanics analytical model that is simple, easy to program, and calculates for composite materials with spring-type interfaces and interlayer interfaces, which is used to predict the effective elastic properties of composite materials with weak interfaces. The following will describe the model established by Hefni and Ali and use it to predict the effect of MWCNT [29] doping on Liqing and milk green mixtures.

Figure 5: Preparation method of nano-calcium carbonate material-modified asphalt.

Figure 6: Shear modulus prediction meso-level model.

Figure 7: Mesoscopic model of elastic modulus prediction.
the interface between the matrix and the inclusions. This model uses displacement discontinuities to simulate weak boundary surfaces. In other words, assuming that the thickness of the boundary surface layer is zero, the stress on both sides of the boundary surface is continuous, but the displacement on both sides is discontinuous, including the displacement in the tangential direction and the normal. In addition, it is assumed that the discontinuity of the interface displacement and the stress are linear.

\[
\begin{align*}
\sigma_r^1 &= \sigma_r^2 = k_2 \Delta u_r = k_r \left( u_r^1 - u_r^2 \right), \\
\lambda_r^1 &= \lambda_r^2 = k_\theta \Delta u_\theta = k_\theta \left( u_\theta^1 - u_\theta^2 \right).
\end{align*}
\]

(7)

In the above formula, \( x_1, x_2, x_3, y_2, z_2, z_3, i_1, \) and \( i_2 \) are, respectively, undetermined coefficients. Considering the equivalent point of view, the following equation can be obtained

\[
\int_{0}^{2\pi} \left[ \sigma_r^x u_{r\theta} + \lambda_r^{\theta \phi} u_{\theta \phi} - \sigma_r u_r^x - \lambda_r \mu_{r \phi} u_{\theta \phi} \right] y \, d\theta = 0.
\]

(12)

In the formula, \( \sigma_r^x, \lambda_r^{\theta \phi}, u_r^x, \) and \( u_\phi^x \) are the normal stress and shear stress and the normal and hoop displacement of the macroscopically equivalent homogeneous medium at the interface \( r = z (z \rightarrow \infty) \), respectively. From (12), we can get

\[
x_3 = 0.
\]

(13)

Formulas (1) and (2), respectively, represent the matrix and the intervening object. \( k_r \) represents the spring stiffness coefficient in the radial direction, and \( k_\theta \) represents the spring stiffness coefficient in the tangential direction. \( k_r \) and \( k_\theta \) also reflect the strength of the interface. For a perfect interface, the areas of \( k_r \) and \( k_\theta \) are infinite, and when the interface is completely separated and cannot transmit any stress, \( k_r \) and \( k_\theta \) are both, so for general interface conditions, \( k_r \) and \( k_\theta \) are respectively a finite positive number. In other words, when \( k_r \) and \( k_\theta \) are a certain positive number, the interface here is weakened to a certain extent, and the interface is not perfect.

At the same time, because the normal stress and the shear stress are continuous at the interface, and the displacement is continuous at \( r = y \) and discontinuous at \( r = x \), it can be known that \( u_r^{xy} = u_r^{yx}, u_\theta^{xy} = u_\theta^{yx}, \sigma_r^{xy} = \sigma_r^{yx}, \lambda_\theta^{xy} = \lambda_\theta^{yx}, \sigma_r^{0x} = \sigma_r^{1x} = k_r (u_r^{1x} - u_r^{0x}), \lambda_\theta^{r \phi} = \lambda_\theta^{\phi \theta} = k_\theta (u_\theta^{1x} - u_\phi^{1x} - u_\phi^{0x}) \). \( f \) is the volume ratio, \( f = x^2/y^2 \): \( k_c \) in the two-dimensional case is the radial spring stiffness coefficient, which is determined according to the degree of interface weakening. For the time being, \( k_c \) is considered to be a known parameter.

After sorting out the continuous conditions of displacement, the following equations can be obtained by combining (13).
Figure 8: The influence of different temperatures on the penetration of the modified asphalt. (a) The influence of nano-calcium carbonates doping on the penetration of modified asphalt at 25°C. (b) The effect of nano-calcium carbonates doping on the penetration of modified asphalt at 15°C. (c) The effect of nano-calcium carbonates doping on the penetration of modified asphalt at 30°C.
3. Exploring the Impact of the Three Major Indicators of Petroleum Asphalt after Mixing

The evaluation method of nano-calcium carbonate-modified petroleum pitch is based on the evaluation method of petroleum pitch. The “three major indexes” [30] and the aging performance test method all adopt the standard methods specified in the industry standard of the People’s Republic of China “Highway Engineering Asphalt and Asphalt Mixture Test Regulations” (JTGE20-2011).

In this experiment, the method of shearing and mixing was used to mix nano-calcium carbonate with petroleum asphalt, and the influence of the addition of modified asphalt on the three indexes of petroleum asphalt under shearing conditions were investigated. The experimental results are as follows:

3.1. The Influence of Modified Asphalt Content on Penetration. The penetration of asphalt is one of the important indicators that reflect the performance of asphalt. It can reflect the viscosity of asphalt under certain conditions and effectively indicate the softness and hardness of asphalt and whether it is sticky. Analyzing the change trend in Figure 8 shows that the addition of nano-calcium carbonate has an effect on the penetration of the modified asphalt. In the range of 10% to 20%, the penetration first increases with the increase of the asphalt doping. It becomes smaller again, and the maximum value is reached when the dosage of nano-calcium carbonate is 15%.


\[
\alpha_1[2 + z_3] + \alpha_0[4x_2v_1 - i_2 + 4z_2(v_1 - 1) - y_2] = 0,
\]

\[
\alpha_1[-2 + z_3] + \alpha_0[2x_2(2v_1 - 3) + i_2 + 2z_2(1 - 2v_1) - y_2] = 0,
\]

\[
2 - 3z_3 - i_2 + 4z_2 + 3y_2 = 0,
\]

\[
i_1 - i_2 + \frac{4z_2}{f} + \frac{3y_2}{f^2} = 0,
\]

\[
x_1 - x_2 + \frac{z_2}{f} + \frac{y_2}{f^2} = 0,
\]

\[
2\alpha_1 = \frac{xk_r}{a_2} \left( -4x_2v_1f + i_2 + \frac{4z_2}{f} - \frac{4z_2v_1}{f} + \frac{y_2}{f^2} + \frac{4x_1v_1f - i_1a_1}{a_2} \right),
\]

\[
-2(i_1 - 6x_1f)\frac{\alpha_1}{a_2} = \frac{xk_0}{a_2} \left( 6x_2f - 4x_2v_1f - i_2 - \frac{2z_2}{f} + \frac{4z_2v_1}{f} + \frac{y_2}{f^2} + \frac{6x_1a_1f - i_1a_1}{a_2} \right).
\]

3.2. Influence of Modified Asphalt Content on Ductility. Analyzing the data in Table 1, it can be seen that as the amount of nano-calcium carbonate added increases, the ductility of the modified asphalt decreases significantly.

3.3. The Influence of Coal Tar Pitch on Softening Point. It can be seen from Table 2 that as the amount of modified asphalt increases, the softening point of modified asphalt gradually rises. After adding nano-calcium carbonate, the high temperature stability of petroleum asphalt has been improved.

To sum up, under the condition of shear mixing, with the increase of nano-calcium carbonate, the ductility of modified asphalt decreases and the softening point increases, and the penetration reaches the maximum when it reaches 15%.

4. Discussion

The main purpose of this article is to explore the improvement factors of petroleum asphalt after adding nano-calcium carbonate. By exploring the production methods of nano-calcium carbonate and petroleum asphalt, two methods of mixing nano-calcium carbonate and petroleum asphalt are found. After dispersing and fusing, one is to stir and fuse little by little.

Under the condition of high-efficiency shearing and mixing, with the increasing amount of nano-calcium carbonate added, the softening point of the modified asphalt continues to rise, and the penetration degree has a maximum value when the addition amount of the modified asphalt is 15%. The ductility decreases significantly with the increase of the modified asphalt content.
5. Conclusions

In order to study the influence of nano-calcium carbonate on the technology of improved road petroleum asphalt, this paper analyzes the preparation process of nano-calcium carbonate and petroleum asphalt, and finds out two methods that can mix nano-calcium carbonate and petroleum asphalt to make modified asphalt. One is to add nano-calcium carbonate to fuse after freezing and dispersing, the other is to add a little nano-calcium carbonate and then add petroleum pitch, then stir and fuse, repeating this process until all fuses. Then through experiments combining the prediction model and the “three major indicators,” the experimental results show that the penetration reaches the maximum at 15%, and with the increase of nano-calcium carbonate, the ductility decreases and the softening point increases.

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.

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