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Application of Nanomaterials in Subgrade and Pavement

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Abstract: With the continuous progress of social science and technology, there are increasingly more kinds of high-tech materials that can be used in the construction of subgrade and pavement. Among them, the application of nanomaterials plays a commendatory role, improving the quality of pavement. Based on this, this paper analyzes the characteristics of nanomaterials and puts forward specific measures for the application of nanomaterials on the basis of further exploring the working principle of nanomaterials in subgrade and pavement, so as to promote the further development of subgrade and pavement construction.

Keywords: Application of nanomaterials; Construction of subgrade and pavement; Asphalt mixture

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1. Introduction

In the course of urbanization, the smooth operation of transportation network is critical to the overall construction of the city. In order to ensure that urban traffic operates smoothly, it is imperative to optimize the construction of subgrade and pavement in a comprehensive manner [1]. It has been found that the application of nanomaterials greatly improves the quality of subgrade and pavement. Therefore, nanomaterials should be used aggressively in the daily construction of roads, so as to effectively promote the development of road construction.

2. Nanomaterials and their properties

Nanomaterials refer to materials in which at least one of its characteristic dimensions in its three-dimensional space is in the nano scale range or composing of nano scale range internal structures as basic structural units. In view of its special structure along with its special physical and chemical properties, this material is widely used in various fields, including medical, engineering, and military fields. The research and development of new high-performance nanomaterials are usually carried out in the nano spatial scale. By naturally changing the arrangement order of material atoms and molecules, they have the characteristics of nanomaterials. Nanoparticles have many properties: chemical, magnetic, electrical, optical, thermal, and mechanical. They are completely different from macro objects, single independent atoms, or molecules. The special properties of nanoparticles dictate their unique nano effects [2]. In general, nanomaterials may be more suitable for various industries compared to other materials because of their unique essential characteristics. Nanomaterials have five basic characteristics. Their nano effects can be manifested as small-size effect, surface effect, quantum size effect, macro quantum tunnel effect, and dielectric

confinement effect. Based on the unique characteristics and effects, nanomaterials can be used in aircraft shielding, sensors, UV absorption, and many other industries. In subgrade and pavement construction, nano materials can be effectively applied to soft soil solidification and asphalt optimization to improve the firmness of subgrade and optimize pavement construction.

3. Application principles of nanomaterials in subgrade

The application of nanomaterials in subgrade is mainly reflected in the solidification treatment of soft, muddy soil. Since the construction quality of subgrade affects road stability, its soil needs to be fully strengthened in the construction process. Therefore, using nanomaterials for the construction of soft, muddy soil roadbed is an effective optimization measure to improve the strength of subgrade. During the solidification of soft, muddy soil, the construction personnel has to mix and stir the cement mixture, soft muddy soil, water, nano silica powder, nano alumina, and other materials in specific proportions, so as to obtain high-strength cement-solidified soil, thus providing high-quality material foundation for the improvement of subgrade stability [3]. The history of cement-solidified soil development is explored. The traditional way of obtaining high-strength cement-solidified soil is to increase the strength of the solidified soil by adding a high dose of cement to soft soil by increasing the proportion of cement. However, the final cement-solidified soil obtained under such working conditions will crack the roadbed in the application process; in addition, the cost of solidified soil mixed with high dose of cement is high, thus reducing the economic benefit of subgrade construction. With the continuous development of science and technology, the quality of high-strength cement-solidified soil has improved in recent years. Through the efforts of researchers and experiments in recent years, it has been found that the addition of nano silica powder, nano aluminum oxide, and other materials to cement-based materials in specific proportions promotes better cement hydration reaction, and subsequently forms a more stable microstructure at the interface between cement stone and aggregate. At the same time, when the cement-based structure is constructed with the addition of nano materials, the micropores in the structure can be fully filled. In short, under the mixing action of nano materials, the production quality of cement-solidified soil and the effect of construction with related structures can be well guaranteed; the overall quality, strength, and properties of subgrade construction materials can also be improved to a great extent.

4. Specific applications of nanomaterials in pavement

4.1. Nano-modified asphalt

Nano-modified asphalt modifier includes nano calcium carbonate, nano ferric oxide, nano-layered silicate, and other chemical agents. This kind of modifier can improve the performance of asphalt by directly adding asphalt in proportion, so as to promote the quality of asphalt pavement construction. In addition to the above modifiers, nano titanium dioxide is a better asphalt modifier. Based on research at home and abroad, nano titanium dioxide, as a modifier, improves the rutting resistance of asphalt pavement through the mixing process with asphalt. At the same time, if nano titanium dioxide modifier is mixed with asphalt materials in a reasonable proportion, the construction of pavement using this kind of modified asphalt will give rise to higher fatigue strength. It can be seen that the addition of nano carbon dioxide can increase the hardness and viscosity of modified asphalt, which helps to promote the optimization of subgrade and pavement construction. In terms of the optimization effect of nano calcium carbonate modifier, it can be appreciated from experiments that the use of nano calcium carbonate can improve the softening point of asphalt; in addition, the penetration of asphalt will decrease with the use of nano calcium carbonate. Overall, the stability of asphalt materials improves under the action of nano calcium carbonate. The effect of nano-layered silicate modifier on the properties of asphalt materials is analyzed. The addition of this kind of modifier can alleviate certain problems, including aging, flow deformation, and use damage. In addition,

the use of nano-layered silicate can improve the high-temperature elasticity of asphalt mixture and the pavement's rutting resistance. In general, the mixing of different kinds of modifiers with asphalt plays different roles, so as to improve and enhance the basic properties of asphalt, and subsequently improve the service quality of pavements.

4.2. Nanomaterial composite modified asphalt

In addition to the aforementioned modifiers, composite modified asphalt needs to rely on nanomaterials and polymer modifiers to optimize its asphalt index. As modifiers often change the properties of asphalt through physical or chemical reactions with asphalt, composite modifiers mainly include nano zinc oxide, nano-layered sodium silicate, carbon nanotubes, and other related composite modifiers. Specifically, the use of carbon nanotube composite modifier can change the penetration, softening point, viscosity, and other parameters of asphalt. Relevant asphalt hardness indexes can be improved with the use of carbon nanotubes. Under the influence of carbon nanotubes, the overall anti-rutting factor and phase angle of asphalt mixture will change favorably. Therefore, the overall performance of composite modified asphalt has been fully optimized, and the quality of pavement construction with this type of asphalt as the main material will also improve significantly. With the use of nano zinc oxide, the stability and aging resistance of asphalt can be fully optimized. Combined with the relevant data parameters of the experimental research results, the use of nano zinc oxide can enhance the bonding strength between the composite modifier and asphalt. The toughness and ductility of composite modified asphalt will be strengthened to a certain extent under the influence of nano zinc oxide. In addition, the use of other nanomaterials can also effectively promote the stability of composite asphalt. The rational use of various composite modifiers can improve the overall performance of asphalt mixture. On the premise that the structural stability, toughness, and overall strength of asphalt materials are strengthened with the aid of modifiers, the effect of pavement construction will naturally be optimized.

4.3. Other applications of nano modified asphalt

On the premise that the above two types of nano modifiers can actively contribute to improving the quality of asphalt, employees and researchers should also actively explore new channels for the use of nanomaterials, so as to make the construction of pavements more efficient. As far as the research results at this stage are concerned, researchers have made advanced achievements in the use of nano titanium dioxide. In conjunction with China's strategic goals for sustainable development and the properties of titanium dioxide, the use of nano titanium dioxide has the potential to ease some of China's existing ecological and environmental issues. Based on experimental research results, nano titanium dioxide has a certain photocatalytic effect. At the same time, it has its own cleaning characteristics, thus effectively purifying the air and improving the air quality. It can be seen that the use of nano titanium dioxide in asphalt mixture can improve the environmental protection of roads in subsequent pavement construction. The use of nano titanium dioxide materials is studied in conjunction with pavement construction. The use of nano titanium dioxide materials can also optimize the degradation effect of roads on automobile exhaust. In short, with the assistance of nano materials, the use of modified asphalt can further enhance the advantages that traditional asphalt lacks. Under the favorable influence of nano modifiers, the quality and efficiency of pavement construction will be improved. Through the application of nanomaterials, not only will the stability of subgrade and pavement be fully guaranteed, but other functions of the pavement will also be optimized and expanded, thus improving the city's road safety.

5. Conclusion

Based on the analysis above, it is clear that using nanomaterials to optimize the construction of subgrade

and pavement in the optimization process of road construction is an important commission. Nanomaterials can be used to achieve not only an environmentally friendly development of pavement construction, but also to lower the cost of related construction work and greatly improve the durability of subgrade and pavement. In order to support the growth of subgrade and pavement construction, it is indispensable to improve the application efficiency and effect of nanomaterials in subgrade and pavement.

Disclosure statement

The author declares no conflict of interest.

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