

Research Progress and Prospect of Road Dust Suppressants

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Abstract: Road dust has great adverse effects on traffic quality, traffic safety, atmospheric environment quality, and human health. Therefore, with the continuous development of modern science and technology, the research of road dust suppressants is also progressing. To promote the rational application and development of road dust suppressants, the research progress and prospects of them are analyzed in this paper. It includes a basic overview of road dust suppressants, the main types, the usage and precautions, and the main development direction. It is hoped that this analysis can provide some reference for further research and development of road dust suppressants.

Keywords: Road dust suppressant; Main types; Precautions; Development direction

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1. Preface

The 12th Five-Year Plan puts forward the requirements of control and monitoring technology for Particulate Matter with a Diameter of 2.5 Micrometers or less (PM_{2.5}). As a crucial method for controlling PM_{2.5}, the development and improvement of chemical dust suppressants and road dust suppressants are becoming increasingly urgent. From the point of view of hygiene and environmental protection, road dust not only seriously harms the physical and mental health of mining personnel, but also pollutes the environment around the mining area and destroys the ecological balance. From the technical and economic point of view, serious road dust pollution will cause greater economic losses, high road dust concentration, and visibility decline, not only will the driving speed be limited, but the vehicle spacing will increase, resulting in a significant reduction in the transportation capacity of dump trucks, but also may lead to vicious crashes and other accidents. Therefore, dust emission control is of great significance for curbing the generation of haze weather, improving the atmospheric environmental conditions in China, and suppressing the occurrence of respiratory diseases, especially pneumoconiosis.

2. Basic overview of road dust suppressant

2.1. Brief introduction

Road dust suppressant is a chemical substance designed to inhibit dust on road surfaces. Its primary goal is to reduce the generation and dispersion of dust, preventing significant amounts from escaping into the atmosphere. This helps to protect traffic safety, the atmospheric environment, and human health.

2.2. Mechanism and core

In terms of the current road dust suppressant, there are three main dust control mechanisms which are solidification, wetting, and coagulation, and its core content is as follows:

- (1) The core of solidification is to make the road have greater strength so that it will not be damaged under the shear friction of the moving object, dynamic pressure, tensile condensation, and other effects.
- (2) The core of wetting is to keep the moisture of the road between 10% and 40% so that the dust has a greater density, which can reduce the rate of decline and achieve good dust suppression ^[1].
- (3) The core of coagulation is to ensure the dust generated by the road wear layer has a particle size of more than 80 mesh, so that the dust has a settling speed of more than 0.1 m/s, and finally the dust is effectively suppressed.

2.3. Application advantages

Road dust suppressant is reasonably applied in road projects, and its application advantages can be shown in the following aspects:

- (1) This substance can form a protective layer on the road surface, binding the small sand and dust particles to prevent them from being lifted by the wind, thereby reducing air pollution and minimizing human health hazards.
- (2) The protective layer formed by this substance has effective oil-proof and waterproof properties, which can protect the road surface from erosion caused by oil and rainwater, thus further extending the service life of the road ^[2].
- (3) The protective layer formed by this substance can effectively reduce the friction coefficient between the road surface and the vehicle, so that the vehicle can move more smoothly and steadily, thus reducing the wear and tear of the vehicle and improving the driving experience.
- (4) The substance does not contain any toxic, harmful, or polluting components, with good environmental performance ^[3]. With these advantages, road dust suppressants have been more widely used in the field of modern road engineering dust suppression. The application and development of such substances have become the focus of relevant researchers in recent years.

3. The main types of road dust suppressants at present

In terms of the commonly used road dust suppressants, there are four main types: wetting road dust suppressant, bonding road dust suppressant, cohesive road dust suppressant, and composite road dust suppressant. The following is an analysis of the basic situation and research on these four main types of road surface dust suppressants.

3.1. Wetting road dust suppressant

The main components of wetting road dust suppressants include surfactants and some inorganic salts. The

main role of the surfactants is to reduce the surface tension of the solvent system to achieve good foaming, emulsification, wetting, penetration, and other application effects. The main role of inorganic salts is to make up for the lack of surfactants in water retention and moisture absorption so that their role is better played. This kind of road surface dust suppressant is more applicable in the field of coal dust suppression nowadays, and it is more often used in the front-line field of coal mine comprehensive mining surface and atmospheric dust reduction. In recent years, the road surface dust suppressant and the existing road surface dust removal devices have realized a well-integrated application, which can further improve the road surface PM_{2.5} removal efficiency ^[2]. In the subsequent research and development, researchers began to devote themselves to the research of more inexpensive wetting-type road dust suppressants.

3.2. Adhesive road dust suppressant

Binder-type road dust suppressants can be further subdivided into two types according to different raw materials. The first one is organic chemical bonded road dust suppressants, whose main components are polymers, resins, carbon cellulose filter media, lignin derivatives, bio-oil residues, olive oil residues, asphalt, cinder oil, paraffin oil, petroleum residue oil, crude oil, and some other organic substances. At the same time, such dust suppressants can be divided into four families, including synthetic resin, lignin, cellulose, and starch. Its main advantage is that the raw materials are easy to obtain and inexpensive, and the preparation technology is relatively mature. After practical research and application, it can be seen that most of the cellulose and lignin organic chemical bonding road dust suppressant bioaffinity and its hydrophilicity are very good. It can play an effective inhibition of industrial waste gas and heavy metal dust and has good pressure resistance and cold resistance ^[4]. At the same time, this kind of road dust suppressant also has better biodegradability than other road dust suppressants, especially lignin road dust suppressants, which have significant performance advantages.

The second is the inorganic chemical bonding type dust suppressant, whose main components are acid, kaolin, gypsum, clay, fly ash, calcium oxide, and halide. After practical research and application, it is found that this kind of road dust suppressant has a better dust-fixing effect in road engineering, but its emulsification performance is relatively low. To make better use of the raw materials, in the subsequent study, the researchers need to achieve a multifunctional composite effect by adding better additives, to further improve its application performance.

At present, the bonded road dust suppressant has been widely used in the fields of dust suppression on bare ground, in open dumps, in construction sites, and on roads. Simultaneously, it has demonstrated improved performance in practical applications. It is believed that in the subsequent continuous research and development, this kind of road surface dust suppressant will play a higher application value in the field of road engineering.

3.3. Condensed road dust suppressant

Cohesive road dust suppressant belongs to a kind of chemical hygroscopic inorganic salt form of cohesive agent. For this kind of road dust suppressant, the current domestic and foreign research is mainly concentrated in the field of calcium oxide (CaO), calcium dichloride (CaCl₂), magnesium dichloride (MgCl₂), and sodium chloride (NaCl), and other inorganic salts with high water absorption. In 1963, the former Soviet Union reported for the first time that CaCl₂ with strong hygroscopicity was uniformly sprayed in the amount of 0.6 kg/m² on the mine road with high relative air humidity, which could effectively inhibit the dusty situation of the road, and the effective period of dust prevention could reach 45–90 d ^[5]. Regarding CaO, MgCl₂, and NaCl, scholars, such as Wang and others, found through research that these inorganic salt materials have better moisture absorption

properties under natural environmental conditions, but compared with the other two inorganic salts, the moisture absorption and dust suppression effect of NaCl can only be well played under high humidity conditions ^[6]. With the advantages of good hygroscopicity and evaporation resistance, cohesive road dust suppressants have been widely used in the field of road dust control in the early stages. However, in the subsequent application, it was found that the moisture-absorbing effect of this kind of road surface dust suppressant was easily affected by the temperature or the salinity of the land so the road surface dust-suppressing effect played in the actual application was not stable. With the continuous development of cohesive road dust suppressant preparation technology, many snow-melting agent-type cohesive road dust suppressants began to be widely used in road projects, and its application effect is more prominent than the traditional inorganic salt type cohesive road dust suppressant.

3.4. Compound road dust suppressant

With the research and development and application of various new materials in recent years, as well as the continuous improvement of the actual application demand of road dust suppressants, composite road dust suppressants began to realize faster development in the field of road engineering. Especially in complex, harsh, and changing environments of road engineering conditions, to avoid failures with single road dust suppressants, researchers conducted an in-depth study of composite dust suppressants tailored to local conditions. Through relevant studies, it is found that the development of compound road dust suppressants by coupling various synthetic technologies is very effective, and it is also a main development direction of road dust suppressants in the future. Usually, the main preparation techniques of composite road dust suppressants include solubilization, emulsification, ion chelation, coordination and copolymerization, and other coupling. However, due to the relatively short development time of this technology, the coupling mechanism is not mature enough, so the development and preparation of this type of road dust suppressant is still difficult. To effectively solve this problem, researchers also need to carry out in-depth research on the coupling mechanism of such road dust suppressants.

4. Methods and precautions of road dust suppressant

4.1. Methods

In the practical application of road dust suppressants, reasonable control of the usage method is the key to ensuring its dust suppression effect. It is known from the established practical application and research summary that, usually, the road dust suppressant can be used according to the following methods:

- (1) Dilution: According to the proportion determined in the study, the road dust suppressor was diluted with water to form a solution.
- (2) Preparation of spraying equipment: Sprayers or spray guns are used as spraying equipment for the road dust suppressant, and the equipment should be clean enough so that no residue of pollutants or other substances could affect the application performance of the road dust suppressant.
- (3) Spraying: The prepared spraying equipment should be used to spray the diluted road dust suppressor onto the road surface that needs to be treated with dust suppression. The spraying distance and spraying angle should be controlled strictly according to the research and design standards ^[7].
- (4) Maintenance: After completing the spraying treatment of the road surface dust suppressant, the staff needs to regularly do the inspection and maintenance of the road surface in the dust suppression area according to the actual situation, and when the dust is found to rise, the road surface dust suppressant needs to be sprayed again ^[8].

4.2. Precautions

To give full play to the application effect of road dust suppressant and meet the actual demand of modern road engineering, it is necessary to pay attention to some precautions in the application process. The precautions in the application of road dust suppressant mainly include the following aspects:

- (1) Before use, its basic chemical properties and safe operating procedures should be fully defined, and the operation should be carried out in strict accordance with the recommendations in the manual.
- (2) During the spraying process, the staff must do a good job of their protection, such as wearing protective clothing and goggles to avoid road dust suppressant getting in contact with their skin and eyes ^[9].
- (3) Road dust suppressant and other chemical agents should not be mixed, so as not to impair the effect of dust suppression or produce toxic and harmful substances to pollute the environment.
- (4) The road dust suppressant should be stored in an area away from open fire and high temperatures to avoid unnecessary accidents. This way, not only can the dust suppression effect of the road dust suppressant be better utilized, but also can further ensure the safety of its application.

5. The main development direction of road dust suppressant

With the increasing awareness of ecological and environmental protection in modern society, the application requirements of road dust suppressants are also constantly improving. The existing road dust suppressants are also non-toxic, harmless, and have good ecological and environmental performance since most of these substances are synthetic chemical substances. However, in practical applications, if the environment is more complex or contains some other chemical components, under the joint action of various factors, the road dust suppressants will inevitably have a chemical reaction and produce toxic and harmful substances. Based on this, biodegradable road dust suppressants with high ecological and environmental performance have become the main development direction of such substances ^[10].

To meet this development goal of road dust suppressants, researchers need to make more effort to research new ecological and environmental protection materials and adopt more advanced biological technology to prepare corresponding biodegradable suppressants, so that their performance can be adjusted according to the actual environmental changes. Additionally, researchers can also combine the actual situation of highway engineering and its specific application needs, multi-functional composite road dust suppressant, and special road dust suppressant research. In this way, the road dust suppressant used in the project can achieve better performance in dust suppression and provide greater ecological and environmental protection. It helps avoid reactions with other chemicals that could produce toxic pollutants, ensuring a safer and more reliable application.

6. Conclusion

To summarize, road dust suppressant is one of the most critical dust suppressants in the field of road engineering. To make the road dust suppressant play a better effect of dust suppression, its formula and preparation process are becoming more complex and diverse. Multifunctional composite dust suppressants and special dust suppressants have become the main direction of the current research. However, due to the current research on the mechanism of multifunctional composite dust suppressors is still in the initial stages, in future research, researchers need to establish a complete set of performance characterization methods and analysis methods. Based on the comprehensive understanding of the principle of the existing preparation technology, the mechanism of the coupling preparation technology of compound dust suppressors was discussed by selecting

suitable materials, so that more excellent road dust suppressors could be brought to the market.

Disclosure statement

The author declares no conflict of interest.

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