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Experimental Studies on Materials for Loess Improvement: A Review

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Abstract

Loess Plateau is one of the regions with the most developed geological disasters in China. One of the reasons for this phenomenon is the particularity of the loess nature. Therefore, strengthening the loess to improve its engineering properties is of great significance to water and soil conservation, engineering construction and disaster prevention in the loess area. Based on the existing research results of loess solidification materials, the solidification mechanism and solidification effects of the main solidification agents are reviewed, the current research status at home and abroad is summarized, also the advantages and disadvantages of various solidification agents are analyzed. Analysis shows that in the future, we should pay attention to the research on the effective improvement of engineering properties and the environmentally friendly loess curing agent. At the same time, the differences in engineering conditions and the field application research of the loess curing agent should be considered.

Keywords

Loess; Soil stabilizer; Stabilization mechanism.

1. Introduction

Loess is a kind of soil with special properties, which is widely distributed in the Loess Plateau in central and western China. In recent years, with the large-scale development of engineering construction in the loess area, loess and compacted loess have been widely used in the construction of embankments, airports, landfills, etc. The loess itself has special properties such as macroporosity, water sensitivity, and collapsibility. Under the hydraulic action of rainfall, irrigation, and groundwater, it is prone to wetting and disintegrating, leading to a sudden drop in strength, thus causing the occurrence of geological disasters such as landslides, collapses, and mudslides. Which caused a series of engineering geological problems such as roadbed subsidence, uneven settlement of buildings, damage to bridges and culverts, etc. [1]. According to incomplete statistics, in the past 100 years, China has caused more than 10,000 casualties due to disasters such as loess landslides, collapses, and mudslides, and countless economic losses [4]. Therefore, it is very necessary to use corresponding methods to modify the loess,

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improve the physical and mechanical properties and the water sensitivity of the loess to meet the needs of the project.

At present, there are three methods for modifying loess: physics, chemistry and biology. Physical improvement methods such as dynamic compaction, vibration compression, etc. have a greater impact on the engineering environment and require higher construction machinery; biological methods are environmentally friendly and have low cost, but they have certain requirements for environmental temperature and lack engineering durability. The chemical method is mainly to add a curing agent to the loess. Which is flexible in construction and can effectively improve the engineering properties of the loess. Using corresponding curing method to improve the physical and mechanical properties of the loess, and explaining the mechanism of performance improvement through the means and methods of materials science has becoming a hot spot in the field of solidified loess in geotechnical engineering [5].

2. Research Status of Curing Agent at Home and Abroad

Adding curing agent in soil is a chemical improvement method. Among the curing agents, lime, cement and fly ash are traditional curing agents. In addition, in recent decades, new ionic curing agents, nano-scale curing agents and polymer soil curing agents have been invented and used. The addition of these new curing agents improves the strength of improved soil by changing the cementation composition of loess particles.

In the fifties and sixties of last century, domestic scholars began to study the properties of improved soil, and the earliest object of study was fly ash. With the deepening of the study, the study of cement and lime improved soil gradually began. In this kind of method, the essence is that the addition of volcanic ash materials and the siliceous aluminum minerals in the soil first take place short-term physical densification, and then take place long-term chemical reactions. By modifying the properties and composition of the soil, the cementation between particles is stronger, and the mechanical strength and durability required for engineering design can be well realized [6]. Although a large number of studies have shown that such volcanic ash materials and mixtures can play a good curing effect on peat, sand and so on, and have been widely used and promoted in the engineering practice of solidified soil worldwide. However, in the process of long-term volcanic ash chemical reaction, the dissolution of silicon and aluminum releases the cations of various minerals in the soil, resulting in a substantial increase in salt content and pH value of the solidified soil [10], changed the hydrochemical environment of solidified soil Significantly [11]. At the same time, this kind of solidified soil has the disadvantages of poor early strength, high soil ph is not conducive to vegetation growth, improved soil ion exchange capacity, water holding capacity and poor permeability. Therefore, some scholars emphasized the need to strengthen the observation and research on chemical environment of solidified soil [11]. However, a large number of studies have focused on the research and evaluation of the physical and mechanical properties of solidified soil, and the evaluation of the chemical environmental effect of solidified soil is seriously insufficient. Only a small number of studies have paid attention to this problem [10]. With the deepening of the construction of ecological civilization, the research of effective low cost and friendly environment curing materials has become the focus of curing research field instead of the traditional volcanic ash curing materials.

Nontraditional chemical curing additives include nanoparticles, ionic curing agents and polymer, etc. [5]. Among them, SH agent curing material is a new organic polymer material based on polyacrylic acid system. SH agent and clay particles in soil have ion exchange, bonding, flocculation, adsorption and other effects, and the use of electrical attraction between colloids and long chain of polymer lap winding effect to form a solid spatial network structure, so that the connection between soil particles is enhanced. The test result of Wang et al.[13] show that

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SH agent can improve the shear strength, low temperature resistance, reduce compressibility and eliminate collapsibility of loess. Cheng [14] carried out the model test of loess slope reinforced by SH curing agent, and considered that the use of SH curing agent to treat loess slope can take into account both soil fixation and ecology. Studies have shown that organic polymer soil curing agent has the characteristics of convenient construction, environmental protection, and can also provide nutrients for plant growth. Studies have shown that organic polymer soil curing agent has the characteristics of convenient construction, environmental protection, and can also provide nutrients for plant growth. However, some studies have found that the addition of 10 % SH curing agent can effectively improve the water stability of solidified loess in the process of immersion disintegration, and it is not as good as cement in the comprehensive improvement of mechanical strength.

Due to its special properties such as high specific surface area, high surface energy and fine particle size, nano-particle materials can play a role of filling and cementing after being mixed into soil, filling large pores, and cementing coarse particles in the soil, which are already solidifying the soil. Has received a certain degree of attention in the research field [15]. Nano-silica solidified soil is a physical reaction. Nano-silica is added to the soil and dispersed to cause homogenization, filling the inner pores of the aggregates, correspondingly forming denser and denser large aggregates, and resulting in a corresponding increase in the pores between the aggregates. Or increase, resulting in greater accumulation of total pores in the solidified soil, and enhanced cohesion, thereby effectively improving the mechanical properties. Nano-silica does not bring about significant changes in the chemical environment, does not produce new minerals, and theoretically does not change the pH of the soil. Scholars have discovered through research that nano-silica can effectively increase the strength of loess [16], reduce the amount of loess in the process of humidification, and analyze the chemical environment changes after solidification [17]. To a certain extent, nano-silica also has the problem of high cost, which limits its popularization and application. According to the research results of Kong Ran [17], nano-silica only needs a very small amount (about 1%) to ensure that the strength of loess can be effectively improved.

Lonic soil curing agent is a water solvent composed of multiple strong ions, and its active ingredients have two parts: "hydrophilic head" and "hydrophobic tail". The "hydrophilic head" easily interacts with water and is completely soluble in water, while the "hydrophobic tail" is mainly composed of organic matter and is insoluble in water. It is precisely because of the duality of the composition of the ionic curing agent that it can regulate the hydration properties of the clay surface and reduce the moisture in the clay when interacting with clay minerals, thereby achieving the purpose of modification. The ionic curing agent has the characteristics of low cost, convenient construction, durability, and environmental protection. It has been widely used in roads, railways, building foundations, farmland water conservancy projects and other fields. Existing studies have shown that the compressive strength, flexural strength and water stability of loess are good after being improved by an ionic curing agent. Studies have also found that ionic curing agents have limited improvement in the performance of soil and road use. Traditional alkaline curing agents such as lime cement must be added to work together. At the same time, the internal mechanism of the improvement of the macro-mechanical properties of soils reinforced by ionic curing agents needs to be further studied.

3. Conclusions and Prospects

At present, many beneficial results have been achieved in the field of loess curing agent research. From the existing research, it can be seen that there are many types of curing agents that can improve the engineering properties of loess. On the whole, solidified loess still generally uses pozzolan such as lime as the main additive, and this kind of solidifying agent may

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cause subsequent environmental problems. Although some new curing agents are used to solidify loess, most of the new curing materials are still not widely used as soil curing agents, and the research level is insufficient, lacking systematic and in-depth research on the water sensitivity, hydraulic characteristics and field site of the solidified soil. Therefore, it is necessary to strengthen the research and application of new and composite materials in solidified loess, systematically study the performance of solidified soil, and seek for the effective improvement of engineering properties and environmentally friendly additives. Which is of great significance to improve the properties of loess and to alleviate soil erosion, reduce the occurrence of geological disasters in the Loess Plateau.

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