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Progress in Research on the Reactive Magnesia Stabilizing Soil based on Carbonation

Zhiwei Zhu, Wang Luo, Xin Yang

School of civil engineering and architecture, Anhui University of Science and Technology, Huainan 232000, China

Abstract

In order to solve the problems of environmental pollution and energy consumption caused by traditional soil consolidation methods, and to understand how to use the reactive magnesia as hardener to stabilize soil by carbonation, the paper summarizes the principle of the reactive magnesia stabilizing soil based on carbonation, the influencing factors of the reactive magnesia stabilizing soil based on carbonation and the durability of the reactive magnesia stabilizing soil based on carbonation according to the existing research results.

Keywords

Reactive Magnesia; Carbonation; Soil Stabilization.

1. Introduction

Subgrade and foundation are the first step of engineering construction and the foundation of buildings. However, when choosing foundation and treatment, the economic benefit, rationality and reliability of buildings are largely determined. With the development of society, with the increase of China's national economic stren-gth and the continuous deepening of China's infrastructure construction, the types of infrastructure construction in China are becoming more and more complex and changeable, and the difficulty and scale are enlarged accordingly and in the forefront of the world. At the same time, because the characteristics of soils vary greatly from place to place in China, insufficient strength and rigidity of soils often occur in the foundation works between the ground and the foundation, which makes it necessary to reinforce the soils before the construction to ensure the stability of the foundation and foundation. Soil reinforcement is usually done by adding curing agent. Nowadays, Portland cement is the most common land curing agent selected in the project. However, both production and use of cement have adverse effects. ① High consumption of raw materials and high calcination temp-erature in cement production require a large amount of thermal resources, which leads to serious energy consumption. ② The production of cement will produce a large amount of CO2, dust and other toxic gases, causing serious environmental pollution. ③The curing time of stabilized soil with cement as curing agent is long and the strength increases slowly, which often can not meet the time requirements of the project [1]. In addition, greenhouse gas emissions, particularly CO2, are increasing dramatically, leading to global warming and the frequency of extreme we-ather events. Currently, global CO2 emissions are up to 240×108t every year, the total concentration reached 379 ppm, an increase of 33% compared with that be-fore the industrial revolution. This figure shows an annual increase rate of 1 ppm, which is expected to reach 388×108t in 2025. [2]. Therefore, the development of green low carbon reinforcement materials and fast and efficient curing technology is of great significance to the sustainable development of the environment. A large number of laboratory experiments have shown that the technology of using the reactive magnesia as curing agent to stabilize soil by CO2 carbonation is not only a good solution for greenhouse gas CO2 storage, but also for the stabilization of soft soil.

 Volume 8 Issue 6, 2022
DOI: 10.6919/ICJE.202206_8(6).0021

2. Principle of the Reactive Magnesia Stabilizing Soil based on Carbonation

The reactive magnesia stabilizing soil based on carbonation is accomplished by a series of physical and chemical reactions. First, MgO is in full contact with water and hydration (MgO+H2O_Mg(OH)2) occurs to produce an expansive Mg(OH)2 due to Mg(OH)2.

The solubility of Mg2+ is low. For hydration reaction, there are some Mg2+ and OH-. Among them, Mg2+ agglomerates with positive ions and generates aggregated soil, which improves the strength of soil. After a period of time, the pore of soil particles will be occupied by Mg(OH)2 and some water, and the surface of Mg(OH)2 will be porous and loose. At this time, CO2 is easily carbonized to produce a series of magnesium carbonates, which bond and fill the soil voids, thus making the soil more compact and strong. Liska et al. [3][4][5] studies on the types of magnesium carbonates show that the main types are prism-shaped magnesium carbonate MgCO3. 3H2O trihydrate and two flaky basic magnesium carbonate Mg5(CO3)4(OH)2. 5H2O and Mg5(CO3)4(OH)2. 4H2O. The chemical reaction equation is as follows:① Mg(OH)2+CO2---MgCO3. 3H2O ② 5Mg(OH)2+4CO2+H2O ---(Mg)5(CO3)4(OH)25H2O ③ 5Mg(OH)2+4CO2+H2O---(Mg)5(CO3)4(OH)2. 4H2O Further research shows that the types of carbonates produced by carbonation are related to reaction temperature, CO2 pressure, initial water content, etc. When the temperature and initial water content are moderate, CO2 pressure is low and the product is MgCO3. 3H2O. At higher temperatures, moderate CO2 pressure and initial water content, the carbide products will be converted to basic magnesium carbonate Mg5 (CO3) 4 (OH) 2. 5H2O and Mg5 (CO3) 4 (OH) 2. 4H2O; Magnesium carbonate trihydrate MgCO3. 3H2O will lose water and change to basic magnesium carbonate Mg5(CO3)4(OH)2. 5H2O and Mg5(CO3)4(OH)2. 4H2O[6] when temperature and CO2 pressure are moderate and initial water content is low. When the temperature is lower than 10 C, granular MgCO3.5H2O is produced [7].

3. Influencing Factors of the Reactive Magnesia Stabilizing Soil based on Carbonation

From the experimental results of existing data, it is shown that the curing effect of the reactive magnesia stabilizing soil based on carbonation is mainly affected by several factors, including initial water content, CO2 gas concentration and pressure, compaction degree, properties of soil and activity of MgO.

3.1 Activity of MgO

The activity of MgO is generally defined as the ability of MgO to produce Mg2+ and OH- by hydration under specified conditions. Liu Songyu and Li Chen mainly use three kinds of magnesium oxide in their experiments on carbonation and consolidation of silty silty clay, and their activities are different. By analyzing the activity of MgO to carbonize and stabilify soil, they point out that the effect of carbonation and consolidation will increase with the increase of MgO activity, and more carbonation products will be produced in this process. In general, the main forms are foil-like Mg5(CO3)4(OH)2.4H2O and column-like MgCO3.3H2O. The corresponding pore volume is smaller and the integrity is better. Good activity can generally achieve carbonation in 3-6 hours. From the point of view of carbonation strength, it is equivalent to 1.39 times of 28 d strength of cement curing. For MgO samples with normal activity, it is equivalent to 7 d strength of cement curing. For low activity, its corresponding strength is 500 kPa [8].

3.2 MgO Content

Cai Guanghua [9] studied the strength and deformation characteristics of the reactive magnesia carbonized silt and found that the unconfined compressive strength test was carried out on five samples with different MgO content with an initial moisture content of 25%. The results showed that the strength of the samples increased with the increase of MgO content, and the critical range for the

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samples to reach the maximum strength was that the MgO content was 20% - 25% and the carbonation time was 8-10 hours.

Li Chen reinforced MgO with 10%, 15% and 20% of the same activity with carbon. The results show that the carbonation rate of the sample and the strength of the soil increase with the increase of MgO content.

3.3 Initial Water Content

Hydration reaction and carbonation reaction are needed in the process of the reactive magnesia stabilizing soil based on carbonation and the initial water content is closely related to it. The initial water content is too high. Although MgO has been fully hydrated, too much water occupies the pore space of soil, so that CO2 gas cannot effectively contact with hydration products, resulting in carbonation reaction, resulting in greatly reduced production of carbonation products and unable to effectively cement soil pores [8]. It is not difficult to find that a reasonable initial moisture content is very important for carbonated stabilized soil.

Yi Yaolin [1] analyzed the factors affecting the carbonation and solidification of soil, that is, different initial moisture content, and pointed out that they maintain a certain relationship. With the increase of initial moisture content, they are lower than dry density and unconfined compressive strength, which increase first and then decrease,

There is an optimal moisture content. When the content of MgO is 10%, the optimal moisture content is 7.5%, and when the content of MgO is 5%, the optimal moisture content is 5-7.5%.

Cai [11] analyzed the influence of active MgO carbonation and stabilization on the strength and resistivity of stabilized soil by studying the silt with different initial moisture content. Through the experiment, it was found that with the increase of initial moisture content, the strength of carbonation reinforced test block will decrease, the resistivity will show a power function decline, and there is an obvious linear relationship between the compressive strength and resistivity of test block. Therefore, in the process of strength test of test block, It can be realized by detecting the resistivity of the test block.

3.4 Compaction Degree

Liu and others [12] have studied and discussed how the change of compaction degree of the test sample will affect the reactive magnesia stabilizing soil based on carbonation. The further analysis from the results of the experiment shows that the carbonation time is fixed. With the increase of compaction degree , the water content first decreases and then increases, at this time, the best compaction degree is obtained. The dry density increased. As for unconfined compressive strength, it firstly increases and then decreases with the increase of compaction degree. It has the largest water content reduction range and corresponds to a compactness of 89%. The unconfined compressive strength is the highest.

Compaction degree of soil has a significant impact on MgO carbonated stabilized soil, and there is an optimal compaction degree For the soil with low compactness, the porosity of soil particles is too large, resulting in insufficient cohesion and bite between soil particles, and it is difficult for carbonation products to bond soil particles well; When the compaction degree is high, the porosity of soil particles is too small, and CO2 can not effectively enter the pores, which makes it difficult for hydration products to carbonize CO2, resulting in too little carbonation products, which can not improve the strength of soil.

3.5 Soil Properties

Yi [13] studied the influence of MgO carbonation on the stability of soil and found that the carbonation time and strength of sandy soil and silt reinforced by active MgO were different. Compared with silt, the carbonation time of sandy soil was shorter and the strength was higher.

Cai[14]and Liu[15] studied the micro-mechanisms of silty soil and silty clay reinforced by active MgO carbonation, respectively. The results showed that compared with silty soil, the time for

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carbonation of silty clay to obtain the maximum strength was 3.0 – 6.0 h, and the relatively slow silty clay required about 6.0h to obtain the maximum strength. This is because the properties of silty clay and silty soil are different. The silty clay has a large amount of clay particles and is prone to ion exchange and agglomeration reaction, which makes the particles aggregate to form large soil aggregates. Moreover, the gas permeability of silty clay is poor, so the gas transport rate and reaction rate in the carbonation reaction process are lower than those of silty soil.

3.6 Carbonation Time, Pressure and Concentration of CO2

The longer the carbonation time of CO2, the more complete the carbonation reaction, so as to achieve the highest strength of stabilized soil. However, the carbo-nation time required to achieve the highest strength of stabilized soil is also related to the pressure and concentration of CO2.

Yi [1]found that the pressure of CO2 had a great influence on the carbonation reaction time, and the carbonation reaction time was proportional to the pressure of CO2. The time required for the stabilized soil with CO2 pressure of 50 kPa, 100 kPa and 200 kPa to reach the maximum strength was 3 h, 1.5 h and 0.75 h, respectively. It takes 48 hours to achieve the highest strength of carbonized stabilized soil in carbonized box with CO2 pressure equal to atmospheric pressure.When the pressure of CO2 affects the carbonation soil, it mainly affects the carbonation rate, but has a relatively low impact on its strength.

Moliwu [16] studied the microstructure of carbonized activated magnesium oxide cement slurry with high concentration of carbon dioxide, and compared the carbonized MgO slurry with high concentration of CO2 (99.9 %) and low concentration of CO2 (0.04 %). It was found that when the content of CO2 was high, the hydrated Mg (OH) 2 was carbonized to produce magnesium carbonate to fill the pores of the stabilized soil. When the CO2 content is low, most MgO can only react with hydration and cannot react with carbonation, so there is no large amount of carbonation products. Therefore, the strength of stabilized soil is low.

4. He Durability of the Reactive Magnesia Stabilizing Soil based on Carbonation

Zheng et al. [17][18] In the study on the characteristics of dry-wet and freeze-thaw cycles of cured soil, it is found that the properties of dry-wet cycles of carbonized and cured silt and silty clay are different. Although the strength of both will decrease to some extent after the dry-wet cycles, after the treatment of dry-wet cycles of carbonized and cured silt, the corresponding strength is 90% of the standard curing at this time, but for silty clay, It is only 35% of standard maintenance. On the whole, dry-wet cycling capability of silt is relatively superior, on the contrary, silty clay is relatively weak in dry-wet cycling capability. Micro-analysis shows that the carbonized and stabilized silt treated by wet and dry cycling has no significant influence on the accumulated pore size, but the sample pore size is increased, thus greatly reducing the sample strength. By means of comparative analysis, the micro-structure and unconfined compressive strength of cement soil samples and freeze-thaw cycled carbonized stabilized soil samples are studied. Both have high strength and the freeze-thaw cycles have no obvious influence on the micro-structure of carbonized soil. Therefore, the activated magnesium oxide carbonized stabilized soil has better freeze-thaw resistance.

Liska et al. [19] Taking MgO cement as research object, through analyzing the sulphate erosion and hydrochloric acid resistance, it is pointed out that the corrosion resistance of carbonated test block is stronger than that of cement test block. Liu Songyu et al. [20] Through comparative study on the compressive strength and microstructures of the reactive magnesia carbonated silt and cement carbonated silt in clean water and two kinds of sulfates, the results show that the compressive strength of the reactive magnesia carbonated and cured silt block basically remains unchanged after being soaked in sulfate for 28 days, while the compressive strength of cement carbonated silt block increases at the early stage after being cured with sulfate. The test block will expand over time and the strength will decrease. From the analysis of microstructure, the carbonation products of the reactive magnesia carbonated and stabilized silt have not changed after being corroded by sulfate. Therefore, the reactive

Volume 8 Issue 6, 2022
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magnesia stabilizing soil based on carbonation has better resistance to sulfate attack than cement stabilized soil.

Wang Liang [21] studied the permeability characteristics of silty clay and the reactive magnesia stabilizing silt based on carbonation , pointing out that the strength of carbonated stabilized soil decreases with the increase of permeability coefficient. The permeability coefficient increases with the increase of MgO content and decreases first and then increases with time. Meanwhile, the permeability coefficient is the lowest at 6h. The impermeability of cement-stabilized soil is similar to that of standard cured soil for 28 days.

5. Summary and Prospect

Today, the world is facing environmental problems such as global warming, and the use of cement-stabilized soil will further aggravate them, which is contrary to the concept of energy-saving, emission reduction and low-carbon environmental protection. The reactive magnesia stabilizing soil based on carbonation can solve the problems caused by cement-stabilized soil and has better properties than cement-stabilized soil in all aspects. It is a good way to replace cement-stabilized soil.

At present, the reactive magnesia stabilizing soil based on carbonation is still in theoretical research stage and has not been involved in a wide range of Engineering practices. Moreover, most of CO2 used in the process of carbonation is purchased commercially, which leads to higher project costs. Therefore, it is necessary to carry out systematic research on the reactive magnesia stabilizing soil based on carbonation, enlarge the scope of field experiments, establish relevant theoretical system and accelerate its participation in engineering application.

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