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Research on Alkali Reduction Technology of Planting Concrete

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Abstract

In order to verify the feasibility of planting concrete slope protection, the current urgent problem is how to reduce the pH value in the pores to the greatest extent and meet the economic and construction requirements under the condition of ensuring the strength and other properties of planting concrete. Three common alkali reduction methods are listed in the study, and their advantages and disadvantages are summarized. Finally, chemical alkali reduction method is selected for research. Alkali reduction materials include citric acid, oxalic acid and superphosphate, and the crystals of the three materials are arranged into solutions of 1%, 3% and 5% concentration respectively to soak the planted concrete. The reasons for the decrease of alkalinity and the change of strength in the pores were analyzed from the microscopic point of view. The results show that although the three concentrations of citric acid solution can reduce the pH value in the pore of planted concrete, the compressive strength of planted concrete decreases with the increase of citric acid concentration. Therefore, citric acid is not suitable as a alkali-reducing agent for planted concrete. In the oxalic acid reduction experiment, 1% and 3% oxalic acid solution can not only reduce the pH value in pores, but also increase the compressive strength of planted concrete. 3% oxalic acid solution has the best effect on reducing pH value, and 1% solution has the best effect on enhancing compressive strength. In the alkali reduction experiment of superphosphate solution, it was found that three concentrations of superphosphate solution can not only reduce the pH value in the pores of planting concrete, but also increase its compressive strength, among which 3% and 5% concentration of superphosphate solution has the best effect and the difference is almost the same. From the economic perspective, it is recommended to use 3% concentration of superphosphate solution for alkali reduction treatment.

Keywords

Planting Concrete; Alkali Reduction; Citric Acid; Oxalic Acid; Superphosphate.

1. Introduction

Plant concrete, also known as ecological concrete, is a kind of porous concrete composed of coarse aggregate, cement and admixture, prepared by special technology, which can meet the requirements of plant survival and growth. Planting concrete not only guarantees a certain strength, but also has good drainage, seepage prevention and water retention properties, can be widely used in slope protection, ecological construction and other projects, is a new type of environmental protection building materials. Compared with ordinary concrete, the biggest feature of plant-planted concrete is its phytology. However, due to the large amount of alkaline substances produced by cement hydration, the pH value in the pores of plant-planted concrete remains high. How to effectively control the pH value in the pores for a long time to reach the normal range of plant growth is a hot spot and difficulty in the current research on plant-planted concrete.

The study of previous literature found that the methods for reducing the pH value in the pores of planted concrete can be classified into three categories: First, by adding fly ash, mineral powder, silica fume and other mineral admixtures to replace part of the cement[1,2] or directly replace the type of cement[3,4], the quality of cement hydration products is fundamentally reduced, but the effect of this method is not obvious, and the use of low-alkalinity cement will increase the preparation cost; Second, by means of physical alkali sealing, rapid carbonization[5-7], polymer spraying[8] and other means are adopted to prevent the precipitation of alkaline substances, so as to control the alkali environment in the pores of planted concrete. This method has obvious effect, but it is difficult to popularize and use in the construction site because of high cost and difficulty in operation. The third method is the most studied and controversial one by scholars, that is, chemical alkali reduction of plant-grown concrete[9-11], that is, spraying chemical solutions of different kinds and concentrations or improving planting matrix, and using the principle of acid-base neutralization to reduce the pH value in the pores. This method is simple and economical, but improper selection will affect the strength of concrete. In this paper, oxalic acid, citric acid and superphosphate were used for chemical alkali reduction of plant concrete, and the results of alkali reduction were analyzed from the microscopic point of view.

2. Raw Material

Cement: P O42.5 ordinary Portland cement produced by Yanxin Holding Group Co., LTD. Its physical properties and chemical composition are shown in Table 1 and 2.

Aggregate: Limestone gravel with 16-19mm single graded particle size is used, and its basic performance indicators are shown in Table 3.

Superplasticizer: polycarboxylic acid superplasticizer produced by Hongxiang building additive Factory in Laiyang City has a water reduction rate of 35%.

Mixing water: tap water.

Alkali-reducing materials: citric acid, oxalic acid, superphosphate.

Table 1. Physical properties of ordinary Portland cement

density(m^2/kg)	specific surface area(m^2/kg)	water requirement of normal consistency %	stability	setting time(min)		rupture strength(Mpa)		compressive strength(MPa)	
				initial set	final set	3d	28d	3d	28d
3020	380	28.6	qualified	245	304	4.9	8.8	24.4	60.2

Table 2. Chemical composition of ordinary Portland cement

chemical component	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Na_2O	LOSS
content(%)	21.38	5.63	3.62	63.72	2.15	1.75	1.02	0.97

Table 3. Performance index of crushed stone

grain size (mm)	performance density(kg/m^3)	bulk density(kg/m^3)	Close packing density(kg/m^3)	clay lump content (%)	elongated and flaky particle (%)	crush index (%)	voidage (%)
16.0~19.0	2645	1453	1573	0.4	6	10.8	40

3. Experimental Method

3.1 Mix Design

According to the relevant literature, when the water-cement ratio is between 0.25 and 0.35, the plant concrete mixture is in the best state; At the same time, in order to meet the growth needs of plants, planted concrete should have certain connected pores, and its porosity should be maintained at 25%~35%. The water-cement ratio selected in this experiment is 0.30; The porosity is 30%. The amount of raw materials is calculated by referring to CJJ/T135-2009 Technical Regulations for pervious Cement Concrete Pavement, that is, volume of coarse aggregate + volume of cementing material + design pore volume =1. After calculation, the mix ratio of porous concrete is shown in Table 4.

Table 4. Mix ratio of planting concrete

grain size (mm)	cement(kg/m^3)	coarse aggregate(kg/m^3)	mixing water(kg/m^3)	water reducer(kg/m^3)
16.0~19.0	343	1542	104	3

3.2 Preparation and Maintenance of Specimens

According to the above mix ratio, the standard cube specimen of 150mm×150mm×150mm is made. The concrete was mixed by the coating method. Firstly, all aggregates and 70% of the mixed water were added for 60 seconds, then half of the cement and water-reducing agent were added for 60 seconds, and finally the remaining cement and the mixed water were added for 60 seconds. After the stirring is completed, the test mold is divided into 3 layers, and after each layer is installed, the ramming rod is evenly inserted and rammed 25 times, and then the surface is leveled, so that the volume of the protruding part and the depressed part is roughly equal; Finally, the mold is removed in the standard curing room for 24h, and the alkali reduction test is carried out after the curing to the specified age.

4. Test Results and Analysis

4.1 Influence of Citric Acid on the Performance of Planting Concrete

Several test blocks with the size of 100mm×100mm×100mm were prepared according to the mix ratio of planting concrete. After the test blocks were cured to 28d, three groups of test blocks were taken out and citric acid solution with the concentration of 1%, 3% and 5% was prepared by adding citric acid with water. Then each group of test blocks was placed in the citric acid solution respectively and treated with film sealing. After soaking for 28d, the compressive strength was measured. The initial pH value in the pores of the planted concrete was 12.54, and the compressive strength for 28d was 12.5.

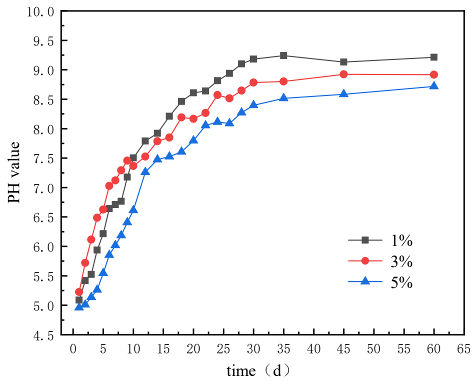

Fig. 1 pH value of solution after citric acid immersion

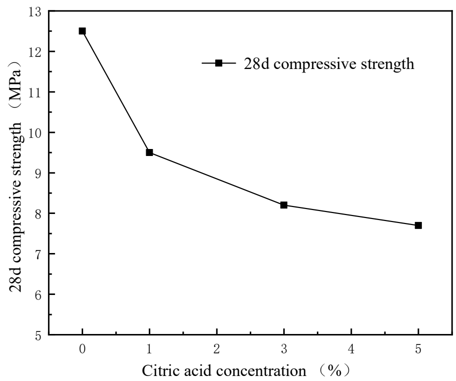

Fig. 2 Compressive strength of planted concrete after soaking with citric acid for 28d

By comparing the three groups of curves in Fig. 1, it is found that the alkali reduction of citric acid solution with 5% concentration is the largest, about 30.5%, followed by the citric acid solution with 3% concentration, about 28.8%, and the alkali reduction of citric acid solution with 1% concentration is the smallest, about 26.5%. According to the slope of the curve, the change trend of pH value in the three groups of experiments can be divided into two stages: In the first stage, after the intense reaction of citric acid with calcium hydroxide, the concentration of citric acid decreases, while the soluble Ca(OH)2 continues to be released from the planted concrete, and the pH rises quickly in this stage. In the second stage, the citric acid in the soaking solution is consumed, and in order to maintain the alkaline balance of the pores of the planted concrete, the cement hydration continues to precipitate soluble Ca(OH)2, and the higher the concentration of citric acid, the more alkaline substances precipitated and the faster the rate. As can be seen from Fig. 2, the compressive strength of the planted concrete soaked with citric acid for 28d is lower than that of the planted concrete without alkali reduction treatment. With the increase of citric acid concentration, the compressive strength of the planted concrete decreases by 24%, 34.4% and 38.4%, respectively.

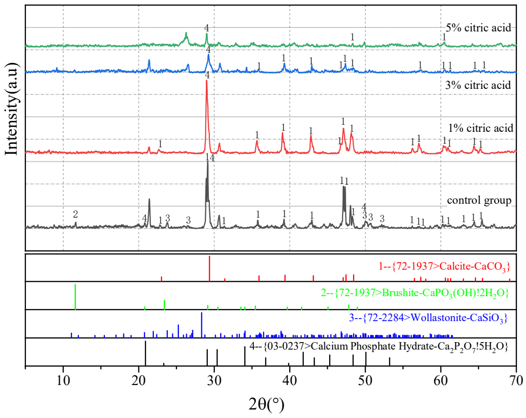

Fig. 3 XRD pattern of planted concrete after citric acid treatment

From a microscopic perspective, as the concentration of citric acid solution continues to increase, the more alkaline hydration products consuming cement, so the higher the concentration of citric acid solution, the better the alkali reduction strength. The surface of cement stone treated by citric acid solution is seriously corroded, and the granular shape is obvious, and the structure of cement stone is damaged, resulting in the strength of planted concrete is reduced. Therefore, citric acid solution should not be used for alkali reduction treatment of plant concrete.

4.2 Influence of Oxalic Acid on the Performance of Planted Concrete

Peroxalic acid particles were prepared into oxalic acid solution with concentration of 1%, 3% and 5%, and the alkali-reducing process of citric acid on planted concrete was repeated. The experimental results and analysis were as follows.

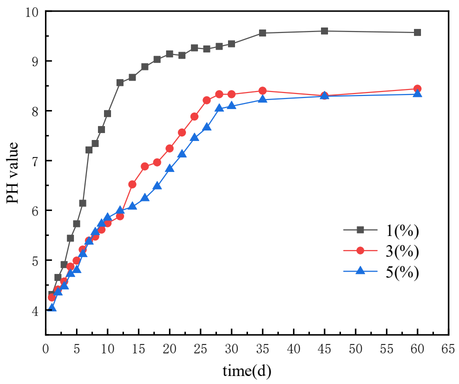

Fig. 4 pH value of the solution after oxalic acid immersion

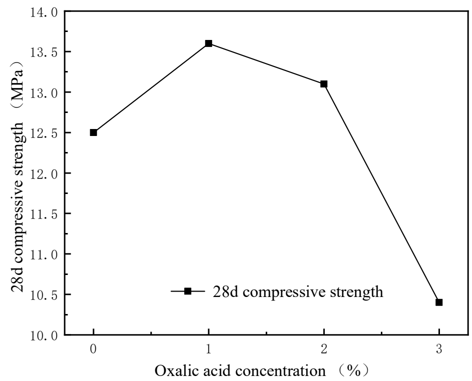

Fig. 5 Compressive strength of planted concrete after oxalic acid soaking

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As can be seen from the three groups of curves in Fig. 4, with the extension of soaking time, the pH value of soaking solution keeps increasing and finally tends to be stable, and the pH value of the pore environment of planted concrete is stable at 9.57, 8.44 and 8.33, respectively, with a decrease rate of 23.4%, 32.5% and 33.4%. As can be seen from Fig. 5, compared with the planted concrete without alkali reduction treatment, the 28d compressive strength of the planted concrete soaked with 1% and 3% oxalic acid solution has improved, among which the compressive strength of the planted concrete soaked with 1% oxalic acid has the most obvious improvement effect, increasing by 1.1MPa. When the concentration of oxalic acid is 5%, the compressive strength of planted concrete decreases.

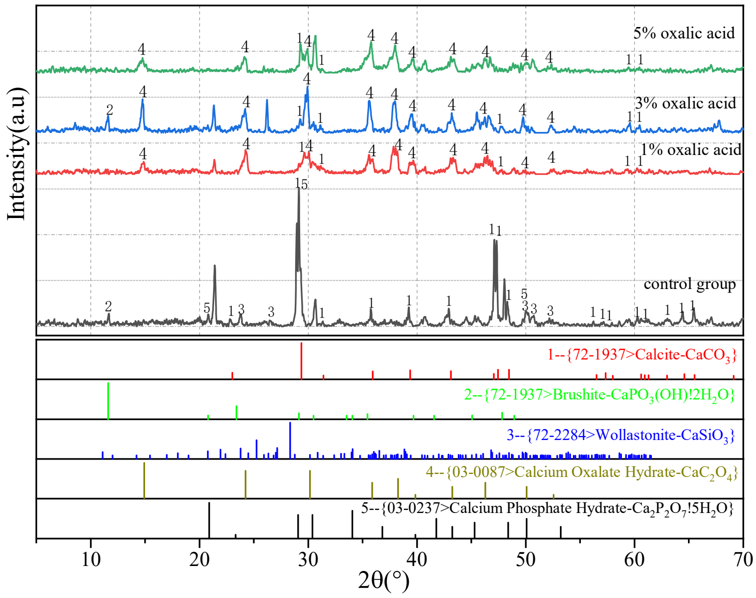

Fig. 6 XRD pattern of planted concrete cement stone treated with oxalic acid solution

From the microscopic analysis, after soaking the plant concrete with oxalic acid solution, a lot of calcium oxalate was generated while reducing the content of alkaline hydration products, which not only reduced the pH value in the pores of the plant concrete, but also made the internal structure of the cement stone more solid with the formation of calcium oxalate. Moreover, calcium oxalate precipitation can also prevent oxalate from further reacting with cement hydration products, thereby increasing the compressive strength of planted concrete. However, with the increase of oxalic acid concentration, the calcium oxalate precipitation can not effectively prevent the progress of the neutralization reaction, and the high concentration of acid solution destroys the concrete structure, resulting in the decline of its strength.

Therefore, when using oxalic acid for alkali reduction treatment of plant concrete, 1% and 3% concentration of oxalic acid can not only effectively reduce the pH value of the pore environment of plant concrete, but also enhance the strength of plant concrete, among which 3% concentration of alkali reduction effect is the best, 1% concentration of oxalic acid increase the compressive strength effect is the best. Although 5% oxalic acid solution can greatly reduce the pH value in the pore environment of planted concrete, it will affect its strength, so it is not used.

4.3 Influence of Superphosphate on the Performance of Planting Concrete

Superphosphate solution with 1%, 3% and 5% concentration was prepared by adding water to plant concrete test blocks. The pH value and compressive strength of the solution were measured regularly.

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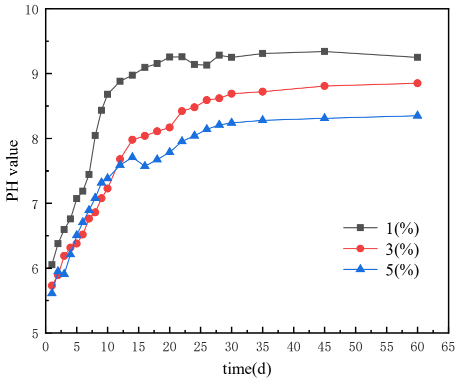

Fig. 7 pH value of solution after superphosphate immersion

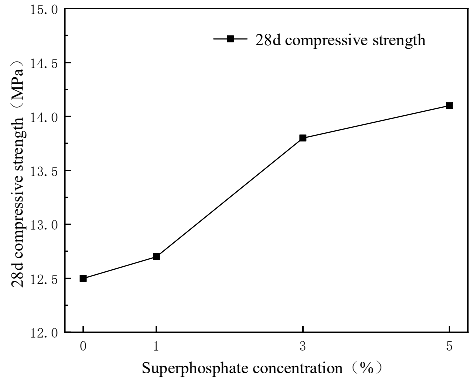

Fig. 8 Compressive strength of planted concrete after soaking in superphosphate

As can be seen from the three groups of curves in Fig. 7, pH values in the pores of planted concrete soaked with 1%, 3%, and 5% superphosphate solution all showed a trend of gradual rise until equilibrium and stability with the extension of time. With the increase of the concentration of superphosphate solution, pH values in the pore environment of planted concrete stabilized at 8.62, 8.02, and 8.09 respectively. Compared with the control group, the 28d compressive strength of the plant concrete test blocks treated with calcium phosphate solution has improved, among which the compressive strength of the plant concrete treated with 1% concentration of superphosphate spray is about 1.6%, and the compressive strength of the plant concrete treated with 3% concentration of superphosphate spray is about 10.4%. The increase of compressive strength of plant concrete treated with 5% concentration of superphosphate is about 12.8%.

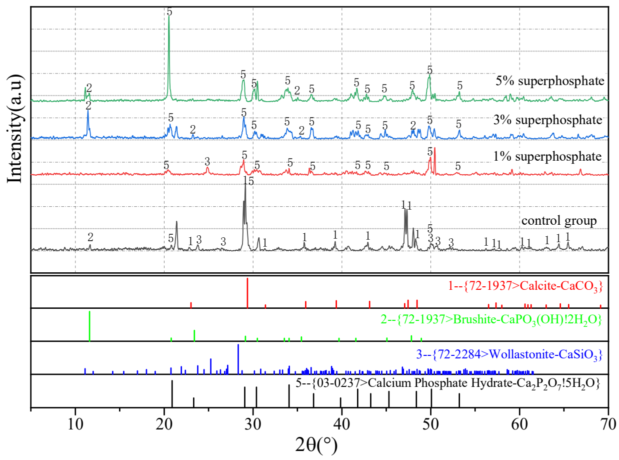

Fig. 9 XRD pattern of planted concrete after superphosphate solution treatment

From a microscopic perspective, the pH value change can be divided into two stages: In the first stage, due to the precipitation of alkaline substances in the planted concrete to maintain the environmental alkaline balance after alkali reduction treatment, the pH value rises. However, due to the reaction between superphosphate and soluble alkali during alkali reduction treatment, Ca3(PO4)2, which is insoluble in water, is precipitated, and a "protective film" of calcium phosphate is formed on the surface of the planted concrete test block, which reduces the precipitation path of alkaline substances. The soluble alkali precipitated from the concrete is limited, so the pore alkaline environment of the plant concrete tends to be stable in the second stage. With the increase of the concentration of superphosphate solution, more insoluble substances such as calcium phosphate are generated, which not only fills the pores between aggregates and increases the stressed area, but also helps to improve the compressive strength of planted concrete.

It can be seen from the above experimental results that alkali reduction treatment with superphosphate can not only effectively reduce the pH value of the pore environment of the planted concrete, but also help to increase the strength and stability of the planted concrete. Since the alkali reduction effect of plant concrete treated with 3% and 5% superphosphate solution is not much different, therefore, under the premise of meeting the strength requirements of plant concrete, from the economic point of view, it is appropriate to choose 3% superphosphate solution for alkali reduction treatment of plant concrete.

5. Conclusion

In this study, citric acid, oxalic acid and superphosphate were selected for alkali reduction treatment of plant concrete. The experimental data were analyzed and verified by XRD diffraction experiment, and the following conclusions were drawn: All three materials can reduce the alkalinity in the pores of plant concrete; Citric acid and oxalic acid solution with high concentration will change the internal structure of cement stone, which will have a certain negative effect on the mechanical properties of planting concrete, and should not be used alone. Superphosphate solution can not only reduce the pH value in the pores of planted concrete, but also increase the compressive strength of concrete. In the process of alkali reduction of planted concrete by superphosphate, it is necessary to master the optimal concentration of alkali reduction to reduce economic losses. In this paper, the chemical alkali reduction technology of plant concrete was studied, and the combination of macro and micro was realized, hoping to provide some reference for the research of alkali reduction of plant concrete.

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