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Experimental Study on Modification of Expanded Soil by Glutinous Rice Mortar Material

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Abstract: ***There are facilities such as highways and houses in the distribution area of expansive soils in Yanji region, while there are large agricultural fields in the surrounding area. In order to ensure that the nature of expansive soil will not have an impact on engineering facilities, and does not hinder the cultivation of farmland. In this paper, the expansion and contraction characteristics, mechanical properties, physical properties and microstructure of Yanji expansive soil were tested using glutinous rice mortar as the improvement material, and the difference between glutinous rice mortar improvement and traditional lime improvement was compared with the two methods of conventional maintenance and CO2 maintenance. The test results showed that: 1) Compared with the plain soil samples, the internal friction angle of the modified glutinous rice mortar samples increased by 98%~166%, the cohesion of the soil samples increased by 81%~310%, and the free swelling rate was reduced to 30%~45% of that of the plain soil samples. 2) Compared with the lime-amended specimens, the internal friction angle of the glutinous rice mortar-amended specimens decreased by 18 ~ 29%, the cohesive strength increased by 21 ~ 37.8%, and there was no significant difference in the free swell and shrinkage rates. 3) The free expansion rate of the specimens under CO2 conditioning was reduced to 21% ~ 48%, the unconfined compressive strength was increased by 122% ~ 258% compared with that of the plain soil, the pH was decreased by 1.7 ~ 2.4, and the peak strength was reached at 7 days of conditioning. The lime-modified soil under. 4) CO2 conditioning generates calcium carbonate crystals between the layers of montmorillonite minerals, and agglomerated cubic and spherical calcium carbonate crystals in the pores of the modified soil with glutinous rice mortar. The results of the above tests indicate that glutinous rice ash slurry can be used as a good modifier to improve expansive soils; CO2-maintained lime-amended soils and ash slurry-amended soils are an ideal ecological management mechanism.***

Keywords: Expansive soil, CO_2 conservation, Dilatation, Dissociation, Resistivity.

1. Introduction

Expansive soil is a kind of special clay soil with the property of contraction by water loss and expansion by water absorption. Clay minerals in expansive soils will contract and expand under the action of wet and dry cycles, making the soil body loose and accelerating water infiltration when the soil body is exposed to water, thus reducing the strength of the soil body, destabilizing the slopes of expansive soils, and affecting the safety of the buildings and structures on the expansive soils site [1]. China is one of the most widely distributed countries in the world with expansive soils, which are distributed in Yunnan, Guizhou, Heilongjiang and Jilin. Among them, expansive soils in the seasonal permafrost region of Northeast China are dominated by slope-accumulated moderately weak expansive soils, which intensify the weathering of their protoliths under extreme freezing and thawing as well as dry and wet cycles. Expansive soils are commonly developed along the highways in Yanbian area of Jilin, and landslides of different degrees have occurred in highway construction since the 1980s [2~5].

In order to cope with the special deterioration mechanism of expansive soils, scholars at home and abroad have taken many measures: physical modification, chemical modification and biological modification [6]. Among them, physical modification is mainly to increase the density of soil, reduce the pore space in the soil of vacuum pre-pressure method, tamping method, etc.; chemical modification method mainly includes lime modification, cement modification, fly ash modification and organic matter modification, etc.; biological modification to microbial-induced calcium carbonate precipitation modification is mainly, which injects bacterial solution, calcium chloride, urea and nutrients into the soil, etc. [7~11]. In engineering practice, lime is often used to treat expansive soils, and its improvement mechanism has been relatively well studied as early as the beginning of this century. However, the lime-improved expansive soil is mixed with a large amount, and the high alkalinity produced by lime does not meet the ecological requirements of green engineering construction proposed in recent years. In order to accomplish the ecological construction goal, it is necessary to test a new type of modified material or to treat the alkalinity of lime modified soil [11~13].

In China's ancient construction, glutinous rice mortar is commonly used as a bonding material. In recent years, some studies have shown that glutinous rice slurry in the process of lime generation of calcium carbonate will play a role in regulating the size of the shape generated, and at the same time the glutinous rice starch in the slurry will fill the size of the pores in the structure, the glutinous rice mortar material in the new era has a new life [14~17]. Wei Guofeng et al. studied the effect of different lime types and additives on the strength of glutinous rice mortar [12]; Jia Dongqin et al. attempted to use glutinous rice mortar to reinforce loess in northern Shaanxi Province and analyzed its micro-mechanism [18]; Zhao Pei et al. used glutinous rice mortar to reinforce site soil [20]. The experiment proves that the glutinous rice mortar material can effectively improve the strength of soil, and the mixing of glutinous rice mortar can reduce the lime mixing amount which is mild and friendly to the environment. In the construction industry, carbon dioxide mineralization curing cement and concrete is an emerging method to strengthen concrete strong [19]. Wu Shengkun et al. found that carbon dioxide mineralization of cementitious materials can generate CaCO3 precipitation and amorphous high polymerization SiO2-nH2O in the pore space of the material [21]; Luo Kuang et al. showed that carbon dioxide mineralization in the process of maintenance of CO2 and Ca (OH) 2 and other alkaline components of the reaction is very rapid, maintenance of 1 h can be completed most of the reaction [22].

Based on the above analysis, this paper takes Yanji expansive soil as the research object, and carries out the modification test with two materials of lime and glutinous rice mortar of different dosage, and conducts the free expansion rate, straight shear test, and unconfined compressive strength test to determine the modification effect of the modified specimens [23~26]. The resistivity of the specimens was also tested to characterize the reaction process of lime-modified expansive soil by the change of specimen resistivity. At the same time, considering the ecological impact of the modification process, this paper tries to maintain the specimens under CO2 environment to accelerate the conversion rate of quicklime to calcium carbonate, reduce the alkalinity of the modified soil samples, and explore the effect of carbon dioxide mineralization maintenance on the properties of soil samples [26~34].

2. Test Materials and Research Program

2.1 Test Materials

2.1.1 Basic properties of soil samples

The soil for the test was taken from the vicinity of National Highway 333 in Xinyan Village, Yanji City, and the sampling point is shown in Figure 1. Expansive soil in this area causes cracking of the roadbed of the nearby highway, affecting the cultivation of farmland, and will affect the normal life of the surrounding villages if left untreated. The sampling time is 2023.4.16-4.17, the coordinates of soil sampling are 42°59′53″N, 129°30′17″E, and the sampling depth is 30-90cm below the ground.

Figure 1: Sampling point topography and expansion contraction cracking situation

Soil samples were retrieved and tested for their basic physical properties according to the Standard for Geotechnical Test Methods (GB/T 50126-2019), and the results are shown in Table 1.In the table, it can be seen that the liquid limit of the expanded soil sample is 45.7%, and the plasticity index is 15.2, which can be categorized as a low-liquid-limit chalk (ML) according to the Standard for the Classification of Soils in Engineering (GB/T 50145-2007).

Table 1: Basic physical properties of expansive soil

Natural Density (g/cm3)	Maximum Dry Density (g/cm3)	Natural Moisture Content (%)	Optimum Moisture Content (%)	Liquid Limit (%)	Plastic limit (%)	Plasticity index
1.97	1.59	29.5	22.9	46.7	30.5	15.2

The particle size composition of the soil samples was measured using a combination of the densitometer and sieve analysis methods, with 32.42% clay particles, 50.3% powder particles and 17.28% sand particles. The cumulative percent soil particle size curve is shown in Figure 2.

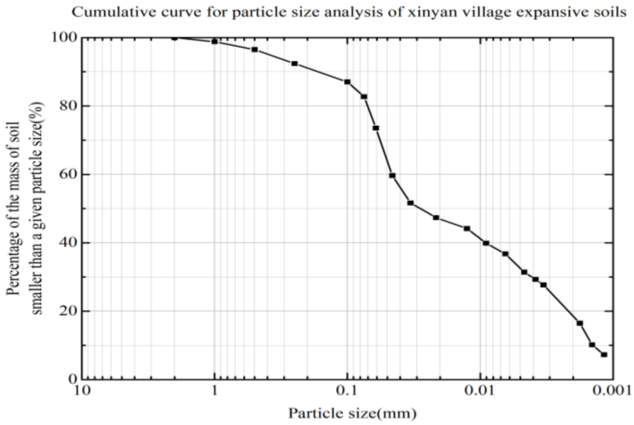

Figure 2: Cumulative curve of particle size analysis for expansive soil

For the swelling test of the test soil sample, free swelling rate test, cation exchange quantity test of barium chloride buffer method and X-ray diffraction test of soil were conducted according to the test standards, and the test results are shown in Tables 2 and 3. The free swelling rate of the soil sample was measured to be 80%, and the cation exchange quantity was 317.05 mmol/kg. Judging from the above conditions, the soil sample has a medium swelling potential.

Table 2: Mineral diffraction results

Samples	Mineral content (%)									
	Quartz	Potassium feldspar	Plagioclase	Calcite	Dolomite	Slaked lime	Pyrite	Ferric oxide Fe2O3	Hornblende	Clay
Xinyan village expansive soil	38.1	9.5	13.0	/	/	/	/	0.6		38.8

Table 3: Diffraction results of clay minerals

Samples	Relative clay mineral content (%)						mixing ratio (%S)	
	S	I/S	It	Kao	C	C/S	I/S	C/S
Xinyan village expansive soil	/	75	22	3	/	/	60	/

S: ammonite I/S: imbricated zone It: Elysium K: kaolin C: Chlorite C/S: greenish-blended layer

2.1.2 Modified materials

The lime used for the test is Huilime brand lime originating from Xinyu, Jiangxi Province, and the calcium oxide content of the lime is about 87%. Glutinous rice flour for the test is Taojingxiang brand water-milled glutinous rice flour, and the ingredients are glutinous rice and water. The materials are shown in Figure 3.

Figure 3: Quicklime and glutinous rice flour

2.2 Specimen Preparation

2.2.1 Preparation of glutinous rice paste

Weigh a certain amount of deionized water with a beaker, pour a certain mass ratio of glutinous rice powder into the deionized water, place the beaker into a constant temperature of 85℃ water bath heating for 30 minutes, stirring during the heating process while heating, to avoid lumps of glutinous rice powder and to make the branched-chain starch in the glutinous rice slurry completely open that is the completion of the pasting, before and after the paste heating and weighing and replenishment of water, to avoid the evaporation of water in the paste process of the concentration of glutinous rice slurry caused by The effect of water evaporation on the concentration of glutinous rice paste is avoided during the pasting process, as shown in Figure 4.

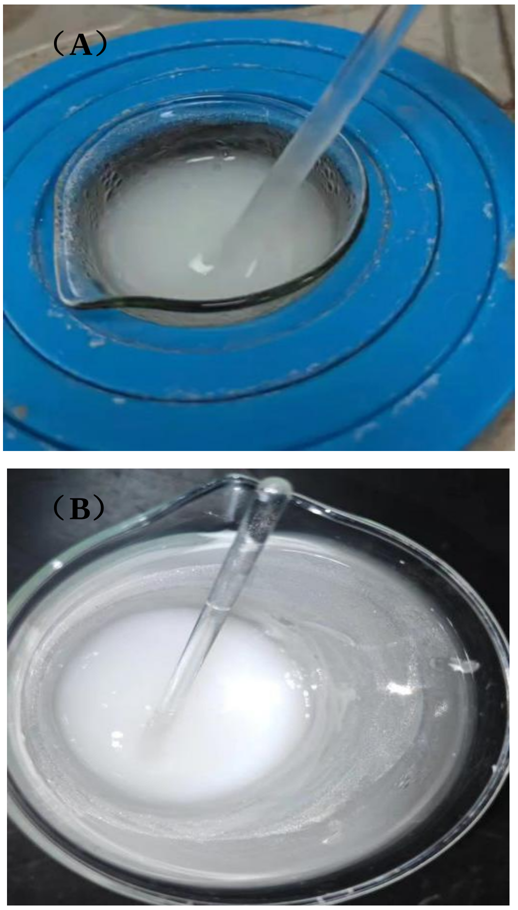

Figure 4: Process of making glutinous rice mortar (A) precipitation reaction (B)

In the preparation process of glutinous rice slurry this paper tried to configure the glutinous rice slurry with the mass fraction of glutinous rice flour of 3%, 4%, 5%, 6%, 7% and 8%. The test proved that when the mass fraction of glutinous rice flour exceeded 6%, the glutinous rice pulp was very easy to precipitate during the preparation process and could not form a uniform rice pulp. Therefore, the concentration of glutinous rice slurry in the subsequent test was set to a maximum of 5%.

2.2.2 Preparation of improved soil samples

In the dry mixing method, a certain percentage of lime was mixed into the soil, and the results of previous tests showed that the best improvement effect was achieved when the quality of glutinous rice slurry accounted for 10% of the sample quality. Therefore, after the dry mixing, 10% of the paste of glutinous rice pulp was added to the mixing, and the water was replenished with a spray bottle during mixing to control the moisture content of all the soil samples produced to the optimal moisture content of 22.9%. The specimens of conventional maintenance were mixed well and then left in the plastic bag for 24 hours for sample making; the specimens of CO2 environment maintenance were mixed well and then put into the pressure cylinder with 0.1Mpa pressure and CO2 filling for 24 hours for sample making. The specimens were made into cylindrical samples with a diameter of 39.1mm, a height of 80mm and a compaction degree of 95% by hydrostatic pressing method, which were used for unconfined compressive strength test and resistivity test; and the ring knife samples with a diameter of 61.8mm and a height of 20mm were used for straight shear test and shrinkage test. After the specimen is made, it is put into the moisturizing cylinder for maintenance.

Table 4: Sample design scheme

Dopant	Conservation methods	Conservation age	Dopant	Conservation methods	Conservation age
CaO2%	routine maintenance	3、7、14、28	CaO2% + Gr5%	routine maintenance	3、7、14、28
CaO3%	routine maintenance	3、7、14、28	CaO3% + Gr5%	routine maintenance	3、7、14、28
CaO4%	routine maintenance	3、7、14、28	CaO4% + Gr5%	routine maintenance	3、7、14、28
CaO2%	CO_2 conservation	3、7、14、28	CaO2% + Gr5%	CO_2 conservation	3、7、14、28
CaO3%	CO_2 conservation	3、7、14、28	CaO3% + Gr5%	CO_2 conservation	3、7、14、28
CaO4%	CO_2 conservation	3、7、14、28	CaO4% + Gr5%	CO_2 conservation	3、7、14、28

2.3 Test Apparatus and Method

2.3.1 Expansion and contraction test of expansive soil

In order to study the effect of glutinous rice mortar material on the expansion and contraction potential of expansive soil, according to the "Standard for Geotechnical Test Methods" (GB/T 50126-2019) on the above improved specimen free expansion rate and contraction test.

2.3.2 Mechanical property test

In order to study the effect of glutinous rice mortar material on the strength of expansive soil and the cohesion and internal friction angle of soil samples, the unconfined compressive strength test was carried out on YYW-2 strain-controlled unconfined manometer with straight shear test. The test operation was carried out according to the Standard for Geotechnical Test Methods (GB/T 50126-2019).

2.3.3 Physical property test

A VICTOR 4091C benchtop digital bridge was used to measure the resistivity of the modified specimens in an attempt to characterize the reaction process in terms of resistivity. In order to test the change of acidity and alkalinity of the soil samples after CO2 conservation, Shanghai Yue Ping PHS-25 pH meter was used to measure the pH of the modified soil samples.

2.3.4 Scanning electron microscope test

In order to study the influence of glutinous rice mortar material on the pore filling and calcium carbonate generation of expanded soil, representative specimens were selected, and the internal structural changes of soil samples were observed using scanning electron microscope after liquid nitrogen freezing and vacuum spraying of gold.

3. Test Results and Analysis

3.1 Effect of Improver Dosage and Maintenance Age on Expansion and Contraction of Expansive Soil

The changes of free expansion rate and shrinkage characteristics of soil samples with the age of maintenance are shown in Table 5:

Table 5: Sample swelling and shrinking properties

Soil sample	Age of conservation/Day	Free expansion rate/ (%)	Shrinkage limit/ (%)	Wire shrinkage/ (%)
CaO2 %	3	23	14.3	3.8
	7	25	14.7	3.5
	14	27	14.9	3.3
	28	18	15.6	3.2
CaO2 % + Gr5%	3	21	13.9	3.4
	7	30	14.1	3.3
	14	29	14.1	2.9
	28	19	14.6	2.7
CaO3 %	3	24	15.4	3
	7	32	15.9	3
	14	26	16.6	2.7
	28	17	17.2	2.3
CaO3 % + Gr5%	3	22	16.2	2.9
	7	28	16.9	3
	14	31	16.9	2.8
	28	20	17.1	2.3
CaO4 %	3	16	18.7	2.5
	7	29	18.8	2.2
	14	23	19	2
	28	27	19.1	2
CaO4 % + Gr5%	3	30	17.9	2.4
	7	25	18.2	2.2
	14	19	18.4	1.9
	28	21	18.5	1.8

The free expansion rate of Yanji expansive soil used in the test was 80%, and it can be seen from the above table that the free expansion rate of the expansive soil samples does not change regularly with the increase of the age of maintenance and the change of the concentration of the improver. Lime and glutinous rice mortar inhibit the free expansion rate of expansive soil with obvious effect, so that the free expansion rate is reduced to 20% ~ 40% of the plain soil and the free expansion rate of all soil samples is reduced to less than 32%, which is below the standard of weak expansion potential. The laboratory free swell test involves drying at 105°C and sieving, which destroys the stabilized agglomerate structure already formed in the soil samples, resulting in no specific pattern in the data results.

In terms of the shrinkage characteristics of soil samples, with the increase of lime dosing in mortar and the increase of the age of maintenance, the linear shrinkage of soil samples decreased and the shrinkage limit increased. This phenomenon shows that the lime in the soil samples gel, crystallization and other effects, in the lime doping is small (≤ 4%), this effect will make the soil particles combined into larger crystals, so that the soil particles cemented into a whole so that the soil particles of the particle size increases, the pore space between the soil particles become larger. At this time, the pore space in the soil sample becomes larger, and the evaporation of water per unit time is faster, which is reflected in the experimental results as a higher shrinkage limit of the soil sample.

Comparing the results of glutinous rice ash slurry and quicklime group, it was found that the addition of glutinous rice slurry would further reduce the line shrinkage rate of soil samples, and the shrinkage limit was also decreased. The unfolded branched starch ends of the glutinous rice slurry after pasteurization will provide attachment sites for lime, making its filling effect in the pores of the soil samples more significant, and while combining the soil particles into larger crystals, part of the lime will also be filled into the pores for the reaction, which relatively slows down the evaporation of water per unit of time. At the same time in the glutinous rice mortar modified soil samples, water is more in the form of water in the glutinous rice slurry, this way of existence is more unfavorable to the evaporation of water, resulting in the reduction of shrinkage limit.

3.2 Effect of Modifier Dosage and Maintenance Age on Mechanical Properties of Expansive Soil

The results of the straight shear test of soil samples are shown in Figure 5:

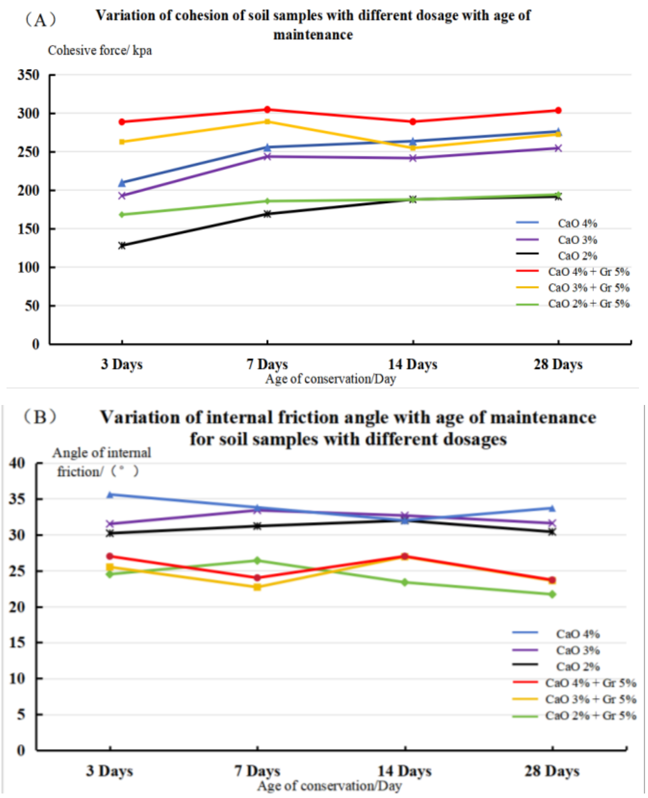

Figure 5: Changes in cohesion (A) and internal friction angle (B) of specimens under different conditions

The results of straight shear test show that: the cohesion of lime-amended expansive soil increases with the increase of maintenance age, the maximum rate of increase in the early stage of maintenance, with the increase of maintenance age, the rate of increase gradually slows down; the angle of internal friction changes slightly, but not obvious. In the process of lime-improved expansive soil: the early strength is formed by cation exchange reaction; with the increase of the maintenance age, the aluminum gel and silica gel in the expansive soil will further react with lime to generate CaSiO3 and CaO-Al2O3, which harden in the aqueous environment to form a stable reticulation around the viscous particles of the expansive soil with strong bonding; at the same time, Ca (OH) 2 and Mg (OH) 2in the soil will also continue to react with the CO2 in the environment, generating strong CaCO3 and MgCO3 particles to fill the cementation between the soil particles so that the cohesion of the soil body is enhanced.

Comparing the expanded soil samples improved with glutinous rice mortar, it is found that the incorporation of glutinous rice mortar will further strengthen the soil cohesion, not only because the viscosity of glutinous rice mortar itself will provide better cementation for soil particles, but also because the branched starch unfolded by pasting will provide attachment sites for Ca2+ in the environment, which will allow gelation and carbonation to take place in a more suitable location. However, the presence of water in the mortar-amended soil in the form of water in the glutinous rice slurry changes the way pore water exists in the original soil samples, resulting in a slight decrease in the angle of internal friction of the soil samples.

3.3 Relationship between Soil Sample Resistivity and Soil Sample Properties

The resistivity test results of soil samples under conventional maintenance are shown below Figure 6:

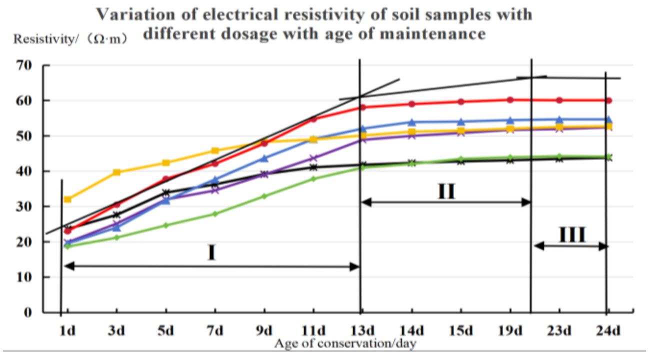

Figure 6: Test results of electrical resistivity of the sample

From the change rule of specimen resistivity can be seen, the reaction of lime in the soil is obviously divided into three stages: in the first stage of the conductive ability of the soil samples linearly weakened, and the gel reaction generated by the gel has the characteristics of the conductivity of the weaker, at the same time, this part of the gel on the pore space of the soil samples to fill the pore, reducing the conductivity of the pore water, which means that in the reaction occurs in the 1 ~ 13 days, the reaction of the soil samples with the gel reaction. In stage II, the resistivity of the soil samples had a slight increase, which was the residual reaction process of the lime-amended soil reaction, and part of the unreacted lime continued to carry out the gel and crystallization reaction, and the filling pattern in the pore space was more stable. In stage III, the resistivity of the soil samples remained almost unchanged, i.e., it proved that the reaction of lime in the soil samples had been complete.

Comparing the lime-improved and glutinous rice mortar-improved samples, it can be found that the resistivity of the glutinous rice mortar-improved soil samples is larger at the same age of maintenance, which means that the lime is more fine in filling the pores and the pores of the soil samples are filled more fully after the addition of glutinous rice mortar. This further verifies the conclusion of the pore filling by glutinous rice mortar in the preceding straight shear test and expansion and contraction test.

In summary, the lime and glutinous rice mortar under conventional maintenance had obvious improvement effects on expansive soils. In terms of straight shear strength and shrinkage, the properties of the soil samples became stronger with the increase of lime content, and this change was more obvious when the lime was increased from 2% to 3%, and the change was smaller when the lime was increased from 3% to 4%. In terms of the age of maintenance, the properties of soil samples become stronger with the increase of the age of maintenance, and this change is more obvious in 14 days of maintenance, and the change is smaller after 14 days. Therefore, 3% lime and mortar admixture can be considered in the actual project of expansive soil improvement for 14 days of maintenance.

3.4 Influence of the Maintenance Method on the Properties of Expansive Soil

In this paper, a CO2 conservation method of soil samples is designed to change the main reaction in the process of lime soil improvement from the gel reaction of lime to carbonation reaction, reduce the pH value of the improved soil samples, and significantly reduce the age of conservation.

The results of unconfined compressive strength test and free swelling rate test of lime soil and glutinous rice mortar soil under CO2 conservation are shown in Table 6.

Table 6: Compressive strength and expansion rate of samples after CO2 curing

Soil sample	CO2 conservation age /day	Unconfined compressive strength /kpa	Free inflation rate /%
CaO2%	3	200	48
	7	240	43
	14	251	44
	28	244	42
CaO2% + Gr5%	3	207	36
	7	233	33
	14	204	30
	28	210	30
CaO3%	3	224	42
	7	286	36
	14	298	36
	28	301	34
CaO3% + Gr5%	3	244	33
	7	295	28
	14	273	30
	28	266	30
CaO4%	3	241	24
	7	299	26
	14	302	22
	28	311	23
CaO4% + Gr5%	3	262	22
	7	323	21
	14	311	24
	28	306	25

The unconfined compressive strength of the CO_2-maintained soil samples was enhanced by 122% to 258% relative to that of the plain soil, and the strength was significantly enhanced at the age of 3 to 7 days of maintenance, but the enhancement was not obvious after 7 days, and the compressive strength of the soil samples improved with glutinous rice mortar even showed a small decrease at 14 days. The reason for this change is that almost all of the lime undergoes carbonation in the CO_2-filled environment, i.e., all of the lime becomes $CaCO_3$ and fills in the pores.

The free swell of the soil samples was reduced to 21% ~ 48%, which is at least 47.5% lower than that of the plain soil, but the soil was more expansive than that of the soil samples under normal conditioning. This is due to the fact that in a CO_2 rich environment, the cation exchange of lime is weakened and a large amount of Ca^{2+} is used to generate $CaCO_3$, which results in a controlled but still present swelling of the clay minerals.

The pH values of the soil samples under CO_2 conditioning compared to normal conditioning are shown in Table 7 below:

Table 7: Acidity and alkalinity of samples after CO_2 curing compared to conventional curing methods

Soil sample	Age of conservation/day	pH under routine care	pH under CO2 conservation
CaO2%	3	10.5	8.8
	7	10.45	8.8
	14	10.45	8.8
	28	10.45	8.8
CaO2% + Gr5%	3	10.45	8.7
	7	10.4	8.7
	14	10.4	8.7
	28	10.35	8.7
CaO3%	3	11.3	8.95
	7	11.2	8.95
	14	11.2	8.95
	28	11.15	8.95
CaO3% + Gr5%	3	11.2	8.9
	7	11.15	8.9
	14	11.15	8.9
	28	11.05	8.9
CaO4%	3	11.75	9.25
	7	11.65	9.25
	14	11.65	9.25
	28	11.45	9.25
CaO4% + Gr5%	3	11.6	9.15
	7	11.55	9.15
	14	11.55	9.15
	28	11.4	9.15

From the above table, it can be seen that the pH value of the specimens under conventional conservation hardly changes with the increase of the age of conservation, which is also in line with the law that the carbonation process is a late reaction in the process of lime-amended soil. Comparing with the specimens under conventional conditioning, CO_2 conditioning will make the pH value of the specimens drop significantly, close to the pH value of the plain soil 8, which also indicates that the alkalizing effect of lime and mortar on the soil samples under CO_2 conditioning is much smaller, which is more friendly to the environment, and the improved soil is still suitable for the growth of plants and animals.

To summarize, CO_2 conservation will make the soil samples improved by lime and glutinous rice mortar reach a certain strength in a very short conservation age, and there is a significant reduction in expansion compared with the plain soil, and the pH value decreases from high alkalinity to close to the plain soil, which is more friendly to the environment.

3.5 Microstructural Characteristics of Soils

The above results show that, in terms of expansion and contraction, the free expansion rate of the improved soil is greatly reduced compared with that of the original soil; the contraction process is faster and the amount of contraction is smaller during contraction. In terms of mechanical properties: the angle of internal friction and cohesion of the improved soil samples increased dramatically, and the compressive strength also increased exponentially. The electron microscope pictures of Yanji expansion soil plain soil, lime soil under CO_2 conservation and mortar soil are shown in Figure 7 below:

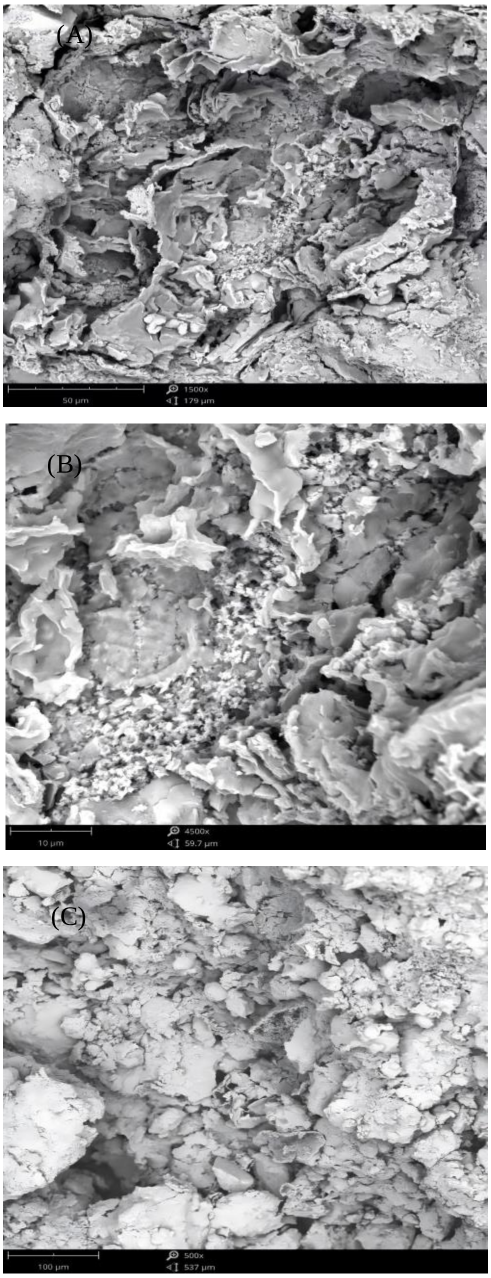

Figure7: Electron microscope photograph of expansive soil

Figure (A) shows the picture of Yanji expansion soil vein soil under 1500 times electron microscope, the clay minerals in

Yanji expansion soil can be clearly observed in the picture, and the shape of immonite layer. Figure (B) shows the picture of lime soil under CO2 conservation under 4500 times electron microscope, the clay minerals in the soil are clearly visible, laminated montmorillonite minerals are distributed in large quantities, and cubic CaCO3 crystals are visible between the mineral layers. The carbonation reaction in the process of lime-improved soil should be a relatively small and slow reaction, but the induction of Ca2+ to generate CaCO3 crystals under CO2 conservation has become a relatively large reaction, which effectively fills the size of the pores in the soil and improves the strength of the soil samples. Figure (C) shows the picture of the mortar soil under CO2 conservation under 500x electron microscope, from which the calcium carbonate agglomerates based on glutinous rice pulp can be observed, i.e., it verifies the assumption that the glutinous rice pulp in the pores of the soil can provide an attachment location for the carbonation reaction of lime. The addition of glutinous rice paste makes the generated CaCO3 crystals bond with each other to form a skeleton to further enhance the strength of the soil.

4. Conclusion

(1) The effect of glutinous rice mortar on the improvement of expanded soil is better than quicklime, glutinous rice mortar can increase the straight shear strength of expanded soil by 127% ~ 271%, so that the free expansion rate of soil samples is reduced by 60% ~ 73% are lower than the weakly expanding latent soil indicators, the optimal ratio of glutinous rice mortar is CaO3% + Gr5%, the age of maintenance is at least 14 days.

(2) CO2 conservation of lime-amended soil and glutinous rice mortar-amended soil will increase the unconfined compressive strength of the soil samples by 122% ~ 258% and reduce the free swelling rate by 47.5% ~ 73% after a short-term conservation period of 7 days, so that the pH of the soil samples will only increase by 0.8 ~ 1.15 compared with that of the plain soil.

(3) Observed by scanning electron microscope images, the crystallization of lime-amended soil under CO2 conditioning occurred mainly by generating small-diameter CaCO3 crystals; the generation of CaCO3 crystals in the glutinous rice mortar-amended soil under CO2 conditioning was based on the glutinous rice starch and most of them were globular crystals, which formed an agglomerated supportive skeleton in the interstitial space of the soil particles.

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