Study on LN Type Curing Agent in Improving the Comprehensive Properties of Composite Soil

Jie Ren[1, a], Xidan Zhang[1, b], Yansong Cui[2, c]

[1] Nanjing University of Information Science and Technology, NANJING 210000, China;

[2] Nantong University, NANTONG 226019, China.

[a] 18061732038@163.com, [b] 18761602310@163.com, [c] 535849192@qq.com

Abstract

Based on the soil quality of seepage canal irrigation area, a suitable type of LN curing agent was selected according to laboratory experiments. Different types of composite soil were prepared by controlling the ratio of different cement, soil, lime and curing agent. Through compaction test, Compressive strength and resilience modulus test evaluation of the comprehensive performance of different formulations of samples.Compaction tests show that as the amount of composite soil cement increases, the optimum moisture content decreases and the maximum dry density increases. However, the amount of curing agent has little effect on the compaction test results. The unconfined compressive strength experiment shows that the unconfined compressive strength of the composite soil increases with the cement content when the cement content is below 10%, but the increase is very limited when the cement content increases more than 10%. LN series curing agent can effectively improve the compressive strength of composite soil. Compressive elastic modulus experiments show that the compressive modulus of composite soil at different ages increases linearly with the amount of curing agent. But after 4 weeks of enhancement tends to be slow. In summary, the use of LN series curing agent can effectively improve the comprehensive index of composite soil, and can reduce the amount of cement used and the time to cultivate the composite soil. It can significantly improve the overall performance of composite soil.

Keywords

Composite soil, Compaction test, Compressive strength, Resilience modulus, Curing agent.

1. Introduction

Channel seepage control is widely used in China water-saving engineering technology.Soil materials, cement soil, stone, concrete, asphalt concrete and membrane materials is used commonly in channel impermeable layer to prevent the channel leakage[1]. In the recent 10 years, channel seepage control engineering technology has drawn universal attention and has been rapidly developed. Many research achievements have been made in impermeable materials, structural forms of seepage prevention and control of frost heaving[2]. The development trend of the anti-seepage channel is from a single material to the composite material, from a single structure to the composite structure and from the construction of the main to mechanization, semi-mechanized direction. Drawing lessons from Japan's experience, the concrete seepage prevention channels built by Japan in the 60s-70s in the 20th century affected the construction of ecosystem in irrigated areas in varying degrees. In order to restore and increase the ecological capacity of irrigated areas, in the past 10 years, in combination with the reconstruction of irrigated areas, In some areas, the concrete seepage prevention channels will be reformed, partial dismantling shall be carried out according to the design requirements, the seepage-proof geomembrane shall be filled, and then the mesh-type eco-protective surface should be re-made to improve the ecological capacity.From the analysis of the construction scale of concrete seepage control channels in our country, we continue to follow the traditional anti-seepage methods. If the ecological reconstruction is carried out, the secondary investment required will be huge. Taking concrete seepage canal construction as an example, its main problems or deficiencies are mainly manifested in the following aspects[3,4]:

1. In terms of investment and construction management, the construction period is long, seasonally affected, construction is not possible under low temperature conditions, and the investment is large, the cost is high, and the technology is complicated.

2. In terms of operation management and maintenance, impervious channels of plain concrete agricultural drains are subject to uneven settlement, resulting in the phenomena of cracks, landslides and water leakage, high maintenance costs, difficulty in implementing maintenance funds and lowering of final grade Canal system efficiency.

3. From the perspective of macro-investment in agricultural water saving, in the next 10 years, the coefficient of water utilization in irrigation and irrigation channels should reach above 0.6, and the demand for direct agricultural water-saving in China will reach over 800 billion yuan in the next 10 years. There is a certain risk of relying on financial fund-raising. There is more difficulty in supporting funds for the end-canal system.

From the perspective of ecological irrigation district construction, the technical measures of impervious concrete hardening seepage are not conducive to the formation of plant diversity and the survival and reproduction of animals, which are not in line with the construction direction of our country's ecological irrigation district.

From this perspective, the promotion and application of ecological seepage prevention channel construction methods, economic and ecological benefits will be enormous.

Composite geomembrane is a new type of engineering materials, which is composed of geotextile, geomembrane, geotextile three layers. Accumulate the advantages of geotextiles and geomembranes[5]. Composite geomembrane is reinforced with polyethylene or polyvinyl chloride, calendered film and polyester acupuncture geotextile heat together into. Has a light weight, tensile, anti-bursting, tear strength, good elongation, deformation Modulus, anti-aging, anti-seepage performance is good, simple construction, low cost and long life characteristics, is an ideal anti-seepage material for the unit has achieved good economic and social benefits. As the composite geomembrane has the above characteristics, is widely used in the construction of agricultural anti-seepage channels. Canal seepage control is to reduce the channel leakage water loss engineering measures. Not only can save irrigation water, but also can reduce groundwater level to prevent secondary salinization of soil; prevent channel scouring and collapse, speed up the flow rate to improve water delivery capacity, reduce channel cross-section and building dimensions; save land and reduce engineering Fees and maintenance management fees[6].

The core of the composite geomembrane preparation is reasonable selection and curing with bentonite[7,8]. In this paper, we take the basic test of composite soil preparation in the laboratory by sampling the soil of the demonstration area and cooperating with LN series soil curing agent, and make the parameters of the composite soil testing and evaluation, based on the feasibility of different composite soil formulations and economic discussions, to determine the optimal bentonite formula.

2. Experimental

In this study, the soil quality of LN series soil curing agent test area was analyzed to study the technical feasibility and economy of the composite soil curing technology as a seepage-proof surfacing material. Feasibility refers to LN series of soil curing agent curing soil which can meet the technical requirements of the canal seepage protection materials, such as strength characteristics, stiffness characteristics and stability. The economy is the construction cost of this solidified soil and concrete plain concrete channel surface seepage contrast to see if it can save engineering costs. Test contents, the main test equipment and test results are shown in Table 1.

Table 1 The main test and equipment

Number	Test content	The main test equipment	Test results
1	Compaction test	Electric heavy compaction device	The best moisture content, the maximum dry density
2	Unconfined compressive strength test	Pavement strength tester	Compressive strength at different ages
3	Elastic modulus test	Rebound modulus	Modulus of resilience

2.1 The compaction test of bentonite

Compaction test is the preparation and precondition of the whole composite soil test. Its purpose is to carry out standard compaction in the specified test tube, draw the soil moisture content-dry density curve, and determine the optimum soil moisture content and maximum dry density as the basis of the experimental data[9,10].

Table 2 The technical parameters of compaction test

Type of experiment	Compaction tube size	Hammer	Other parameters
Heavy	Inside diameter(10cm)	Weight(4.5kg)	Hammer layers (5)
	Height (12.7cm)	Hammer at the end diameter(5.0cm)	Hammer layers per layer (27)
	Volume(997 cm^3)	Decrease height(45cm)	Maximum particle size (25mm)

According to the experimental plan prepared by composite soil, three types of composite soil are formed. The dosage of the cement determined in the experimental scheme is 5%, 8%, 10%, 15% and 20%. The dosage of the calcium and magnesium lime is fixed at 10%. The dosage of the hardener is 0.01%, 0.02%, 0.03% and 0.04%.

2.2 The Unconfined compressive strength test of bentonite

The unconfined compressive strength is the maximum axial stress that the specimen can withstand without any restriction and can exactly reflect the strength characteristics of the specimen. Unconfined compressive strength test is easy to operate, widely used in indoor mix design and on-site testing. In this experiment, the specimens were prepared by static compaction method according to the preset dry density. The specimens were all of high height: a cylinder with a diameter of 1: 1 and a compaction degree of 95%. Specific to this test with the specimen diameter and height of 100mm, each forms nine specimens. On the day before the scheduled test, a test of 1000g was made to determine the air-dried moisture content. Then according to the above method, we can determine the best moisture content and maximum dry density of each group. According to the best moisture content, the maximum dry density and the volume of test mode,we calculate the weight of a mixture which should be put on the test mode. The weighed weight of the mixture was divided into 3 times into the test mode, with a test stick after each light insert solid. The entire test mode on the reaction force within the framework of the jack, until the pressure up and down,and the pressure column to the test mode so far, static pressure for 1 min, then put the stripping machine off the test mode. Specimens from the test model prolapse out of height, weighed weight, the plastic bag into the bag to exclude air clean, tie the bag mouth, then wrapped specimen into the conservation room. The standard curing temperature is 20 ℃ ± 2 ℃, and the standard regimen humidity is over 95%. Specimens space is at least 10-20mm on the iron frame. Keep the specimen surface with a layer of water film to avoid the samples be washed directly by water. Specimen curing six days immersion water for 1 day. Then take the standard curing specimens from the water and absorb the surface water with a soft cloth, weighing, measuring height, put them on the pavement strength tester for compression test. In the experiment, keep the loading rate of 1mm / min and make sure the specimen placed in the vertical position of the center to avoid the effecting of the test results. In order to avoid surface unevenness or protrusions result in stress concentration during the test, the test surface should be flat before the test. Record the maximum pressure P (N) when the specimen is destroyed, and then calculate the compressive strength of the specimen.

2.3 The Elastic modulus test of bentonite

In order to ensure that the composite soil seepage canal can withstand repeated erosion of water flow, it not only should have a certain strength, but also some rigidity. If the stiffness fails to meet the requirements, the grassroots will produce excessive shear deformation or even shear failure under repeated actions of hydraulic longitudinal and lateral loads. Compressive resilience modulus is an important parameter to characterize the stiffness of the base material, which reflects the sensitivity of material deformation to external forces. Composite soil strength due to the role of curing agent is significantly improved, but the base material strength will increase the compressive resilience modulus of the material increases. The strength of the grass-roots material will increase the compressive resilience modulus of the material. The ability to resist deformation weakened will make the grassroots cracks. In this study, the compressive resilience modulus of the three test schemes was determined by the top method. The top method refers to direct installing the dial indicator on the top plate of both ends of the test piece, measuring the deformation value of the test piece during loading and unloading through a dial indicator. The experiment is divided into three groups, with nine specimens of each group. Compacted soil compaction test results based on the 95% compaction degree specimens prepared specimen maintenance period of 180d, the last day of age soaking, and then test the compressive resilience modulus. The compressive resilience modulus of the primary material mainly refers to the ability to resisting vertical deformation in the elastic phase of the material. Under a certain load, the larger the modulus of elasticity, the smaller the deformation. This test will increase the deformation of a test device. The device comprises a metal circular top and bottom loading plate, the diameter of which is larger than the diameter of the test piece, and the posts are provided with dial posts on both sides of the diameter line. The following are preparation procedures. First, the compaction test determine the best moisture content of the mixture and the maximum dry density. The forming method of the test piece and the same method are as the unconfined compressive strength test. The specimen size is a cylinder of diameter × height = 150 mm × 150 mm and 9 specimens are prepared for each group. The curing period of cement-stabilized specimens was 90 days. The two ends of the cylindrical specimen completely wiped with cement paste, immersion of 24h, the water surface is about 2.5cm above the top of the specimen. After the specimen is immersed in water, the cloth is dried with a cloth and placed on a loading floor. A small amount of fine sand is sprinkled on the top surface of the specimen, and then a deformation measuring device is installed. A specimen having a deformation measuring device installed thereon is placed on a strength tester,. Record the reading of the micrometer at the time of loading and unloading.

The formula for calculating the compressive resilience modulus is as follows:

$$E=PH/L \tag{1}$$

P - unit pressure, MPa; H - the height of the specimen, mm; L - specimen deformation, mm

Compression resilience modulus test and unconfined compressive strength test use the same specimen size, specimen preparation, and the method of curing the specimen, only the loading method is different. Unconfined compressive strength is constant load until specimen failure. Compressive resilience modulus is loaded step by step. The average of 9 specimens from each test result is used as the final test result..

3. Results and discussion

3.1 The compaction test of bentonite

The results of the typical compaction test of the above different composite soil ratio are shown in Table 3:

Table 3 Compaction test results for different amounts of cement

Cement /%	Calcium Magnesium Lime /%	curing agent /%	The best moisture content /%	Maximum dry density/g/cm^3
5	0	0	11.3	1.873
5	0	0.04%	10.9	1.876
5	10	0	10.1	1.913
8	0	0	9.6	1.952
8	0	0.04%	9.5	1.954
8	10	0	8.6	2.018
10	0	0	7.9	2.042
10	0	0.04%	7.6	2.045
10	10	0	7.4	2.054
15	0	0	7.1	2.073
15	0	0.04%	7.0	2.075
15	10	0	6.9	2.092

Three types of composite soil With the increase of cement dosage, the optimum moisture content of the mixture decreases and the maximum dry density increases. However, the change of curing agent dosage has little effect on the result of compaction test. There are two reasons: First, the dose of curing agent is too small, only 0.04%, the impact of moisture content is almost negligible; Second, the curing agent and cement are added in the compaction test before infiltration of a good mixture, so , Cement and hardener did not react in such a short period of time, so the maximum dry density has no effect.

3.2 The Unconfined compressive strength test of bentonite

The unconfined compressive strength test results of three types (cement composite soil, cement curing agent composite soil and lime cement composite soil) at different ages (7d, 28d, 90d) are shown in Table 4, Table 5and Table 6.

Table 4 Unconfined compressive strength of cement composite soil at different ages

Cement /%	Calcium Magnesium Lime /%	curing agent /%	Unconfined compressive strength average / MPa		
3	0	0	1.12	1.75	1.76
5	0	0	1.30	2.14	2.39
8	0	0	2.02	2.75	3.02
10	0	0	2.56	3.24	4.28
15	0	0	2.62	3.77	4.44

Table 5 Unconfined compressive strength of cement curing agent composite soil at different ages

Cement /%	Calcium Magnesium Lime /%	curing agent /%	Unconfined compressive strength average / MPa		
3	0	0.04	2.27	4.21	6.49
5	0	0.04	3.23	6.51	7.62
8	0	0.04	4.12	7.42	9.02
10	0	0.04	5.37	7.74	9.95
15	0	0.04	5.53	7.78	10.03

Table 6 Unconfined compressive strength of lime cement composite soil at different ages

Cement /%	Calcium Magnesium Lime /%	curing agent /%	Unconfined compressive strength average / MPa		
3	10	0	1.40	2.19	2.20
5	10	0	1.63	2.68	2.99
8	10	0	2.53	3.44	3.77
10	10	0	3.20	4.05	5.35
15	10	0	3.27	4.71	5.55

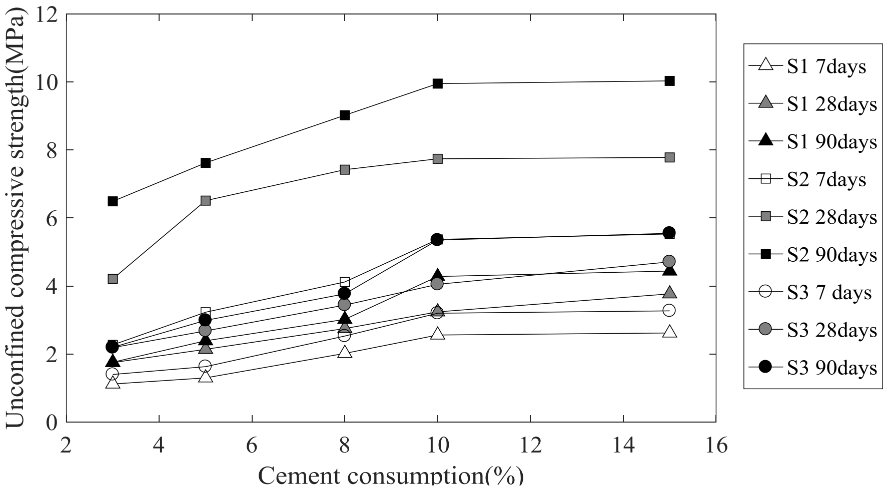

Fig.1 Three kinds of composite soil compressive strength changes

From the test results shown in Fig.1, the unconfined compressive strength increases with the amount of cementite and the amount of curing agent fixed. However, The increase of cement content from 10% to 15%, the increase of unconfined compressive strength at different age is very limited, this situation shows that simply by increasing the amount of cement to increase the compressive strength of composite soil is uneconomical.In addition, cement curing agent composite soil compared with the traditional lime-cement composite soil, the unconfined compressive strength significantly increased, indicating LN series curing agent to improve the composite soil resistance Compressive strength has a significant effect. The unconfined compressive strength comparison is shown in Table 7. It can be seen from Table 7 that when the amount of cement is 5%, the unconfined compressive strength of the curing agent is the most significant.

Table 7 Comparison of Compressive Strength of Two Kinds of Compound Soil in Different Stages

Cement /%	Lime-cement composite soil average / MPa		Cement curing agent composite soil average / MPa		Compressive strength contrast increase rate /%	
	28 d	90 d	28 d	90d	28 d	90 d
3	2.19	2.20	4.21	6.49	92.24	195.00
5	2.68	2.99	6.51	7.62	142.91	154.85
8	3.44	3.77	7.42	9.02	115.70	139.25
10	4.05	5.35	7.74	9.95	91.11	85.98
15	4.71	5.55	7.78	10.03	65.18	80.72

3.3 The Elastic modulus test of bentonite

In order to study the impact of the curing agent on the compressive resilience modulus of the base material, different curing agent doses were changed for testing. The test results are shown in Table 8.

Table 8 Compression resilience modulus test results

Cement /%	curing agent /%	Compression resilience modulus value (Mpa)		
		7d	28d	90d
5	0.03	914	1017	1203
	0.04	969	1042	1344
	0.05	1095	1197	1407
8	0.03	1134	1287	1482
	0.04	1143	1322	1528
	0.05	1229	1479	1681
10	0.03	1345	1565	1764
	0.04	1389	1611	1797
	0.05	1420	1862	2122

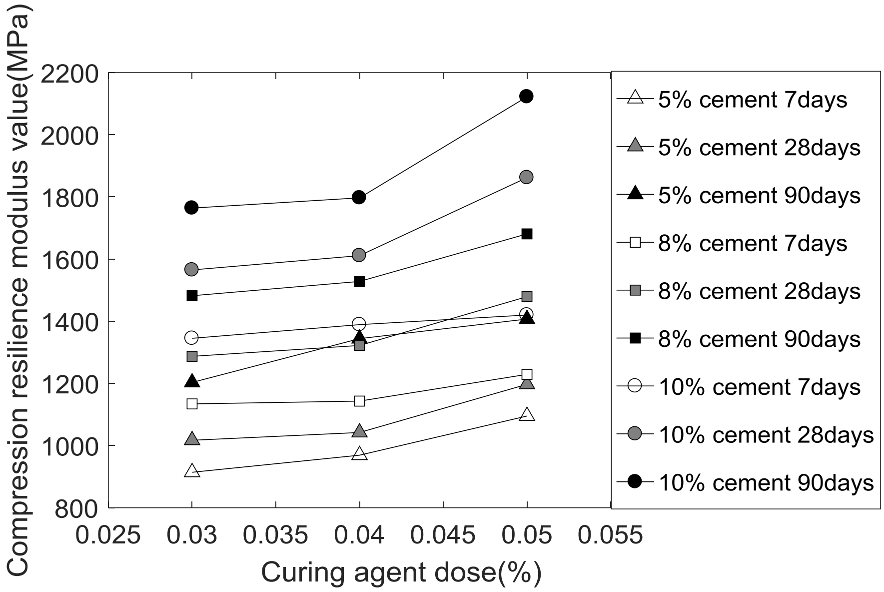

Fig.2 Effect of Curing Agent Dose on Compressive Rebound Modulus

1, curing agent dose on the impact resilience modulus analysis:

The microscopic relative movement of composite soil is at the macro level the deformation of the specimen. Under the action of external load, the deformation is smaller and the larger the value of compressive springback modulus, the smaller the relative displacement of soil particles on the microscopic scale. The movement of soil particles inside the composite soil needs to overcome the following resistances: the friction between the sand particles, the bite force, and the binding force that the cementitious material exerts on it. The greater the resistance inside the solidified soil, the more difficult it is for the particles to be displaced, the less deformation that occurs and the less deformation of the material.

From the Fig.2 It can be seen that the compressive resilience modulus of composite soil at different ages increases linearly with the increase of curing agent dosage. And in the 7d-28d composite soil compressive resilience modulus increased faster, late slower.

2, Influence of cement dosage on compressive springback modulus of composite soil

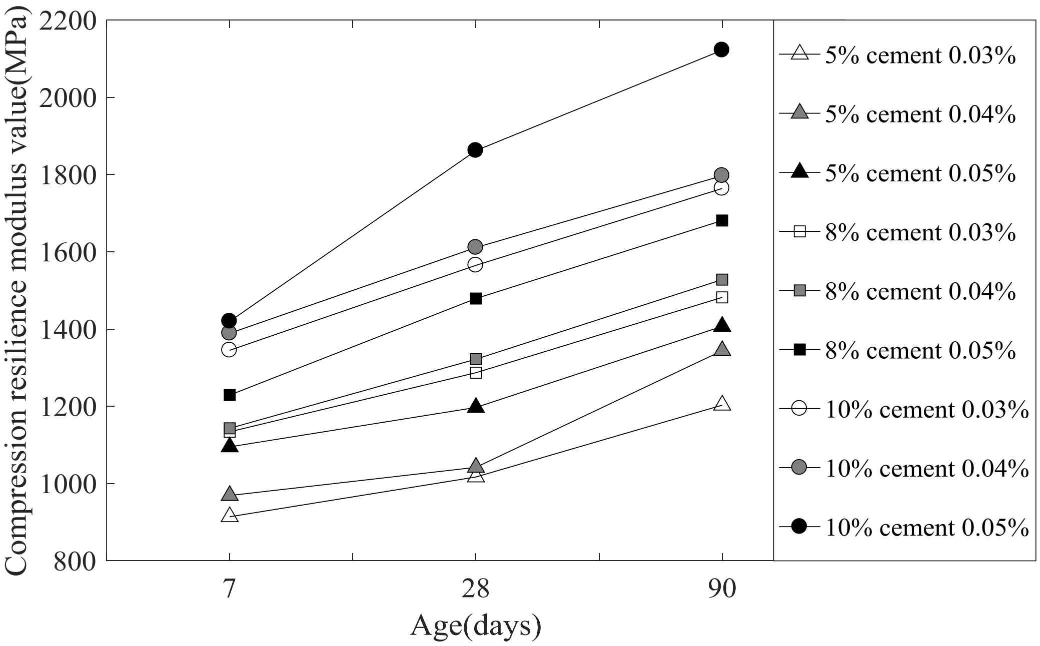

Fig.3 Effect of cement dose on compressive springback modulus at different ages

Fig.3 shows the effect of the change of cement dose on the compressive springback modulus of cured soil when the curing agent dose is 0.03%, 0.04% and 0.05%. The compressive resilience modulus of 7d, 28d and 90d increased with the increase of cement dosage. The increase of cement content shows that the more hydration products of cement in the composite soil, the stronger the joint action between sand particles and the stronger the resistance to deformation.

4. Conclusion

1 As the cement dosage increases, the optimum moisture content of the mix (three types of composite soil) decreases and the maximum dry density increases. However, the change of curing agent dosage has little effects on the result of compaction test.

2 The unconfined compressive strength increases with the increase of cement content, but when the cement content increase exceeds 10%, the increase of unconfined compressive strength at different ages is very limited. Therefore, simply by increasing the cement content to enhance the composite soil resistance compressive strength is not economical. In addition, LN Series curing agent can improve the compressive strength of composite soil.

3 The compression modulus of composite soil at different ages increased linearly with the increase of curing agent dosage. And in the 7d-28d composite soil, the compressive resilience modulus increased faster in the first 4 weeks and then increased slowly. The compressive resilience modulus of 7d, 28d and 90d increased with the increase of cement dosage. This results from the cement hydration products and more sandstone particles to increase the coupling between the role and resistance to deformation.

References

[1] Q. Huang, J. Wang, et al. Analysis on the relationship between canal seepage prevention and effective utilization of irrigation water [J] .China Water Resources, 2009 (3): 22-24

[2] W. He, Y. Xing, M. Cai,et al. Channel anti-seepage and freezing new materials and new technologies [J]. Water Saving Irrigation, 2003 (1): 000004-11.

[3] H. Li. Construction Technology of Concrete Anti-seepage Canal in Water Conservancy Project [J] .Technical Prospect, 2017, 27 (4).

[4] Y. Wang. Concrete seepage canal construction and operation management brief [J]. Hydropower economy, 2017 (5): 91-91.

[5] Y. Zhang. Application analysis of composite geomembrane in anti-seepage reinforcement of canal [J] .Science & Technology Innovation and Application, 2016 (20): 231-231.

[6] Y. Su, T. Yang, K. Yang, et al. Experimental research on acid-alkali resistance of composite geomembrane [J] .Journal of Zhejiang University of Technology, 2016, 44 (4): 456-460.

[7] Y. Song, P. Li, R. Hao. Application Status and Suggestions of Soil Solidification / Stabilization in China [J]. Environmental Protection, 2015,43 (15): 28-33.

[8] J. Mi, H. Wang, J. Liu, et al.Research and Application Progress of Soil Curing Agents [J] .Materials Report, 2017 (S1): 388-391.

[9] L. Zhang, X. Zhang, Q.Sun .Effect of SSA Soil Curing Agent on Compaction, Shearing and Permeability of Loess [J] .Journal of Agricultural Engineering, 2009, 25 (7): 45-49.

[10] D. Zhang. Application of Soil Curing Agent to Reinforce Fine-grained Subgrade [J]. Shanxi Communications Science and Technology, 2016 (5): 11-13.