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Experimental Study on the Engineering Characteristics of Lime Soil with Different Lime Content

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Abstract: Stability of roadbed can be effectively improved when the roadbed filler is mixed with lime content, while the physical properties of the limestone soil are very complicated. The variation characteristics of dry density, optimum moisture content and resilient modulus are studied with laboratory experiment. Firstly, set three group weathered mudstone soil with different lime content (4 %, 6 %, 8 %), then compare with the mixed soil of clay and sand, at last, to do the compaction test of each group. The research shows that engineering properties of the strong weathered mudstone is effectively improved. The finite element shows that the settlement and stability of roadbed is obviously improved after replacement with lime soil.

Keywords: Limestone soil, Resilient modulus, Optimum water content, Settlement, Lime content.

1 Introduction

In recent years, with the rapid development of highway and the continuous improvement of the various road norms, the demands on controlling the road construction quality are getting higher and higher. Because the roadbed directly affects the stability and strength of pavement, it's particularly important to control the roadbed quality firstly. At present, in the process of the roadbed construction, if the designers are faced with bad geological and soil conditions, they often use lime soil as filler, not only for the low cost and convenient construction, but also for the special engineering characteristics of lime soil. The main ingredients of lime are calcium oxide and magnesium oxide. After adding it in the soil, through physical and chemical action, there can form a gel forming the gel group structure. Along with the age growth, there will slowly generate a kind of stick and fibrous crystal, which forms the crystal network and the mixed structure of gel-crystal. The ion exchange reaction in lime soil can form the colloid flocculation of clay, which greatly improves the wet collapse of soil and obtains the early stability of lime soil. Carbonate reaction and pozzolanic reaction improve the strength and stability of lime soil. When their products are in the gel state, lime soil will be in the condensed structure state. And along with the generation of crystalline grid, it will gradually transform into crystalline condensed structure, increasing the strength and stiffness of lime soil [1-2]. the strength of the lime improving expansive soil were studied by Yingqi [3], the experimental results showed that lime improving expansive soil during the initial filling water content was slightly larger than the compaction curve by the reaction of the optimum water content to be able to achieve higher strength. using lime as admixture bed packing for soil improvement, and combined with the newty built railway Shijiazhuang to Taiyuan passenger railway engineering by Suzhuonghua [4], good results such as improves the bearing capacity of subgrade, reduced the defection, guarantee the quality of the construction have been achieved. Zhousongquan [5-7] has emphasized the importance of lime soil moisture content control of raw materials by discussing calcareous soil mixture construction quality from raw materials, mixture ratio, mixture gradation, etc. According to study the engineering characteristics of calcareous soil is necessary because it plays an important role to improve the strength and stability of the roadbed. lime soil compaction degree is an important index of pavement compaction quality control In the process of construction [8-10].

2 Experiment Design

For study the engineering property of limestone soil, we use roadbed filling to design three group limestone soil which are mixed 4 %, 6 % and 8 % lime respectively, and then we also design mixed soil of clay and sand with different ratio as 4:6,5:5 and 6:4 which can be compared with the original roadbed filling. As defined in table 1.At last we test the dry density and resilient modulus of limestone soil and roadbed soil respectively.

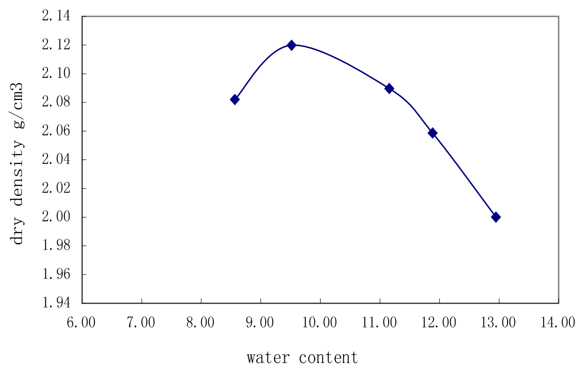
3. Engineering Property of Limestone Soil

3.1. Analysis of Compaction Test

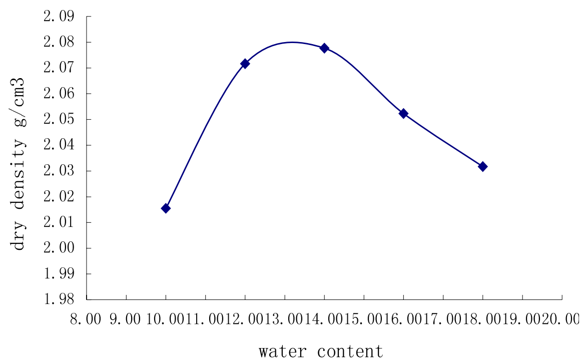
According to Standard for soil test method (GB/T50123-1999) [14], each group soil above is studied with compaction test, and we obtain the relationship curve between dry density and moisture content of limestone soil with different lime content is drawn., as seen in Fig. 1, and then the maximum dry density and the optimum water content of soil samples are as Table 2.

Table 1. Conditions of soil samples.

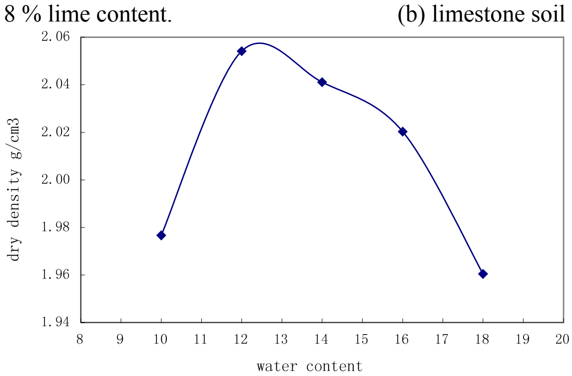
Soil sample	Experiment design			
Strong weathered mudstone soil	Roadbed filling			
Limestone soil	Lime content	4 %	6 %	8 %
Clay and sand soil	Quality ratio	4:5	5:5	6:4



(a) limestone soil with 8 % lime content.



(b) limestone soil with 4 % lime content.



(c) limestone soil with 6 % lime content.

Fig. 1. Relationship between dry density and water content of limestone soil.

Table 2. Results of compaction test.

Soil samples		Optimum water content **(%)**	Maximum dry density **(g/cm³)**
Strong weathered mudstone soil		9.4	1.907
Limestone soil	8 %	12.0	2.070
	6 %	12.5	2.055
	4 %	13.0	2.081
Clay and sand soil	4:6	9.3	2.017
	5:5	9.1	2.098
	6:4	9.6	1.918

The test results show that the optimum water content of the weathered mudstone soil with different lime is decrease with the increase of the lime content, while the decrease extent is relatively small, and the dry density is decrease firstly and then increase with the lime content, and the range of variation is small. The regulation applies to the weathered mudstone soil which is mixed lime, because different types of soil samples have different conditions after mix lime. For example, the silt with lime is studied in literature [10], and the result may vary. So the soil sample of different property after mix lime has different performance.

3.2. Analysis of Resilient Modulus of Soil Sample

Resilient modulus is an important index to evaluate the compressive strength of roadbed in pavement design, the more the resilient modulus of roadbed, the less the vertical displacement of roadbed. If the vertical displacement is a fixed value, the capacity of the roadbed to bear the external load is improved with the increase of resilient modulus of roadbed. So it can provide certain reference for design to study the limestone soil with different lime content.

3.2.1 Experiment Principle

The resilient modulus is similar to the elastic modulus, which is the ratio between repeat peak stress and up-rebound strain of corresponding direction on specimens. Because of the sync between repeat peak stress and up-rebound strain, the resilient modulus is only an approximate concept. As seen in Fig. 2. The resilient modulus is calculated by the next formula 1.

$$M_R = \frac{\sigma_d}{\varepsilon_R}, \tag{1}$$

where M_R is the modulus of resilience; σ_d is the peak f axial repeated stress（meridional stress）, ε_R is the peak of the axial elastic strain.

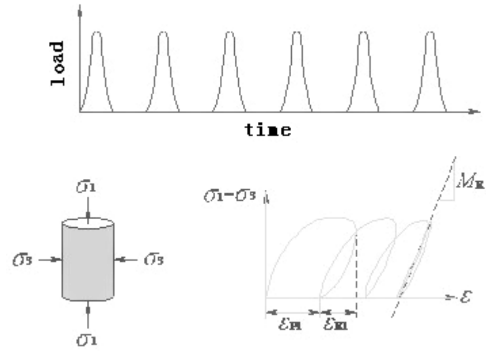


Fig. 2. Resilience test principle.

3.2.2. Experiment Process

The experiment of resilient modulus is test with triaxial apparatus, as seen Fig. 3, repeated cyclic loading, and then calculated with formula 1.

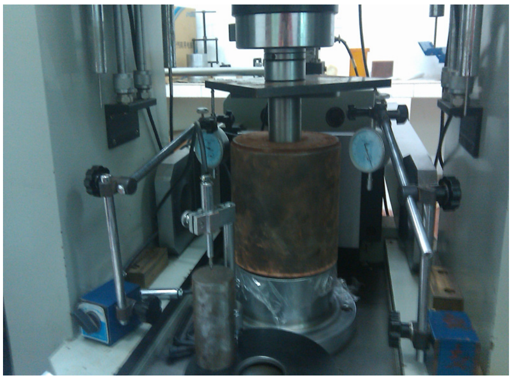


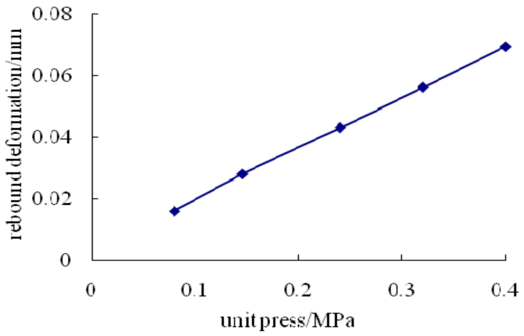
Fig. 3. Resilient modulus test.

According to the experiment data, we can draw the curve between unit press and rebound deformation, as shown in Fig. 4.

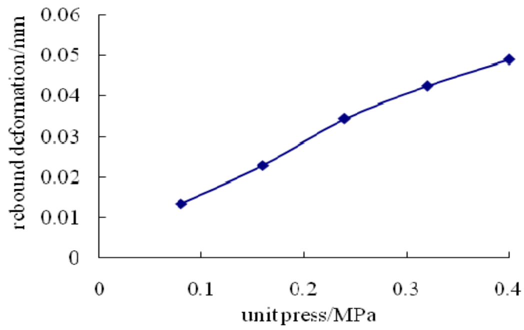
According to above curve, we can obtain the results as follows:

- Resilient modulus of limestone soil with 8 % lime content is 342.3 MPa; Resilient modulus of limestone soil with 6 % lime content is 248.7 MPa, Resilient modulus of limestone soil with 4 % lime content is 190 MPa.
- Resilient modulus of clay and sand with ratio 6:4 is 227.6 MPa, Resilient modulus of clay and sand with ratio5:5 is 362 MPa, Resilient modulus of clay and sand with ratio 4:6 is 199.6 MPa.
- Resilient modulus of strong weathered mudstone soil is 268 MPa.

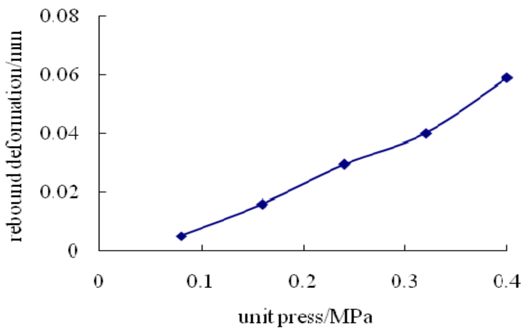
Because of the laboratory experiment was conducted under the condition of confining, the test results are needed to amendment. According to the Specifications for Design of Highway Asphalt Pavement (JTG D50-2004), for super highway, the resilient modulus should be greater than 40 MPa, the results of laboratory experiment should be multiply by correction factor 0.78. the final results are seen as Table 3.



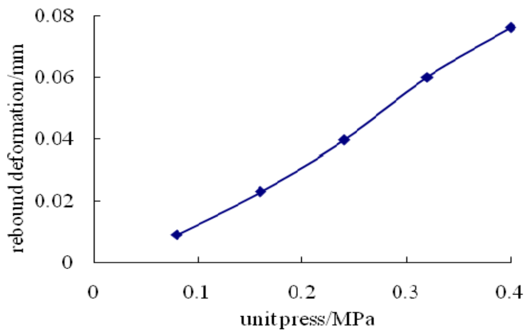
(a) Limestone soil with 4 % lime content.



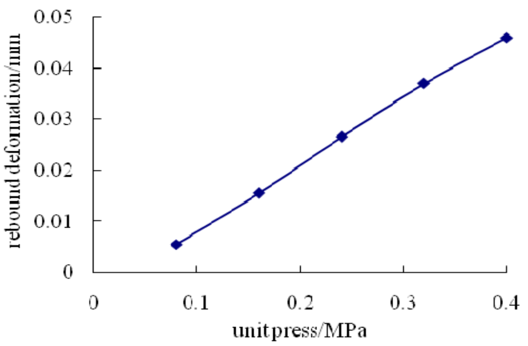
(b) Limestone soil with 6 % lime content.



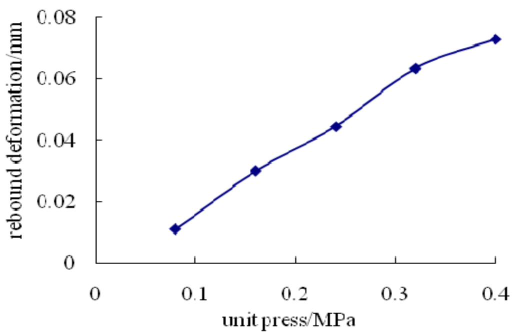
(c) Limestone soil with 8 % lime content.



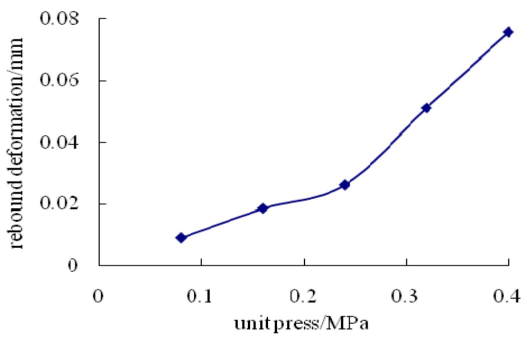
(d) Clay and sand soil with ratio 6:4.



(e) Clay and sand soil with ratio 5:5.



(f) Clay and sand soil with ratio 4:6.



(g) Strong weathered mudstone soil.

Fig. 4. Relationship between Unit pressure and r deformation of limestone soil.

Table 3. Resilient modulus of soil.

Soil samples	Strong weathered mudstone soil	Limestone soil			Clay and sand soil		
		8 %	6 %	4 %	4:6	5:5	6:4
Resilient modulus (MPa)	209	267	194	148	155	282	178

4. Analysis of Case

For improve the stability of pavement structure on the corner of high speed loop, we use the limestone soil with 8 % lime content to replace the subgrade, as seen Fig. 5, and analyze the high speed loop with finite element. Replacement with limestone soil and without replacement on high speed loop is analyzed comparatively.

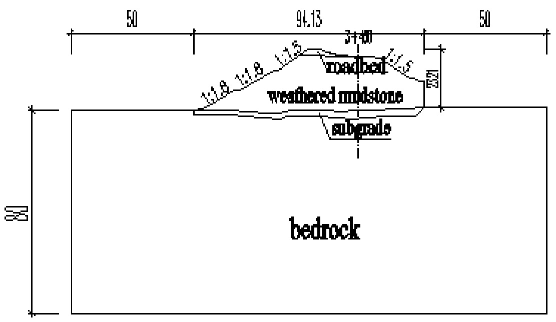


Fig. 5. Section of design.

4.1. Calculation Parameters

The settlement of the high fill embankment is analyzed with finite element method in this paper, the filling parameters are used according to the results of laboratory test. As shown in Table 4.

4.2. Calculation Model and Condition

According to the design requirements, the designers replace roadbed limestone with 1 meters and 8 % limestone and use strong weathered mudstone as embankment filler. The model of finite element is shown in Fig. 6.

Calculate conditions:

1) Condition 1: not using lime soil as the roadbed filler;

2) Condition 2: using lime soil as the embankment filler.

Table 4. The parameter of the model.

Name	Bed rock	Lime soil with 8 %(10 days)	Weathered mudstone	Clay
Elastic modulus /MPa	3000	45.8	50.0	16.0
Poisson's ratio	0.3	0.33	0.34	0.38
Density/kg/m^3	2500	2070	2086	1824
Cohesion /kPa	2800	106.3	65.9	300
Internal friction angle /°	35	18	27.9	12

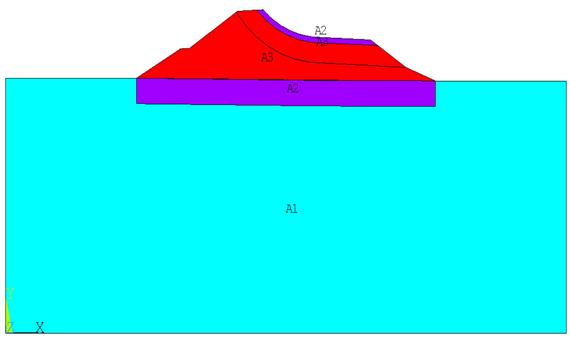


Fig. 6. Model of finite element.

4.3. Result Analyses

According to the finite element calculation, settlement changes of subgrade with and without replacement of limestone can be derived, as shown in Fig. 7.

The calculation results show that, when not using lime soil as the roadbed filler, the maximum settlement of filled roadbed is 14.14 cm. And in the case of Condition 2, the maximum settlement of filled embankment is 13.81 cm. Only after filling the roadbed with 1 meter and 8 % lime soil, the settlement reduce 1 cm.

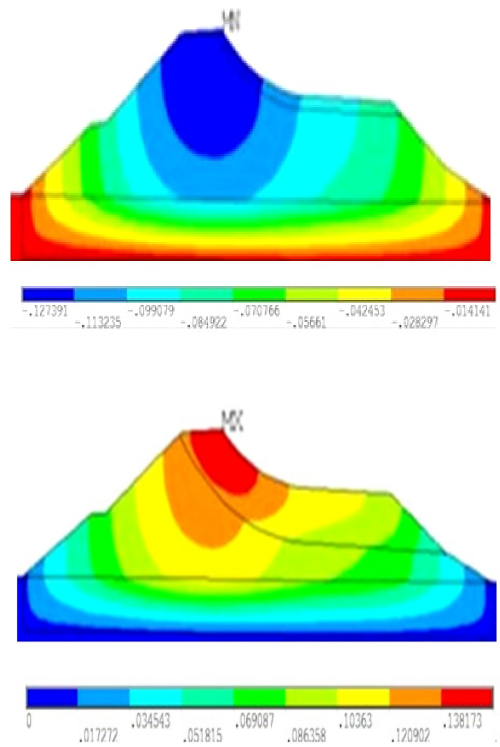


Fig. 7. Settlement changes of subgrade with and without replacement of limestone.

5. Conclusions

For study the engineering properties of limestone soil, we do some experiments with strong weathered mudstone soil which is mixed with different lime content, and we analyze the influence of dry density and resilient modulus by lime content replacement, then we obtain the major conclusions are as follow:

1) The optimum water content of strong weathered mudstone soil with lime content is decrease with the increase of the lime content, while the decrease extent is relatively small, and the dry density is decrease firstly and then increase with the lime content, and the range of variation is small.

2) The resilient modulus of limestone soil is increase with the increase of lime content, when the strong weathered mudstone is mixed different lime content. So it can be improved the engineering properties of roadbed filling, and it also can be control the settlement deformation of post construction and improve the stability, in fact, we should consider the optimum of economic, and then determine a reasonable amount of lime by combining with the minimum standards required to meet the design.

3) According to the case of roadbed replaced with limestone soil, it shows that the settlement of roadbed is obviously decreased, and the stability of roadbed is improved after replacement with lime soil. Just so you know, the experiment in this paper is major aimed to the strong weathered mudstone soil with lime content in Chongqing, so the regulations are obtained will different from the other area.

Acknowledgments

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