Study on constitutive model of stress elastic modulus of subgrade soil under different wet and dry conditions

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Abstract. In the process of highway construction, the compaction of subgrade soil is generally carried out under its best moisture content, which can ensure that the subgrade soil reaches the maximum dry density to provide sufficient bearing capacity. However, in the actual project, the moisture content of the subgrade soil after compaction will change due to many factors, which will have a great impact on its resilience modulus. In this paper, the dynamic triaxial modulus test method is adopted to carry out experimental research on a roadbed soil of a road project in Chongqing, to investigate the resilience modulus and its stress-dependent characteristics of the roadbed soil in different dry and wet states, and the results show that the resilience modulus of the roadbed soil increases with the increase of the compaction degree under the condition of the same water content; the resilience modulus of the air-dried specimen is significantly greater than that of the specimen with optimal water content, and the resilience modulus of the submerged specimen is greatly reduced. Therefore, the roadbed design of this project should control the compaction quality, do a good job of drainage, and guarantee the strength and stability of the roadbed.

Keywords: Water content, subgrade soil, resilience modulus, compactness, constitutive model

1 Introduction

The subgrade, as the foundation of the highway, supports the pavement structure and carries the load of vehicles. Its strength determines the bearing capacity of the subgrade, which directly affects the overall service quality of the highway [1]. The moisture content of subgrade soil is one of the most significant factors affecting the strength of subgrade. Whether it can reasonably judge the state of subgrade moisture content during the period of use is the key to correct design and evaluation of subgrade bearing capacity. In the process of highway construction, the compaction of subgrade soil is generally carried out under its optimal moisture content, which can ensure that the subgrade soil reaches the maximum dry density to provide sufficient bearing capacity [2]. However, under the actual conditions of highway construction and service, the moisture content

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of subgrade soil after compacted will change due to many factors, which will have a great impact on its resilience modulus.

At present, many scholars at home and abroad have studied the factors affecting the resilience modulus of subgrade soil [3-10], determine the dynamic resilience modulus of roadbed soils such as pulverized soils and high liquid limit clays under different water content, compaction and stress states by repeated loading dynamic triaxial test, and analyze the change rule of it, but there are few researches on the engineering characteristics of Chongqing laterite. In order to further explore the engineering characteristics of roadbed soil under different dry and wet conditions and compaction degree of a road project in Chongqing, this paper adopts dynamic triaxial modulus testing method to carry out evaluation and research, and obtains the law of influence of water content change on its resilience modulus under different compaction degree conditions, which is convenient to guide the on-site construction and later maintenance of highway engineering.

2 Resilience modulus test scheme

In order to explore the influence of water content change on the resilience modulus of roadbed soil specimens with different compacting degrees, the following test scheme is proposed:

- Measurement of optimum moisture content and maximum dry density of subgrade soil

The test scheme is shown in Table 1.

Table 1. Test scheme of optimum moisture content and maximum dry density of subgrade soil.

Specimen number	Moisture content (%)	Tests
1	8	Heavy compaction test, moisture content determination
2	10	Heavy compaction test, moisture content determination
3	12	Heavy compaction test, moisture content determination
4	14	Heavy compaction test, moisture content determination

- Determination of resilience modulus and stress dependence characteristics of subgrade soil samples under various conditions

The test scheme is shown in Table 2.

Table 2. Test scheme of resilience modulus and stress dependence characteristic change analysis.

Moisture content state	Compactness (%)	Trial
Optimum moisture content	90	Dynamic triaxial test, moisture content determination
	95	Dynamic triaxial test, moisture content determination
	100	Dynamic triaxial test, moisture content determination
Moisture content of air drying	90	Air drying, dynamic triaxial test, moisture content determination
	95	Air drying, dynamic triaxial test, moisture content determination
	100	Air drying, dynamic triaxial test, moisture content determination
Moisture content of immersion	90	Immersion, dynamic triaxial test, moisture content determination
	95	Immersion, dynamic triaxial test, moisture content determination
	100	Immersion, dynamic triaxial test, moisture content determination

The triaxial cyclic dynamic load test is widely used internationally to determine the dynamic resilience modulus. In this paper, the loading sequence is selected with reference to the American National Highway and Transportation Association standard test method for roadbed soils and mixed aggregates (AASHTO: T307-99 (2012)), as shown in Fig. 1, which consists of 16 loading sequences consisting of preload 0 and formal loading (1~15). A total of 5 groups of stresses were applied, in order of 12.4, 24.8, 37.26, 49.68 and 62.01 MPa. This test method can better simulate the stress effect of actual vehicle load on the pavement base layer through different combinations of axial loading stress and specimen circumferential pressure. The test instrumentation was a GCTS dynamic triaxial tester with the standard specimen size of D = 100 mm in diameter and H = 200 mm in height, and the molding method was hydrostatic molding. The specimen was loaded with semi-positive vector impulse load, with a loading time of 0.1s, a recovery time of 0.9s, and a preload number of 1000 times.

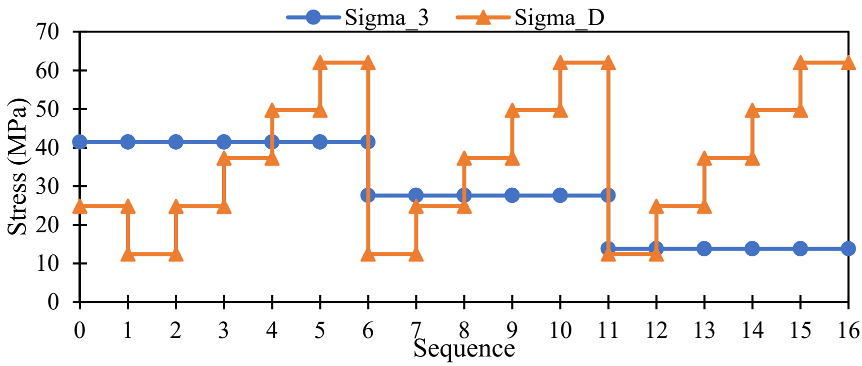


Fig. 1. Dynamic triaxial loading sequence of subgrade soil in AASHTO T307-99

3 Test process.

(1) Sift and dry the sample, as shown in Figure 2.

Fig. 2. Drying the sample

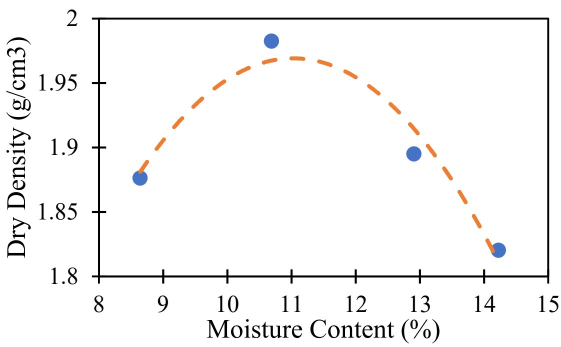


Fig. 3. Optimum moisture content maximum dry density curve of the sample

(2) According to the test plan of the best water-maximum dry density, the heavy compaction test was carried out to obtain the curve of the best water-maximum dry density, as shown in Figure 3, the best water content of the sample can be determined to be 10.7%.

(3) The triaxial specimens were formed by the heavy compaction test method, and the specimens to be air-dried and water-soaked were disposed according to the corresponding conditions, as shown in Figure 4.

(4) The specimens under the optimum moisture content condition were not treated, and the triaxial test was conducted directly, as shown in Figure 5.

(5) The air-dried specimens were subjected to the triaxial test, and their moisture content was measured after the test. Figure 6 shows the air-dried specimens after the test.

Fig. 4. Specimen air-drying (left) and water-soaked (right)

(6) Triaxial test was carried out on the specimen after soaking, and its moisture content was measured after the test. Figure 7 shows the soaked specimen after the test.

Fig. 5. Dynamic triaxial test

Fig. 6. Air-dried specimen

Fig. 7. water-soaked specimen

4 Analysis of test results

The average moisture content of the three air-dried specimens and the three water-soaked specimens was 9.7% and 19.3%, respectively. Compared with the optimal moisture content of 10.7% when compacting the specimens, the moisture content of the specimens was reduced by 1% on average by air drying and increased by 8.6% on average by water immersion.

Only 6 of the 9 specimens were successfully tested in the dynamic triaxial test, and the 3 soaked specimens failed to complete the test because they reached the maximum vertical permanent strain (5%) in advance during the test. The results of the dynamic triaxial test are shown in Figure 8, where "Com 90" stands for "specimens with 90% compaction and optimal water content"; "Dry 95" stands for "specimens with 95% compactness and 15 days of air drying"; "Wet 100" stands for "test piece with 100% compaction and 15 days of immersion."

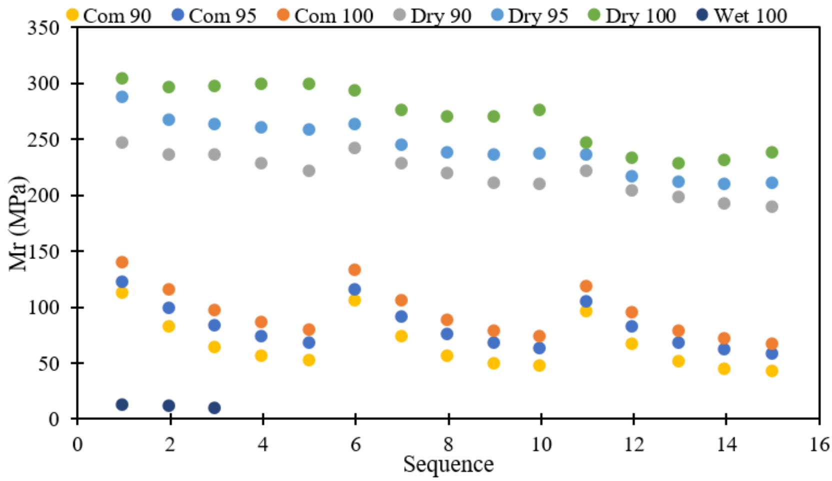
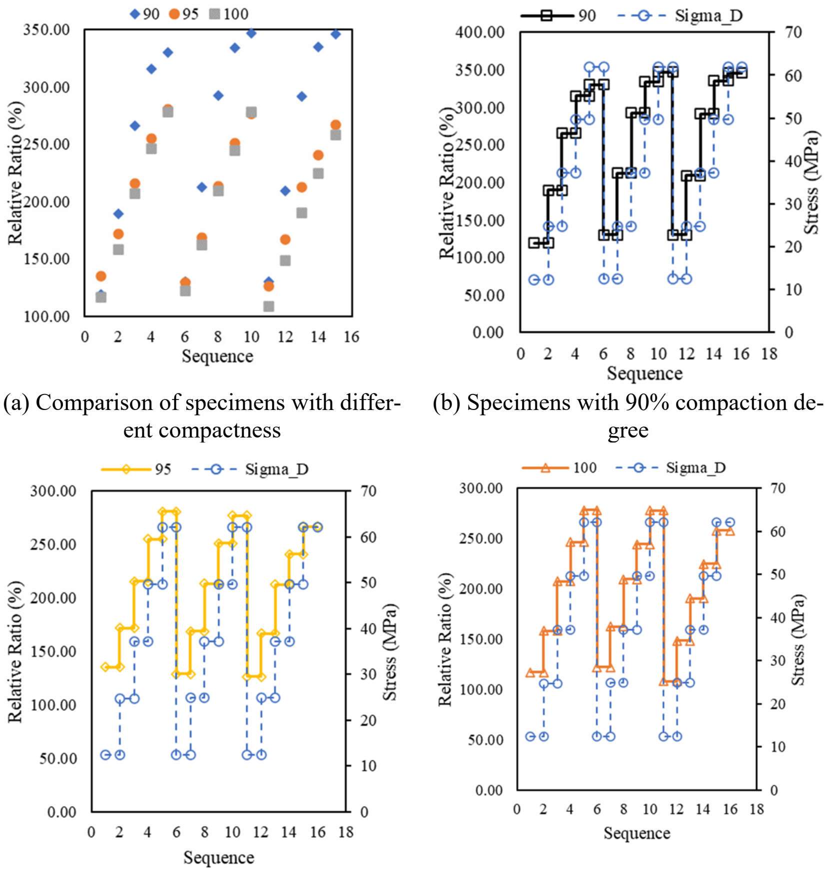


Fig. 8. Results of dynamic triaxial test

As can be seen from Figure 8, although the specimens after 15 days of immersion failed to complete the dynamic triaxial test, it can still be concluded that the subgrade soil showed obvious stress-dependent characteristics under different compaction degrees. For both air-dried specimens and specimens with optimal moisture content, the resilience modulus is related to the compactness of the specimen, and the resilience modulus increases with the increase of the compactness. This is due to the fact that when the more dense the particles in the soil material of the roadbed, the average number of contact points of each particle will increase accordingly, so that the average contact stress under the external load reduces the deformation of the particle contact point is also reduced accordingly, so that the resilience modulus increases. For the water-soaked specimen, the resilience modulus of the specimen with 100% compaction decreases from 303 MPa to 12MPa.

As can be seen from Figure 9, the resilience modulus of the air-dried specimen is significantly greater than that of the specimen with the best moisture content, and its amplitude increases with the increase of the cyclic deviating stress, with the minimum increase of 108.33% and the maximum increase of 347.17%.



(a) Comparison of specimens with different compactness

(b) Specimens with 90% compaction degree

(c) Test specimen with 95% compaction degree

(d) Test specimen with 100% compaction degree

Fig. 9. Increase of resilience modulus of specimens after air drying

5 Conclusion

After studying the influence of water content change on the resilience modulus of Chongqing laterite (hereinafter referred to as subgrade soil) after compaction under different compaction degree conditions, this study draws the following main conclusions:

(1) The subgrade soil has obvious stress-dependent characteristics, and the resilience modulus increases with the increase of the degree of compaction. Therefore, the quality of compaction should be strictly controlled during the construction of the roadbed to improve the compaction degree and guarantee the stability of the roadbed.

(2) After air drying, the resilience modulus of roadbed soil specimen is significantly greater than that of the optimum moisture content specimen, and its amplitude increases with the increase of cyclic deviating stress, with the minimum increase of 108.33% and the maximum increase of 347.17%.

(3) The flooding condition is very unfavorable to the subgrade soil, and the resilience modulus of the specimen with 100% compaction degree decreases from 303 MPa to 12MPa. Therefore, the first priority in carrying out the roadbed design for road projects in the region is to provide good drainage and to safeguard the strength of the roadbed.

(4) The research results can reflect the rebound modulus of the roadbed soil in the region under the unfavorable humidity state, which can provide a reference basis for the construction and design of roadbed pavement in the same kind of area, but there are still some limitations, and further research can be carried out in the later stage for different stress state and different gradation.

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