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Engineering characteristics of argillaceous soft rock subgrade filling

The mechanical properties and engineering characteristics of argillaceous soft rock are special, and its application in subgrade filling can effectively improve the utilization rate of resources. The research on the road performance of argillaceous soft rock materials has become a hot topic. Based on the research status of the road performance of argillaceous soft rock, this paper designs the compaction test, CBR test and compression consolidation test of argillaceous soft rock respectively, rationally analyzes the experimental data, and explores the optimum water content, expansion quantity, compression coefficient and other engineering properties of the argillaceous soft rock, which provides theoretical guidance for the application of subgrade filling engineering of argillaceous soft rock.

Keywords: *Argillaceous soft rock, compression consolidation, compression coefficient, engineering characteristics*

1. Introduction

With the continuous extension of the highway network in our country, the highways in mountain areas and even mountainous hilly areas are also gradually paved. The selection of subgrade filling is always an important problem in highway construction due to its difficult terrain. The argillaceous soft rock is mostly distributed in abandoned area of mountain area, which causes unnecessary damage to the ecological environment in mountain area. If the argillaceous soft rock can be used in subgrade filling, the problems of high cost of filling and the destruction of ecological environment can be solved effectively [1].

However, the argillaceous soft rocks are mostly loose clay minerals, and the adaptability of its engineering characteristics and mechanical properties to subgrade filling is still to be studied. Based on the current situation of the road use of argillaceous soft rocks, this paper designs an experiment to explore its road use indexes, and analyzes the engineering characteristics of argillaceous soft rock as the subgrade filling material, providing theoretical guidance for the selection of subgrade filling materials.

2. Research status of the argillaceous soft rock road performance

The argillaceous soft rock is not a special name for some rock, but the general name for silty mudstone and argillaceous siltstone. It is widely distributed in the Northwest China [2]. The rock mass is easy to soften after water immersion, and becomes loose after water loss, and its shear strength is low, therefore, it is not suitable for material operation with high strength. It is widely distributed, but its strength properties are poor, so its filling performance should be studied more.

2.1 Engineering Characteristics of Soft Rock under Water Environment

Under water environment, the engineering characteristics and mechanical properties of argillaceous soft rock will have obvious changes. On the one hand, the rock structure of the argillaceous soft rock will be destroyed under water soaking, so the shear strength of the rock will be completely lower than that of the ordinary rock, which means that it will be softened and decomposed after water loss. On the other hand, under the coupling effect of rock mass stress and physico-chemical reaction of argillaceous soft rock under groundwater environment, the expansion deformation phenomenon occurs. From the experiment and the construction of the constitutive model of salt rock [3], Udo Hunsche, Zhengmeng Hou and others analyzed the deformation effect of expansion and fracture of rock mass, which is of great significance to the study of the disturbance of the rock mass underground engineering. The triaxial compression test of the argillaceous soft rock under water environment was carried out by A.S. Chiarelli, and the numerical analysis was applied to verify the theory. They also verified the expansion characteristics of argillaceous soft rock under water environment [4].

2.2 Mechanical Properties of Argillaceous Soft Rock

In the process of creep and viscoplastic deformation of argillaceous soft rock, its mechanical properties are becoming worse due to its volume expansion and loosening. Under the coupling effect of plasticity and damage, there is a nonlinear

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change behaviour of the properties resistance to plastic deformation of argillaceous soft rock. N. Conil established the pore plasticity model through experiments, and introduced the Drucke-Prager yield criterion to describe the effect of damage of argillaceous soft rock on its hydro-mechanical coupling [5].

2.3 Humidification Stability of High Slope of Argillaceous Soft Rock

Because of the special engineering properties of argillaceous soft rock under water environment, the humidification stability of argillaceous soft rock subgrade filling has been studied. Under the influence of rainfall infiltration, the softening and deformation mechanism of argillaceous soft rock subgrade filling with water is studied and in the process of subgrade excavation and slope formation, the change rule of the horizontal displacement and vertical displacement of the slope is studied. Through the study on the engineering characteristics of the argillaceous soft rock and the law of strength attenuation, the measures of seepage prevention and backfilling of the roadbed slope are put forward, which can effectively guarantee the strength of the subgrade and improve the stability of the side slope. Xu Hua and others used the Bishop slip circle method to analyze the change rule of subgrade slope stability under different conditions of argillaceous soft rock filler [6].

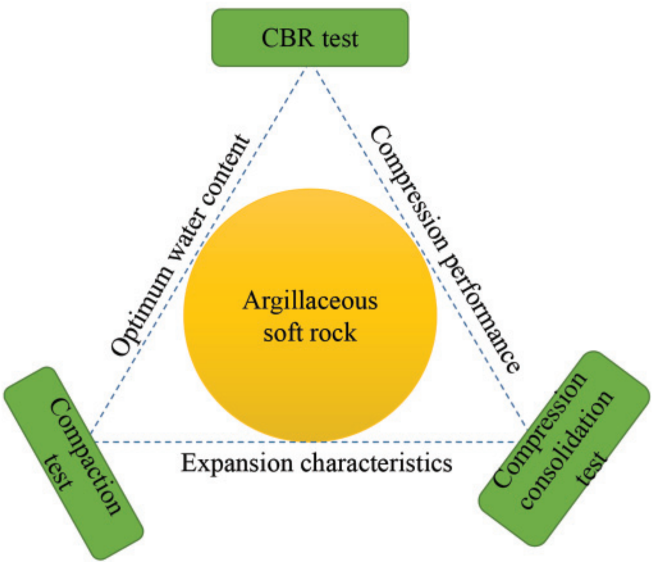

Fig.1 Experimental framework for performance index of muddy soft rock

3. Experiment on road performance index of argillaceous soft rock and the research on its engineering characteristics

The experimental framework for performance index of muddy soft rock is shown in Fig.1.

In this paper, the argillaceous soft rock material used in a highway section of a mountain area was selected as the experimental material, and the argillaceous soft rock was divided into three types: A, B and C, according to the different particles and colour of the argillaceous soft rock. Respectively from the perspective of physical and mechanical properties and road performance index of argillaceous soft rock, the compaction test, the CBR test and the compression consolidation test were carried out to explore the engineering characteristics of the argillaceous soft rock subgrade filling. The argillaceous soft rock classification diagram is shown in Fig.2.

3.1 Compaction Test

In the process of argillaceous soft rock subgrade filling, the best water content and density are two quality guarantees which influence the compaction effect, and they are also the key indexes to determine its usage, which are of great significance in the engineering practice. In this experiment, three kinds of materials of argillaceous soft rock were divided into three groups. According to the "Test Method of Soils for Highway Engineering" (JTG E40-2007), the three parallel tests were carried out. The equipment and parameters used for compaction were: Heavy II-2 standard. The hammer bottom was a heavy hammer with a diameter of 5cm. The mass of hammer was 4.5kg, and the falling height was 45cm. The samples were prepared by quartering method. The height was 12cm and the volume was 2177cm^3. The samples were compacted in 3 layers, the impact times of each layer were 98 times, and the work done by compaction was 2677.2kJ/m^3.

In the process of compaction of argillaceous soft rock, part of the gas was discharged from the rock mass, the content of water did not change, and the process of compaction was only to increase the density of rock mass. The compaction experiment was carried out, and the maximum dry density and the optimum water content were obtained through studying the variation curve of rock mass density with moisture content, as shown in Fig.3.

Using the MATLAB software and fitting method to deal with the experimental data, we get the change function and

Fig.2 Argillaceous soft rock classification diagram

Table 1. Compaction test (moisture content, maximum dry density and maximum wet density).

Experiment	Wet density(g/cm3)			Dry density(g/cm3)			Average moisture content(%)		
Classification	A	B	C	A	B	C	A	B	C
1	2.218	2.239	2.23	2.146	2.153	2.156	3.328	3.991	3.461
2	2.254	2.351	2.339	2.163	2.21	2.228	4.328	6.369	4.996
3	2.352	2.372	2.405	2.218	2.207	2.255	6.05	7.48	6.667
4	2.326	2.282	2.373	2.157	2.08	2.176	7.846	9.731	9.022
5	2.307	2.222	2.309	2.096	1.97	2.099	10.07	12.804	9.998

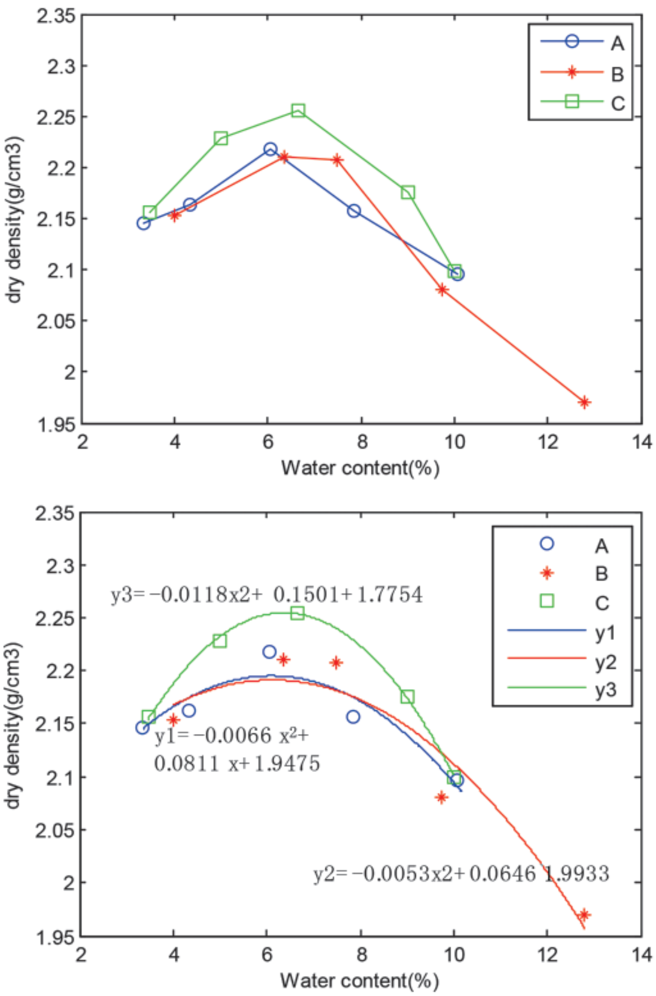

Fig.3 The variation curve of rock mass density with water content change curve of the dry density of three kinds of rock mass with the moisture content. It can be concluded that when the compaction method is determined, the dry density of rock increases with the increase of water content, and then decreases with the increase of water content. The maximum dry density and the optimum water content are as follows:

The optimum water content of A rock mass is 6.05% and the maximum dry density is 2.218g/cm^3.

The optimum water content of B rock mass is 4.996% and the maximum dry density is 2.21 g/cm^3.

The optimum water content of C rock mass is 6.67% and the maximum dry density is 2.255 g/cm^3.

3.2 CBR Test

The Califonia Bearing Ratio test is called CBR test for short. Its function is to determine the strength of subgrade material, and the strength index is a key index to explore the performance of roadbed materials. The CBR value refers to the ratio of the unit pressure the test sample bears to the standard load of the same penetration of standard gravel when the sample's penetration is 5mm, which is usually expressed as a percentage. In this simulation test, the samples were prepared under the optimum conditions of water content and the optimum degree of compaction, and the adverse conditions were simulated by soaking in the water for four days and nights before the pressure loading. The specific test process is as follows.

Based on the above compaction test data, 3 samples were selected under the optimum water content condition, and then the compaction test was carried out again, and then the total mass of the sample was weighed.

Cover the sample barrel with filter paper and fix the perforated plate. On the other side of the test sample, the perforated roof plate with the adjusting rod was fixed in the same way, and 1.25kg loading plate was placed on the sample respectively. Then, the whole fixed test sample was put into the sink, and the expansion volume measuring device was installed to read the initial value. The water in the sink was kept up to 25mm above the top of the sample. After soaking for four days and nights, the height change was measured, and the expansion quantity was read. Take out the sample and dry the water on the top surface. After keeping still for 15min, the load plate, perforated plate and filter paper were removed. The total mass of the sample was weighed, and the change quantity of water content and dry density of the sample was calculated.

Penetration test adopted microcomputer controlled electronic universal testing machine, which can effectively measure and record load porosity ratio data.

From the above table, we can see that with the change of water content, the expansion quantity and CBR value of rockmass will also change significantly. The trend of change is that the expansion quantity and CBR value of rock mass will

Table 2 The expansion and CBR value of different soil moisture content

Classification of rock mass	Water content	Four day night height and change of water immersion (mm)	Expansive volume (%)	CBR 5.0mm/%
A	4%	0.76	0.0063	53.435
	6%	0.88	0.0073	42.02
	8%	0	0	11.12
	10%	0	0	20.151
B	4%	0.62	0.005	24.113
	6%	0.97	0.008	37.7
	8%	0.36	0.003	4.115
	10%	0.11	0.001	2.248
C	4%	0.66	0.005	60.135
	6%	0.7	0.0056	66.156
	8%	0	0	156.506
	10%	0	0	89.546

decrease as the water content of rock mass increases. Therefore, because of its high water content, the expansion quantity of rock mass, namely the amount of water absorption, will inevitable decrease. The small CBR value indicates that the larger the water content of the rock mass is, the worse the engineering property is. When the rock mass is at the optimum water content, the value of CBR is the greatest.

3.3 Compression Consolidation Test

3.3.1 Experimental method

Compression consolidation test is an important test for determining the performance of subgrade filling materials. The porosity ratio, compression coefficient and compression modulus are mainly determined and calculated. The large consolidation apparatus was selected as the test equipment in this paper. According to the “Test Method of Soils for Highway Engineering”, the sample made by the consolidation apparatus was: the area was 30cm^2, and the height was 20mm. The samples with optimum water content rate were selected and mixed with water. The bearing capacity of the roadbed met the test requirements, and the compaction degree of the roadbed was controlled at around 94%. The sample was divided into three layers in the barrel, and the thickness of each layer was about 8cm. Finally, when the compaction degree met the requirements, the consolidation barrel was filled. The results of the test are shown in Table 3.

3.3.2 Result analysis

Analysis of the relationship between porosity ratio e and load p and lgp. According to the formula

$$e = e_0 - \frac{\Delta H}{H_0}\left(1+e_0\right) \quad \text{... 1}$$

the porosity ratio e is calculated. In the formula

Table 3. *e-p* relation table for large compression test

A		B		C	
load (kPa)	void ratio e	load (kPa)	void ratio e	load (kPa)	void ratio e
0	0.326	0	0.356	0	0.315
50	0.314	50	0.332	50	0.303
100	0.279	100	0.305	100	0.297
200	0.271	200	0.289	200	0.283
300	0.257	300	0.275	300	0.275
400	0.251	400	0.268	400	0.262
500	0.244	500	0.259	500	0.254
600	0.236	600	0.250	600	0.247
700	0.229	700	0.242	700	0.233
800	0.222	800	0.235	800	0.227

$e_0 = \frac{Gs\left(1+\omega\right)}{\rho_0}\rho\omega - 1$, Gs is the specific gravity of soil, ω is the initial water content of soil sample, ρ_0 is the initial density of soil sample(g/cm^3), $\rho\omega$ is the density of the water (g/cm^3). The e–p curve and e–lgp curve can be drawn separately through the above formula, so as to determine the compression coefficient a, the compression modulus Es and the compression index (Figs.4 and 5).

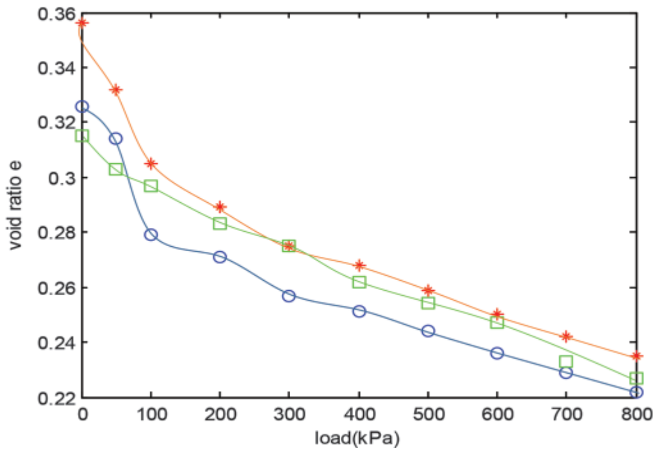

Fig.4 Compression test *e-p* curve

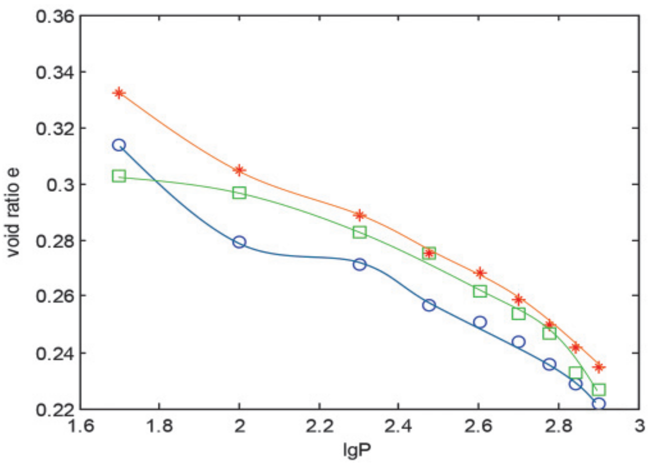

Fig.5 Compression test *e*-lgp curve

Compression coefficient a: It can be obtained by the above curve. When the pressure changes Δp, the porosity ratio changes Δ*e*, the slope can reflect the compression coefficient of rock mass, that is

$$a = \tan a = -\frac{\Delta e}{\Delta p} \quad \text{... 2}$$

Compression modulus Es: Under the condition of limited rock mass, it is the ratio of the stress change in the vertical direction and its strain change, that is

$$Es = \frac{\Delta P}{\Delta \varepsilon} \quad \text{... 3}$$

Compression index Cc: From the *e*-lgp curve of the consolidation test, the compression index is defined as the ratio between the change of porosity ratio and the logarithmic change of load, that is

$$Cc = \frac{e_1 - e_2}{\lg p_1 - \lg p_2} \quad \text{... 4}$$

In the compression consolidation test, the rock mass with the optimum water content was selected, and the maximum particle size was 15cm. Through the experiment, it can be obtained that when the load is from 100kPa to 200kPa, the compression coefficient of A rock mass under the optimum water content is a=0.2652, the compression modulus is Es=4.98, and the compression index is Cc=0.026/lg2.

TABLE 4 COMPRESSION CONSOLIDATION TEST RESULTS

A	B	C
Compression coefficient a(0.1-0.2)(MPa) =0.2652	Compression coefficient a (MPa)=0.2841	Compression coefficient a (MPa)=0.2737
Compression modulus Es(0.1-0.2) (MPa)=4.98	Compression modulus Es (MPa)=4.26	Compression modulus Es (MPa)=4.71
Compression index Cc=0.026/lg2	Compression index Cc=0.014/lg2	Compression index Cc=0.019/lg2

4. Conclusions

Through the compaction test of argillaceous soft rock and the analysis of the experimental results, the optimum water content and maximum dry density of various rock masses can be obtained, which can provide an effective experimental basis for CBR and other tests. The CBR test is the key experiment to determine the expansion characteristics of the argillaceous soft rock directly. Through the CBR experiment, the immersion expansion quantity of the A type rock mass can be accurately measured between 0.006~0.01, the immersion expansion quantity of the B type rock mass is between 0.007~0.009, and the immersion expansion quantity of the C type rock mass is between 0.005~0.006. Through the compression consolidation test of the optimum water content and the curve of the experimental data, the compression coefficient, compression modulus and compression index of the rock mass are obtained, and the road filling performance of the argillaceous soft rock is explored, providing a reasonable theoretical reference for its application in the subgrade filling project.

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