Experimental Study on the Performance of Improved Collapsible Loess Mixture with Concrete Crushed Gravel

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Abstract. Based on the climatic and geological characteristics of the non-weight collapsible loess area, the paper analyses the cooperative working conditions of the concrete surface structure and the non-weight collapsible loess subgrade. The thesis uses coal gangue powder, fly ash, calcium carbide slag powder, and silica fume to modify the permeable concrete, and studies the unconfined compression test after the modification, the load ratio (cbr) test, and the eds-sem scanning electron microscope test. And other physical and mechanical properties. The experimental results prove that the modified soil with 30% calcium carbide slag powder after 28 days of curing has the best compressive performance, but has a heavier industrial peculiar smell; 30% silica fume and 30% silica fume are mixed the compressive performance of the modified soil with coal gangue powder is close; the compressive performance of the modified soil with 30% fly ash is relatively low. Among the four different admixtures in the test, the improved soil mixed with 30% calcium carbide slag powder and 30% concrete gravel has the best compressive effect, and the other three improved soils have similar effects. In the experiment, after four different admixtures were used to improve soil mixing and concrete crushed gravel, the bearing ratio of the modified soil obtained by mixing 30% calcium carbide slag powder and 30% concrete crushed gravel was the best and much higher than that of the other three materials. Scanning through the electron microscope, it was observed that the admixture had a greater effect on the adhesion of the soil foundation and the concrete gravel, which made the soil structure more stable.

Keywords: Improved collapsible loess, unconfined compressive test, load ratio (cbr) test, eds-sem scanning electron microscope test, concrete gravel, roadbed performance.

1. Introduction
As the main pavement structure of high-grade highways, cement concrete pavement has the characteristics of high strength, good durability and insensitivity to temperature. Cement pavements can be built on different grades of roads according to different raw materials and paving techniques, which can make full use of local resource advantages and benefit the development of the local economy [1]. Therefore, since the construction of the expressway, cement pavement has developed rapidly. As of the end of 2019, the total mileage of cement pavement nationwide has reached 1.0237 million kilometres, accounting for 69.89% of the total mileage of paved roads.
Collapsible loess is widely distributed in my country. It has the characteristics of relatively uniform soil texture and loose structure. It will lose a certain bearing capacity after being soaked by water. The urban waterlogging disaster in the collapsible loess area is very severe. Non-weight collapsible loess has good strength when it is not wetted by water, but after being wetted by water, the soil structure will be damaged to a certain extent, but it can still have a certain strength. Therefore, how to pave concrete in the non-weight collapsible loess area is an urgent problem [2]. Based on this research background, the paper analyses the cooperative working conditions of concrete surface structure and non-self-weight collapsible loess subgrade based on the climate and geological characteristics of non-self-weight collapsible loess area. The thesis uses coal gangue powder, fly ash, calcium carbide slag powder, silica fume and concrete gravel to modify the collapsible loess, and studies the unconfined compression test after the modification, the load ratio (cbr) test, and the eds-sem scanning electron microscope test. And other physical and mechanical properties.

2. Experimental materials and methods

2.1. Material preparation

Coal gangue powder, fly ash, calcium carbide slag powder, silica fume, collapsible loess, crushed to concrete gravel below 1cm.

2.2. Preparation and maintenance of samples

The thesis puts the prepared homogeneous mixed soil into a cylindrical mold with a diameter of 4cm and a height of 8cm. Before the mold is loaded, a layer of petroleum jelly is evenly coated on the inner wall, and then a layer of cling film is uniformly covered to facilitate demoulding; in order to eliminate the test The air bubbles in the sample and make the sample compact, the mixed soil adopts quality control, layer-by-layer compaction melding method, and is loaded into the mold in three layers (the thickness of each layer is about 2.67cm, and each layer is filled with a three-axis compactor Compaction 25 times, the weight of the hammer is 300g, and the drop distance is 30 cm. Then use a knife to gently pull the upper surface (to make the layer evenly dense), and then install the next layer of compaction until a sample is completely prepared; After each sample is completed, stir the mixture again to ensure the uniformity of the mixture.

2.3. Experiment content

2.3.1. Unconfined compression test. Put the prepared sample together with the mold into a standard curing box for curing. The curing temperature is 20±2℃ and the humidity is >90%. After curing for 24 hours, the sample will be demoulded [3]. The sample is wrapped with plastic wrap and cured to the design age. For 28 days, a strain-controlled unconfined compression tester was used for the test. We calculate the axial strain $\varepsilon$, the average cross-sectional area $A_a$ and the axial stress of the lightweight soil sample according to formulas (1)-(3):

$$\varepsilon = \frac{\Delta h}{h_0} \quad (1)$$

$$A_a = A_h / (1 - 0.01\varepsilon) \quad (2)$$

$$\sigma = 10CR / A_a \quad (3)$$

Where $\varepsilon$ is the axial strain, %; $h_0$ is the initial height of the sample, cm; $\Delta h$ is the axial deformation, cm; $A_h$ is the sample area after calibration, cm$^2$; $A_a$ is the initial area of the sample, cm$^2$; $\sigma$ is the axis Directional stress, kPa; C is the dynamometer calibration coefficient, N/0.01mm (or N/mV); R is the dynamometer reading, 00.01) mm (or mV); 10 is the unit conversion factor.
2.3.2. Bearing ratio (cbr) test. Through the unconfined compressive strength test, the unconfined compressive strength of the undisturbed soil is measured as $q_u = 88.19\, KPa$. According to Terzaghi theory, the formula for ultimate bearing capacity of foundation can be obtained:

$$p_u = c'N'c + qN'q + 1/2 \gamma b N'r$$

(4)

Where: The shear strength index $c', \phi$ is determined according to the "Technical Regulations for Cast-in-Situ Foam Lightweight Soil", $c = q_u/2, \phi = 0, N'c, N'q, N'r$ is the ultimate load factor.

2.3.3. EDS-SEM scanning electron microscope test. In order to further study the relationship between the microstructure difference and mechanical properties of loess before and after modification, the natural loess before and after modification were analysed by electron microscope and energy spectrum.

3. Results

3.1. Unconfined compression test

(1) Improved soil data: Take 10%, 20%, and 30% improved soils at 0, 7, 14, 28 days, and carry out unconfined compression experiments and compare them at the curing age. Figure 1 shows the horizontal comparison [4]. In the test, after 28 days of curing, 30% calcium carbide slag powder has the best compressive performance, but it has a heavier industrial peculiar smell; 30% silica fume and 30% coal gangue the compressive properties of modified silt soil are close; the compressive properties of modified soil with 30% fly ash are relatively low.

(2) Data of mixed concrete crushed gravel: we take the mix ratio of 30% (the highest compressive strength) to mix 30% concrete gravel with modified soil, and perform unconfined compressive resistance at 0, 7, 14, 28 d and curing age Experiment and compare. Among the four different admixtures in the test, the improved soil mixed with 30% calcium carbide slag and 30% concrete gravel has the best compressive effect, and the other three improved soils have similar effects. Figure 2 shows the results of the unconfined compression test with different materials.

Figure 1. Horizontal comparison of unconfined compression test
Figure 2. Unconfined compression test results with different materials

3.2. Bearing ratio (cbr) test

(1) Take various modified soils with a mix ratio of 30% admixture, conduct cbr test, and compare the values. (2) Take various modified soils with a mix ratio of 30% admixture, mix 30% concrete gravel, conduct cbr test, and compare the values. The results of the study found that after four different admixtures were used to improve soil mixed concrete gravel, the load-bearing ratio of the improved soil obtained by mixing 30% calcium carbide slag and 30% concrete gravel was the best and much higher than the other three materials Bearing ratio. Figure 3 and Figure 4 show the load ratio test diagrams.

Figure 3. Test curve of load-bearing ratio of improved concrete
3.3. *Eds-sem scanning electron microscope test*

The paper analyses the stability and element situation of various improved soils in the picture. In view of space requirements, the paper takes 8# silica fume + concrete crushed gravel modified soil as an example, as shown in Figure 5 and Table 1 is the microstructure photo and energy spectrum of 8# silica fume + concrete crushed gravel modified soil. A transparent clay cement was produced between the particles within 1 h. The energy spectrum element analysis of the cementation material shows that the content of Si element has increased significantly, even exceeding the content of Ca element [5]. The peak value of Al element is very obvious, while the peak value of Al element is almost absent in the original soil, which can be determined as the content contained in the modified raw material. Al is an element and forms a cementing substance between the particles.

![Figure 4. Comparison of stress-strain curves of modified soil of 28d concrete crushed gravel](image)

![Figure 5. Element situation](image)
Table 1. 8# Silica Fume + Concrete Crushed Gravel Modified Soil Element Table

| Elt. | Line | Intensity (c/s) | Conc | Units | Error 2-sig | MDL 3-sig |
|------|------|-----------------|------|-------|------------|-----------|
| C    | Ka   | 0.00            | 0.000| wt.%  | 0.000      | 0.000     |
| O    | Ka   | 2,996.37        | 10.794| wt.%  | 0.235      | 0.299     |
| Na   | Ka   | 1,262.97        | 1.825| wt.%  | 0.059      | 0.073     |
| Mg   | Ka   | 771.31          | 0.932| wt.%  | 0.039      | 0.050     |
| Al   | Ka   | 5,744.63        | 6.698| wt.%  | 0.100      | 0.124     |
| Si   | Ka   | 12,380.84       | 14.432| wt.%  | 0.147      | 0.183     |
| Cl   | Ka   | 316.80          | 0.490| wt.%  | 0.036      | 0.048     |
| K    | Ka   | 224.44          | 0.401| wt.%  | 0.049      | 0.070     |
| Ca   | Ka   | 1,739.55        | 3.427| wt.%  | 0.094      | 0.117     |
| Mn   | Ka   | 215.71          | 0.870| wt.%  | 0.072      | 0.092     |
| Fe   | Ka   | 538.56          | 2.566| wt.%  | 0.126      | 0.156     |
| Nb   | La   | 980.87          | 3.857| wt.%  | 0.203      | 0.284     |
| Pd   | La   | 1,407.25        | 8.159| wt.%  | 0.253      | 0.317     |
| Ag   | La   | 0.00            | 0.000| wt.%  | 0.000      | 0.000     |
| Au   | La   | 261.66          | 40.982| wt.%  | 2.608      | 3.046     |
| Ra   | Ma   | 0.00            | 0.000| wt.%  | 0.000      | 0.000     |
| Th   | Ma   | 270.52          | 1.741| wt.%  | 0.173      | 0.241     |
| Pu   | Ma   | 412.35          | 2.825| wt.%  | 0.172      | 0.222     |
|      |      | 100.000         | 100.000| wt.%  |            |           |

Scanning through the electron microscope, it was observed that the admixture had a greater effect on the cohesiveness of the soil foundation and the concrete gravel, which made the soil structure more stable. As shown in Figure 6.

Figure 6. Eds-sem scanning electron microscope results

4. Conclusion
This paper also proposes a theoretical method combining electron microscopy microstructure and energy spectrum analysis, as well as dynamic tests to test the mechanical strength of soil. This method can effectively test the engineering mechanical properties of soil from the micro level, and is helpful to propose more reliable modification schemes. This has a certain reference function for the construction of high-speed railways and highways in the loess area.
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