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Correlation Analysis of Loess Collapsibility Coefficient with Its Physical and Mechanical Properties in Weibei Area

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Abstract: Based on a large number of drilling and laboratory test data in Weibei loess tableland area, the correlation of three conventional physical and mechanical indexes of loess in this area, such as void ratio, compression coefficient and collapsibility coefficient, was analyzed and studied. The results show that void ratio is positively correlated with compression coefficient and collapsibility coefficient, and the correlation between void ratio and collapsibility coefficient is higher. The correlation between compression coefficient and collapsibility coefficient is obvious when the compressibility of soil is small, but there is no obvious correlation between collapsibility coefficient and compression coefficient when the compression coefficient is large.

Keywords: Loess, Physical and mechanical parameters, Spatial variation regulation.

1. Introduction

Loess is a kind of special soil [1].Its physical and mechanical properties are complex, with large porosity, loose soil and vertical joint development. In the dry state, it has high strength, and after soaking, due to the dissolution and dispersion of minerals, and the rapid destruction of loess structure, it is prone to collapsible deformation and failure, and then various engineering problems occur, which has great harm to the engineering construction in loess area [2,3]. The collapsibility coefficient of loess is an important parameter in engineering construction. Previous studies have shown that the collapsibility of loess is closely related to its particle composition, soluble salt content, void ratio, dry density and structure [4-6]. At present, the evaluation of loess collapsibility is mainly based on indoor collapsibility test, but the indoor collapsibility test often has large error. The relationship between the collapsible strength of loess and the conventional test parameters such as void ratio and compression modulus is studied to facilitate the preliminary determination of the collapsibility of loess in engineering practice. Therefore, this paper takes the construction site of a project in Heyang County, Weibei Loess Plateau as an example. According to a large number of field drilling and laboratory measured data, through statistical analysis, the collapsibility coefficient of loess in this area and its correlation with some physical indexes are analyzed and evaluated. The purpose is to provide reference for the selection of rock and soil parameters in the follow-up projects and surrounding areas.

2. Introduction of Research Area

The study area is located in Weinan City, Shaanxi Province, and the geomorphic unit belongs to Weibei Loess Plateau. It is a warm temperate continental semi-arid monsoon climate, characterized by clear four seasons, warm and dry spring, rapid and unstable temperature rise, and sometimes cold spring with less precipitation; hot summer thunderstorms, heavy rains and paroxysmal gales, between the drought; its autumn is cool and humid, the temperature drops quickly, rainy, after October precipitation decreases rapidly, the weather is fine; winter is cold and dry, the temperature is low and the snow is scarce. In this study, the sampling depth range is mainly distributed in the upper Pleistocene aeolian loess (Q_3^{eol}), residual ancient soil (Q_3^{el}) ; there is no groundwater distribution in the range of sampling depth in the middle Pleistocene aeolian loess (Q_2^{eol}) and residual ancient soil (Q_2^{el}).

3. Sample Collecting and Experimental Program

To analyze the correlation between the physical and mechanical properties of loess in the study area, the loess was drilled and the soil samples were taken for indoor test. A total of 14 boreholes were drilled on the site, with the deepest footage of 39.2 m, and about 200 test samples were taken. The moisture content, dry density, liquid plastic limit, shear strength and other indoor geotechnical tests were carried out on the test samples. The moisture content was tested by drying method, the dry density was tested by ring knife method, the liquid plastic limit was tested by cone loss and rubbing method, the collapsibility coefficient was tested by double line method, and the compression coefficient was measured by consolidation instrument. This paper mainly analyzes the correlation among the compression coefficient, collapsibility coefficient and porosity of loess in this area.

According to the sampling and test results, the basic physical and mechanical properties of loess in this area are shown in Table 1.

Table 1. Basic physical and mechanical properties of loess in the study area

Characteristics	Water content (%)	Dry density(g/cm^3)	Void ratio	Liquid limit (%)	Plastic limit (%)	Plasticity index	Collapsible coefficient	compressibility coefficient (Mpa^{-1})
Value	8.6~26.5	1.14~1.64	0.653~1.389	24.0~34.3	15.9~19.6	10.1~14.7	0.001~0.095	0.09~1.89

4. Statistical Characteristics of Physical and Mechanical Properties

The void ratio reflects the total porosity and compactness of the soil, and indirectly characterizes the microstructure of the soil to a certain extent [7]. The large porosity of loess is the root cause of collapsibility [8]. According to the previous research on the microstructure of loess [9-12], according to the causes of pores and the arrangement of skeleton particles that constitute pores, the pores of loess are divided into: macropores (including large-size pores such as root holes, wormholes, mouse holes and dissolution holes), overhead pores, mosaic pores and intragranular pores. Overhead pores are sensitive to pressure and have a great influence on collapsibility [10] and compressibility of loess. The void ratio has a certain relationship with the overhead pores in loess. The smaller the void ratio, the denser the soil, the closer the arrangement between the soil particles, the less the number of overhead pores, and the less prone to collapsibility. It can be seen from Fig.2 and Fig.3 that the void ratio is positively correlated with the compression coefficient and the collapsibility coefficient, and the correlation coefficients R2 are 0.4517 and 0.6028, respectively. Wu Xiaopeng et al. [7] obtained through experiments that 0.9 can be defined as the initial void ratio e0 of loess collapsibility for Malan loess in Guanzhong area. This rule can also be seen from Figure 3. When the void ratio is 0.9, the collapsibility coefficient is mostly above 0.015.

Fig.3 shows the relationship between collapsibility coefficient and compression coefficient. It can be seen from figure 3 that when the compression coefficient is about 0.3Mpa-1, the collapsibility coefficient of loess in the study area increases with the increase of compression coefficient, and the correlation is obvious. When the compression coefficient is greater than 0.3Mpa^{-1}, there is no obvious correlation between the collapsibility coefficient and the compression coefficient. The compression coefficient characterizes the ratio of vertical stress variation to void ratio variation under a certain level of pressure. It is mainly affected by the structural strength of the soil, the compactness of the soil particle arrangement and the moisture content of the soil. The relationship between the collapsibility coefficient and the compression coefficient is reflected in : the compression coefficient is small, which may reflect that the soil is denser, and the deformation is less affected by the external pressure or the immersion condition, that is, the two show a positive correlation, which is also confirmed in References [7] and [8]. In addition, if the strength of the soil structure is large, the compression deformation is small at the beginning, but in the case of immersion, if the water stability is poor, the structure may be destroyed quickly, and the expected collapsible deformation is large. The compression coefficient is negatively correlated with the collapsibility coefficient, and if the water stability is good, the opposite is true [13]. When the compression coefficient of the soil is large (> 0.3 MPa^{-1}), the soil belongs to the medium and high compressibility soil, and the structural strength is small. After soaking, the soil structure will quickly destroy and undergo large deformation, so the correlation with the compression coefficient itself is not very strong.

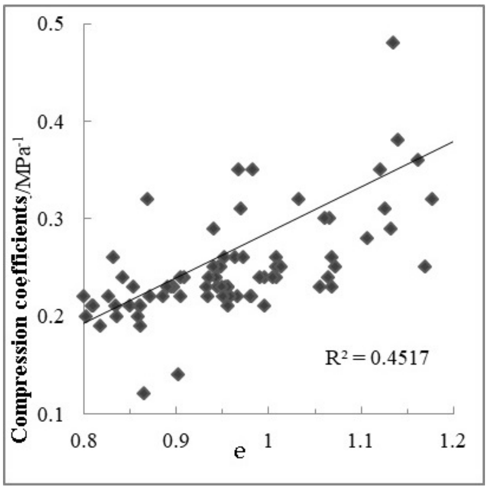

Figure 1. The relationship between compression coefficients and void ratio

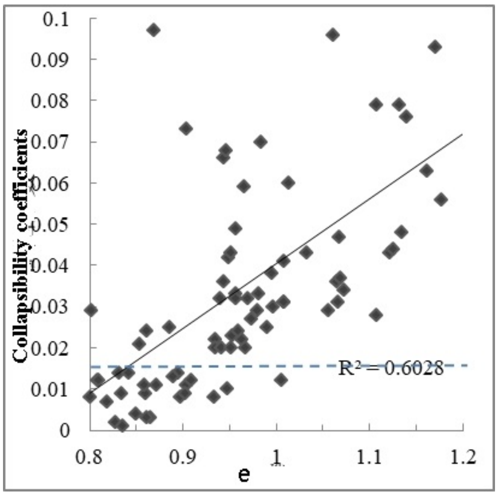

Figure 2. The relationship between collapsibility coefficients and void ratio

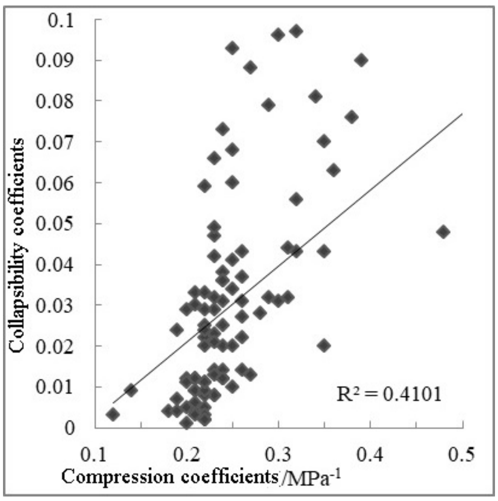

Figure 3. The relationship between collapsibility and compression coefficients

5. Conclusions

Based on the statistical analysis of a large number of measured data of loess in Heyang County located in Weibei Loess Plateau, the correlation between the three physical and mechanical indexes of compression coefficient, collapsibility coefficient and void ratio was investigated. The main conclusions are as follows:

The void ratio is positively correlated with the compression coefficient and the collapsibility coefficient, and the correlation coefficient R^2 is 0.4517 and 0.6028 respectively. The correlation between void ratio and collapsibility coefficient is higher.

When the compression coefficient < 0.3 Mpa^{-1}, the collapsibility coefficient of loess in the study site increases with the increase of compression coefficient, and the correlation is obvious. When the compression coefficient > 0.3Mpa^{-1}, there is no obvious correlation between the collapsibility coefficient and the compression coefficient.

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