Scholar Publishing Group
International Journal of Engineering Technology and Construction
https://doi.org/10.38007/IJETC.2020.010203
ISSN 2789-7176 Vol. 1, Issue 2: 26-36

Application and Development of Scanning Electron Microscope Testing Technology in Geotechnical Engineering

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Keywords: Scanning Electron Microscope, SEM Testing Technology, Geotechnical Engineering, Microstructure, Quantitative Analysis

Abstract: Because the structure of soil has important restrictions on the engineering properties of soil, the study of soil structure has become one of the core issues in soil mechanics research. Therefore, it is of great significance to study and analyze soil microstructure and obtain corresponding qualitative and quantitative information. The appearance of soil micro-testing technology, especially the appearance of scanning electron microscope, provides a basis for the research of soil micro-testing technology. Based on the above background, the research content of this article is the application and progress of scanning electron microscopy in geotechnical engineering. So far, some testing techniques have been developed, such as M-ray fluoroscopy, stereo photography, laser speckle method, M-ray diffraction, and optical microscope. This article mainly introduces the most commonly used scanning electron microscope testing technology in the study of soil microstructure, and through experimental simulation, the results show that at 500 ℃, the ratio of the internal pore area of the sample increases significantly, indicating that the internal cracking is serious, at this time The compressive strength of the sample is greatly reduced, and the bearing capacity is reduced. The directionality of the particles decreases with the increase of stress, and the fractal dimension of the particle distribution increases with the increase of stress, indicating that the degree of agglomeration of the soil particles decreases, the bearing capacity decreases, and the soil samples tend to be unstable. This is because the pore water continues to infiltrate under the action of external load, accumulates to a certain extent and then moves down to the bottom of the soil sample, so that the soil particles in this layer become loose and the cohesion decreases, resulting in unstable soil.

1. Introduction

In recent years, many important achievements have been made in the study of soil microstructure.

The center of gravity of microstructure has been transferred to qualitative research through qualitative research to find the direct constraint relationship between soil microstructure and engineering properties. There are also some problems in the current research progress.

The structure of the soil is one of the most fundamental factors that determine the mechanical properties of the soil. It also reflects the role of the three factors of particle size, density and humidity to a certain extent [1]. The fundamental task of soil structural research is to find a quantitative index that can fully reflect the arrangement and connection characteristics of soil particles [2]. The structural parameters of the soil can reflect various changes in the mechanical properties of the soil under the action of stress, and have a broad application prospect in revealing the dynamic properties of the soil [3]. With the deepening of the research on the microstructure of cohesive soil, Chinese scholars have carried out research on the microstructure of special soils such as laterite, loess, expansive soil and frozen soil [4]. By studying the structure of more types of soil, the understanding of the importance of various types of soil structure is further deepened [5]. For traditional deformation measurement methods such as placing displacement sensors or drawing grid lines on the model, due to the limitation of the installation position of the measurement instrument boundary and the limited number of measurement points, these methods have been unable to meet the micromechanics of rock and soil Requirements for qualitative and quantitative research on performance and deformation characteristics of the whole field [6]. Therefore, it is necessary to develop new experimental measurement methods according to the characteristics of model experiments [7].

Scanning electron microscopy is widely used for precise micro / nano image exploration. In the past few years, several strategies have been proposed to fine-tune those microscopes. Hatamleh proposed a new fine-tuning strategy for the scanning electron microscope sample stage using a four-bar piezoelectric actuator. In addition, Hatamleh proposed another algorithm to search for the best inverse kinematics solution. [8]. In Naik's method, fungal samples are cultivated on the surface of sterilized mycorrhiza, and samples containing reproductive structures (such as spores of potato dextrose agar) are directly transferred to carbon bands fixed on aluminum mycorrhiza and imaged by ESEM. The images obtained from ESEM describe the complete morphological characteristics of the fungal mycelium and its reproductive structure. Naik's method can be used for rapid identification of fungal classification [9]. The three-dimensional (3D) reconstruction of the sample surface from the images taken from two angles of the scanning electron microscope (SEM) has a history of decades. Currently, there are several commercial stereo photogrammetry software packages. To test these software packages, Tondare used SEM images of virtual samples simulated by Monte Carlo in the study. The virtual sample is a model in the computer, and its real size is known. Due to the uncertainty of measurement, it is impossible for the real SEM sample. The simulated SEM image can be used for algorithm testing, development and verification. Tondare tested two stereo photogrammetric software packages and compared the reconstructed three-dimensional model with the known geometry of the virtual sample used to generate the simulated scanning electron microscope image. Both of these software packages performed quite well on SEM images of samples with simulated surface roughness [10].

The 21st century is an era of informatization and an era of rapid advancement of high and new technologies. As a relatively traditional discipline, geotechnical engineering in this environment requires the penetration of new technologies and the integration of various disciplines. Only in this way can we inject new vitality into geotechnical engineering. The method of mechanics is to analyze the relationship between the structure of the soil and the engineering properties of the soil. In fact, it has been a long time since the soil mechanics has been used to study the structure of the soil. The sensitivity of cohesive soil, the collapsibility coefficient and initial pressure of loess, the expansion coefficient of expansive soil, and the resistance to liquefaction and shear stress of saturated sand all reveal The structure of different soils. However, most of the previous studies only discussed one aspect of soil structure.

2. Proposed Method

2.1. Scanning Electron Microscope

The high-energy incident electron beam irradiates the solid sample, and the interaction with the atoms in the sample will generate various signals. In the scanning electron microscope, the signals used for imaging are mainly secondary electrons, followed by backscattered electrons and absorbed electrons. The energy used to analyze the component signals directly characterizes the properties of the elements. Some other signals, such as cathodic fluorescence, electron beam induced electrical effects and transmitted electrons, are not as widely used as the above signals.

Secondary electrons: When inelastic scattering occurs between the incident electrons and the outer electrons of the nucleus in the sample, a part of the extranuclear electrons gain energy to escape from the surface of the sample. These electrons are called secondary electrons. Since the valence electron binding energy is very small, it is about 10eV for metals. Therefore, the secondary electron energy is relatively low, generally less than 50eV, most of which is between 2 ~ 3eV. During the interaction between incident electrons and atoms in the sample, other methods can also generate low-energy electrons that escape the surface. They are indistinguishable from secondary electrons. Therefore, it is customary not to detect the energy above the sample and the energy is less than 50eV free electrons are called secondary electrons. Backscattered electrons: This is a part of the electrons reflected by the atoms on the surface of the sample after the incident electrons are scattered by the nucleus Rutherford in the sample. Their energy loss is very small, and their energy value is close to the incident electrons, but relative to the division of secondary electrons In general, electrons with energy greater than 50eV are called backscattered electrons. Electron absorption: As the incident electrons and the atoms in the sample increase the number of inelastic scattering, the energy loss is exhausted and they can no longer escape the surface. This part is the absorption of electrons. If a highly sensitive current amplifier is connected between the sample and the ground, the detected current signal is the absorption of electrons or sample current signal. Characteristic X-ray: Characteristic X-ray is an electromagnetic radiation wave with characteristic energy and wavelength that is directly released during the electron transition process after the inner electron of the atom is excited. When the incident electrons are irradiated on the solid sample, if the inner electrons of the atoms in the sample are excited, then the atoms change from the ground state to the unstable excited state, the outer electrons will transition to the inner electron vacancies during the energy transition process. X-rays with characteristic energy and wavelength can be directly released in. If the electrons in the inner layer of K are excited and the electrons in the L2 layer transition to the K layer, the characteristic energy of the released X-rays is equal to the energy difference between the two energy levels. Auger electron: After the L2 layer electron transitions to the K layer, the released energy EK-EL can be released in another form in addition to the X-ray form. This energy can release another electron outside the core. After the electrons leave the atom, they are called secondary electrons with characteristic energy-Auger electrons. Different elements have their own specific energy values. The Auger electron energy is generally 50 ~ 1500eV. Light elements have a higher probability of generating Auger electrons than heavy elements; when the Auger electrons can only escape within a few atomic layers from the surface layer to maintain their characteristic energy, the Auger electron signal is particularly suitable for the light of the sample surface. Elemental composition analysis.

2.2. Geotechnical Microstructure

The microstructure of soil includes three aspects: morphological characteristics, that is, the size, shape, surface characteristics and quantitative proportional relationship of structural units; geometric characteristics, that is, the arrangement characteristics of each unit in space; energy characteristics, That is, the connection characteristics between the unit bodies. The study of the microstructure of soil should start from the following aspects: the shape and size of the basic unit of microstructure. Under the microscope, those with obvious physical boundaries are called the basic unit of microstructure, which can be divided into primary unit and secondary unit. The primary unit body refers to a micro-aggregate that has a strong original cohesion and is difficult to separate. The second-level unit body refers to aggregates such as flakes and granules, which are assembled by first-level micro-aggregates. These secondary microstructure units can be divided into agglomerates (> 10μm), fine particles (5 ~ 10μm), fine particles (1 ~ 5μm) and ultrafine particles (<1μm) according to their aggregate size; Contact state. In sheet-shaped or plate-shaped aggregates, the contact is generally in the form of face-face, edge-edge, edge-face, etc., while in granular aggregates, direct contact or mosaic contact is present. Some are through the cemented substance is connected; the connection form between the basic unit bodies. The interaction force between the basic unit bodies is very complicated, and the action form includes the existence of charges, water films and cemented substances. Scanning electron microscopy can only observe its shape, but the interaction the force test must also be combined with probe analysis and chemical analysis for comprehensive determination.

The loess skeleton particles are the pillars constituting the loess structural system. Loess skeleton particles are mainly composed of debris particles (particle size> 0.005mm) and special skeleton particles-aggregates. Aggregate is composed of the aggregation of fine particles, has a certain rigidity, and also plays a supporting role in the skeleton. The morphology of loess skeleton particles is diverse. The shape of the coarse mineral particles in the debris particles, especially those with a diameter greater than 0.01 mm, often varies with the type of mineral. Quartz has the highest mineral content in loess. The surface of the particles is clean, the edges are flat, and most of them are elongated; the content of feldspar is second only to quartz, and the shape of the particles is mostly plate-shaped or columnar; the mica minerals are mainly plate-shaped and band-shaped.

Aggregation is made up of a large amount of fine-grained debris and a small amount of clay particles cemented by microcrystalline carbonate, which is commonly found in loess. Aggregates generally have a relatively regular shape, mainly spherical and ellipsoid. The number of aggregates and the form of existence are closely related to climatic conditions and clay content. Generally speaking, the climate is dry, and the calcium carbonate in the aggregate is well preserved and rigid, and it is easier to form a loose structure of the scaffold to create conditions for collapsing; while the climate is wet, the calcium carbonate is leached, softened to form a clot, and the skeleton is cemented Particles. In addition, in the old strata, a single aggregate is generally not seen because the soil is easily compacted under the pressure of the overlying strata, and the aggregates disappear or become agglomerates.

The contact relationship of the skeleton particles refers to the existence state of the skeleton particles in the space, including the arrangement mode and the connection form. It is an important factor that determines the mechanical strength of loess. The contact relationship of the skeleton particles can be divided into the following three categories. One is the support contact, which is characterized by a small contact area between the particles, mainly point contact, corner and face contact. The particles scaffold each other, forming large intergranular pores. However, this kind of contact is very unstable. When it is greatly affected by the pressure of the overlying formation and water, it may be converted into mosaic contact. The second is mosaic contact. The characteristic of this contact is that the skeleton particles intersect each other, and the contact area is large, in the form of mosaic. This contact relationship is relatively stable. The above two contact relationships are relative and often appear at the same time. The third is dispersed distribution. The mineral particles are separated by clay particles (cement), basically not in contact, in a dispersed state, and mainly exist between the particles with strong cementation. The pores are small, not easily affected by external forces and water, and the soil is not easily deformed.

2.3. SEM Test Technology

Due to the particularity of geotechnical materials, in order to ensure that the observed microstructure scan image can truly reflect the original shape of the sample, the collected sample must be kept in its original state without disturbance. Take a part of the soil sample according to the requirements and pay attention to select the part that can represent the structural characteristics of the soil sample. For example, when preparing the sample after the mechanical test, samples of different parts inside and outside the failure surface or the shear zone should be selected. Orient the sample. Under normal circumstances, the sample should be broken apart by hand, and as far as possible without using mechanical knives, cutting with a knife has actually changed the original microstructure of the soil. On the other hand, since there are often smooth surfaces inside the cohesive soil, the smooth surfaces should be avoided when making samples to ensure that the observed microstructures can represent the overall situation of the soil sample.

According to the requirements of different models of scanning electron microscope, a sample of a certain size is made and the smoother section is selected under the magnifying glass. In order to remove the disturbing particles on the surface of the sample, a thin layer of glue can be lightly coated on the surface of the sample. After the glue dries, the rubber skin is torn off, and the loose particles are blown off with a rubber ball to obtain a fresh section of the sample. However, for the samples mainly composed of fine clay minerals, when the rubber skin is torn off, the clay mineral flakes will be pulled up, so the operation should be very careful. The samples used for SEM observation must be solid materials to ensure the vacuum degree of the SEM vacuum system, so the samples containing moisture must be dried in advance. In order to eliminate the charging phenomenon, the samples stained with oil must also be carefully washed with a solution such as acetone to ensure the cleanliness of the sample surface. The air-drying method is the most common and simplest application in China, that is, the sample is slowly dehydrated and dried in the atmosphere. When the soil moisture content is low and the shrinkage limit is less than 10%, it is more suitable. Excessive moisture content will inevitably cause serious changes in the microstructure of the soil. The replacement drying method is to replace the water in the soil sample with low surface tension liquids such as methanol, acetone, alcohol, isopentane, etc., and replace them with liquids of different concentrations for many times, and also use ziene replacement, and then air dry and dry. Or vacuum drying. The successful development of the freezing vacuum sublimation dryer has greatly improved the level of microstructure preparation samples. The basic principle is that at the temperature of the refrigerant, the sample is quickly frozen, so that the water in it quickly freezes into tiny ice crystals, and then under vacuum conditions, the temperature of the sample is raised to -50 ℃ ~ -100 ℃ the tiny ice crystals are directly sublimated, and the soil sample is dried. Scanning electron microscopy can only observe its shape, and the interaction force test must also be combined with probe analysis and chemical analysis for comprehensive determination.

The microstructure information includes the total area, total perimeter, average area, average perimeter, average shape factor, average particle diameter or pores of the particles or pores, and the correlation between them. The shape factor of a particle or pore is defined as:

$$F_i = C / S \tag{1}$$

In the formula, C is the circumference of the same area as the particles or pores, and S is the actual circumference of the particles or pores. The average shape factor is defined as:

$$F = \sum_{i=1}^{n} F_i \;/ n \tag{2}$$

In the formula, n is the number of statistical particles or pores.

The orientation of the microstructure unit includes orientation distribution, main orientation angle and anisotropy rate. Since the orientation of the unit body is mirror-symmetrical in the range of 0 ~ 360 °, it is only necessary to calculate the orientation of the unit body in the range of 0 ~ 180 °. The Videolab image analysis and processing system divides the range of 0 ~ 180 ° into 10 ° units into 18 azimuth zones, which can analyze the orientation strength of the microstructure unit in each partition, thereby obtaining the orientation of the structure unit in the entire image Distribution (generally elliptical distribution) and main orientation angle. In order to reflect the overall orientation of the clay soil microstructure, the Videolab image analysis system introduces the concept of anisotropy rate, which can be expressed as follows:

$$I_n = \frac{R - r}{R} \times 100\% \tag{3}$$

In the formula, in is the anisotropy rate, 'is the long axis length of the ellipse, and r is the short axis length of the ellipse. It can be seen that the variation range of I_n is between 0 and 100%. When I_n = 0, the particles or pores are randomly distributed, which is isotropic; when I_n = 100%, it is completely anisotropic.

3. Experiments

3.1. Experimental Setup

Drawing on the existing soil micro-deformation testing methods, this article still uses the more mature semi-cylindrical pressurized cabin to load the test piece. Therefore, according to the shape and size of the semi-cylindrical pressurized cabin, it is necessary to make semi-cylindrical soil samples. First, using the equipment for making soil samples, a cylindrical soil sample with a diameter of 39.5 mm and a height of 80 mm is made. Then cut a certain depth along the symmetrical axis of the cylindrical soil sample and gently break it into two semi-cylindrical soil samples, and gently shake off the floating soil on the cross section, and take any half of it as the research object. The shape is broken, rather than cut with a soil cutter. This is mainly to ensure that the side of the semi-cylindrical soil sample is broken, most of it is a fresh section, rather than the section after being disturbed, thus maintaining the original state inside the soil sample. After the soil sample is prepared, if the experiment cannot be carried out immediately, the semi-cylindrical soil sample needs to be sealed with a fresh-keeping bag to prevent some of the water in the soil sample from evaporating in the atmosphere and affecting the mechanical properties of the soil sample. Then open the fresh-keeping bag and take out the soil sample.

3.2. Scanning Electron Microscope Image Processing

Overscanning electron microscopy is the most commonly used technique for observing microstructures, and the results obtained by applying these techniques are usually multiple images that reflect the structure of the soil. To quantitatively analyze these images, some computer software packages have been developed. These image processing techniques have made a lot of achievements in quantitative evaluation of the microstructure of the body, especially in the processing of microstructure unit cells and the characteristics and orientation of pores.

Quantitative analysis of microstructures uses scanning electron microscopy as the test method, takes structural unit bodies and pores as the research objects, and uses statistical, nonlinear theory methods and computer technology to combine the structural unit bodies with the scanning electron microscope pictures of soil. Quantitative analysis and evaluation of the morphology, orientation, pore characteristics and their comprehensive characteristics provide important quantitative data for explaining the mechanical behavior of soil. The characteristics of structural units and pores mainly include size, structure, shape, surface characteristics and the quantitative relationship between them. They can pass the total area, total circumference, average area, average circumference and abundance of structural units and pores., Shaped index, etc. The spatial distribution of structural units and pores includes orientation angle distribution, principal orientation angle, and anisotropy rate. In this paper, the microstructure of the sample was observed, and the image processing of the scanning electron microscope photo was carried out, and the corresponding quantitative information was obtained.

4. Discussion

4.1. Reliability Analysis

First, the microscopic imaging tracking system is used to obtain sequence images at different focal points. Two images (a) and (b) of an ecological soil under the same load state are selected to verify the processing method proposed in this paper. In order to further determine its effect from a quantitative perspective, two evaluation functions are proposed: signal-to-noise ratio and mean square deviation. The signal-to-noise ratio and mean square error before and after image processing are shown in Table 1.

Table 1. SNR and mean square error before and after image processing

Image	(a)	(b)	(c)
SNR	8.2494	8.0798	8.7318
MSE	312.0619	324.4145	279.2517

It can be seen that the use of wavelet transform multi-resolution technology not only improves the signal-to-noise ratio of the image, but also reduces the variance of the grayscale of the image, resulting in a higher-quality image. Subsequently, image processing techniques are used to analyze the soil on different images. The microstructure parameters were extracted to obtain the comparison of the four microstructure parameters shown in Figure 1.

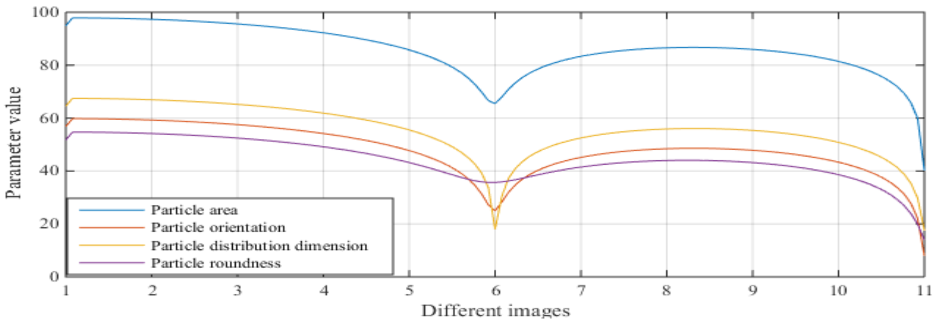

Figure 1. Comparison of four microstructure parameters

It can be clearly seen from the figure that the microstructure parameters of the image processed by wavelet transform are closer to those processed by Photoshop software, which shows that the multiresolution technology of wavelet transform can not only solve the problem of insufficient depth of field of the image, but also ensure the image microstructure parameters Reliability of extraction. Since only two images are used for wavelet transform in this paper, the processed results are not very satisfactory. At the same time, in the optimization of the wavelet coefficient algorithm, the method of searching for the largest coefficient by point-by-point comparison is processed to weaken the contrast of the image. Therefore, in the next step of research work, we consider the extraction of wavelet coefficients through domain processing.

4.2. Analysis of Pore Area Ratio and Pore Size Distribution at Different Temperatures

The pore area ratio refers to the percentage of the pore area in the section of the concrete specimen under the two-dimensional image, which reflects the density of the specimen inside. The pore area of the test piece at different temperatures is shown in Table 2.

Table 2. Ratio of pore area of specimens at different temperature

Pore area ratio	20°C	155°C	300°C	500°C
Plain	0.933%	0.625%	1.197%	3.276%
0.2% PP	0.892%	0.747%	0.997%	2.704%

Combining the data in Table 2, the pore area ratio and pore size distribution analysis at different temperatures can be obtained, as shown in Figure 2.

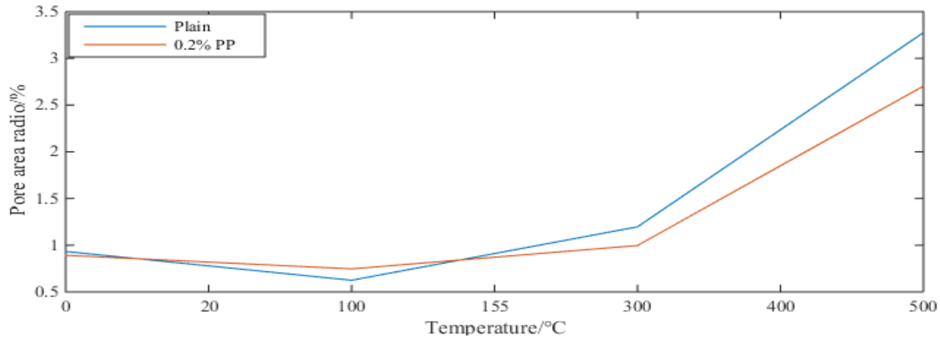

Figure 2. Analysis of pore area ratio and pore size distribution at different temperatures

It can be seen that as the temperature increases, the damage of the sample becomes more and more serious, and the pore area ratio increases. But at 155 °C instead it decreases. This is because the silicate slurry is mainly composed of hydrated calcium silicate, calcium hydroxide, and hydrated calcium sulfate. In addition to the adsorbed water, the saturated slurry also has a large amount of free water and capillary water. After the high temperature of 155 °C, the pore area ratio of the sample did not rise but decreased because of the loss of free water in the sample, part of the interlayer water and part of the chemically bound water in the CSH in the hydrated cement slurry, and the aggregate was thermally expanded. Make the inside of the concrete more dense, and the ratio of pore area decreases. At 500 °C, the ratio of the internal pore area of the sample increased significantly, indicating that the internal cracking was serious. At this time, the compressive strength of the sample was greatly reduced, and the bearing capacity was lost. Comparing the specimens without fibers and polypropylene fibers, it was found that the pore area ratio of the two specimens was similar at room temperature and 155 °C, but at 300 °C and 500 °C, the pores formed after the polypropylene fiber melted released steam in time The pressure reduces the destruction of the matrix by the steam pressure at high temperature, so the pore area of the fiber-filled specimen is always smaller than that of the fiber-free specimen.

4.3. Effect of Fabric Difference on Permeability Properties

In the engineering properties of fine-grained soil, the fluid conductivity is more significantly affected by the fabric. The anisotropy of fabric arrangement can cause obvious permeability anisotropy, and reshaping the original clay can reduce its permeability by about half. The decrease of permeability of soft clay and sensitive clay related to remodeling can be explained by the collapse of open flocculation fabric and the collapse of macropores. The comparison of permeability of samples with different fabrics is shown in Figure 3.

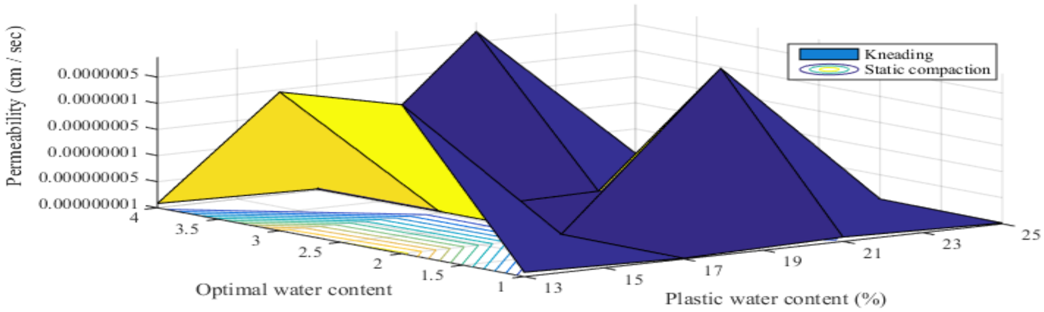

Figure 3. Comparison of permeability of samples with different fabrics

When the water content is lower than or slightly exceeds the optimal water content, the permeability has nothing to do with the sample preparation method. However, after the plastic water content exceeds the optimal water content by more than a few, the static compacted sample still retains most of its flocculation structure characteristics, and the kneading effect causes the flocculation structure in the sample to change more, forming a dispersed structure characteristic, and its penetration The performance is obviously lower than the static compaction sample. Shear deformation breaks the connection between particles and aggregates. If a sliding surface is generated, the flat particles can be preferentially oriented along the sliding surface with their long axis. Different methods were used to prepare samples with two different initial test configurations, one is mainly dispersed structure, and the other is mainly flocculated structure. Their stress-strain behavior is as follows: when the strain is low, When the deformation is equal, the partial stress required by the flocculated structure is much larger than that of the dispersed structure; but when the stress is as high as ~ a fixed value, the flocculated structure begins to break, and then the curve decreases rapidly, indicating that after the deformation increases to a certain amount, the same increase The amount of deformation required for the flocculated structure rapidly decreases.

4.4. Analysis of the Influence of Micro-Parameter Change Law

The change rule of micro parameters in each area is shown in Figure 4.

The soil sample has little compressibility in the first layer, and the whole sample shows a slight upward trend. This is because under undrained conditions, with the increase of stress, the micropores and microcracks in the soil sample began to expand, and some originally isolated pores communicated one after another, forming a local range of pore zones or fissures, which caused the pore area of the sample section has increased. The curve shows obvious fluctuations, which also shows the complexity of the microstructure deformation of the soil sample, so that some pores in the soil sample do not expand blindly during the loading process, but expand from time to time when they are closed, but overall they are growing. The roundness of the particles is related to the compressibility of the soil sample. If the initial roundness is high, the particles will change significantly during the compression process. On the whole, the circularity gradually decreases with the increase of stress, indicating that the soil particles in this layer are developing towards a flat and long shape, and the spatial arrangement has become loose. The orientation of the particles decreases with the increase of stress, and the fractal dimension of the particles increases with the increase of stress, which shows that the layer of soil particles in this layer is reduced in grouping degree, the bearing capacity is reduced, and the soil sample tends to be unstable. This is due to the fact that pore water oozes out under the action of external load, accumulates to a certain extent, and then moves down to the bottom of the soil sample, so that the soil particles in this layer become loose and the cohesion decreases, resulting in unstable soil.

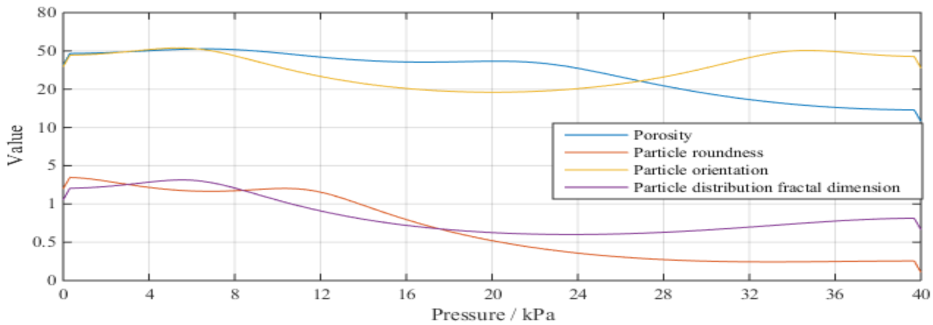

Figure 4. Variation laws of micro parameters in various regions

5. Conclusion

Traditional geotechnical constitutive models are generally based on macro-phenomenology. With people's understanding of the structure of soil, establishing corresponding constitutive models from the perspective of soil microstructure has gradually become one of the goals that people strive to explore. The microscopic testing technology of soil, especially the appearance of scanning electron microscope, provides a research basis for it. From a statistical point of view, it is a new development direction to establish the soil constitutive model to reflect the soil's macroscopic properties based on the soil's microstructure and the physical and chemical properties of the clay particles.

In order to make the system better quantitatively analyze the microstructure of the soil, this paper has carried out in-depth and meticulous research on the scanning electron microscope testing technology in theory and practice, and explored the feasibility of its application in geotechnical engineering. In this paper, based on the establishment of the mathematical model of tracking target motion parameters, by improving the image correlation formula, the peak of the maximum correlation coefficient is more prominent, which meets the requirement of rapid positioning of the microscopic imaging tracking target. At the same time, the variable template search method is used to greatly improve the positioning accuracy of the target and ensure the reliability of the system operation.

This article still has some shortcomings. It has been found through experiments that after multiple experiments, it is found that the key to ensuring better performance of the microscopic imaging tracking system is to ensure that the displacement control rate and the image tracking calculation rate are consistent under the loaded state, which requires In the future work, the relationship between the two will be adjusted to further coordinate. At the same time, it should also be noted that the deformation amount of the target must be within the search area, so as to ensure the accuracy of target tracking.

Funding

This article is not supported by any foundation.

Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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