Measurement and Calculation of Fissure Area and Density for Shrinkage Soil

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Abstract. Fissure density is an important evaluation indicator of the degree of fissure development for fissure soils, which is not easily measured by traditional methods. A new statistical method based on Visual Basic programming was proposed to calculate fissure density. The basic principle of this method is to convert colour pixels into black-white pixels based on brightness calculation, and then calculate the fissure density according to the proportion of black-white pixels. Through the above methods, the statistics of the fissure density and fissure area of shrinkage soil sample can be realized.

1. Introduction

Both red clay and expansive soil are soils with strong shrinkage soil, and red clay will produce fissures after the dry-wet cycles (see figure 1). Fissures are through-channels for rainwater to penetrate into the subgrade. Due to the water-sensitive properties of red clay, the strength of red clay will decrease sharply after water immersion, causing slope instability and subgrade damage [1-4]. The variation of fissure generation and development has always been a hotspot in the study of shrinkable soils [5-7], lots of which based on the shrinkage and moisture content curve. In addition, due to the limitation of observation methods, the quantitative description of fissures is only based on other physical quantities to measure the fissure density [8-9]. Due to the lack of quantitative description of red clay’s fissure, the fissure characteristics and the mechanism of slope instability are still not convincing.

(a) Fissure of red clay subgrade             (b) Fissure of expansive soil subgrade
Figure 1. Fissure on the surface of shrinkage soil subgrade
Due to the irregularity of fissure shape, the conventional method is not competent for fissure area calculation, so a method based on Visual Basic programming is proposed, which can easily calculate the fissure density and fissure area of shrinkage soil samples.

2. Fissure density definition
It is of great significance to study the variation of soil fissure evolution to control the fissure. It is not easy to control the boundary and test conditions by field dry-wet cycles test, so laboratory research is an important method of fissure development.

The fissure density is often used to evaluate the evolution of the shrinkable soil after dry-wet cycles. The so-called fissure density refers to the area of fissures on the sample surface compared with the total area of the sample, so it is often called area fissure rate, and its calculation method is shown in Equation (1).

\[
\delta_{fa} = \frac{\sum_{i=1}^{n} A_i}{A} \times 100\% \tag{1}
\]

Where \(\delta_{fa}\) is fissure density, \(A\) is total sample area, \(A_i\) is the area occupied by the \(i\)th fissure.

As from Equation (1), the larger the fissure density, the more fissures in the sample of soil under the same conditions, the greater the strength reduction after rainfall, the more unfavorable to the stability of subgrade and slope.

3. Calculation method of fissure density based on Visual Basic program
Fissures on the surface of sample are often irregular shape after dry-wet cycles (see figure 2 a), some new methods were used [10-12] to process the fissure image, but it is more difficult to compare the image fissure after processing is consistent with the original image.

In this study, Visual Basic programming is used to process the original color image to black-white image. The basic principle is that all kinds of colours can be decomposed into three-primary colours: red, blue and green, with a range value of 0-256 for each color. Then, the brightness value is synthesized according to the three colours of red, blue and green, and the future pixels will be displayed in white or black according to the brightness size.

The specific treatment method can be completed by the following 7 steps.

- The image software Photoshop is used to improve the contrast of the fissure image, and the high contrast image is obtained (see figure 2 b).

(a) Original image                                    (b) Processed image
Figure 2. Contrast precessing for fissure

- Use point function in Visual Basic software to get the color of a pixel in the image. The method can be realize by Equation (2).

\[P = \text{Point}(I,J)\]  \tag{2}
Where \((I, J)\) are the coordinates of arbitrary pixel points of the fissure image (see figure 4); \(P\) is a long integer variable; \(\text{Point}\) is a function of Visual Basic program, which can obtain the RGB color value of a certain point of the fissure picture.

- Dividing the color pixel into three primary colours, that is, converting the \(P\) value in the Equation (2) into three color values of red, green, and blue, and the algorithm can be expressed by the Equation (3), (4), (5).

\[
R = P \mod 256 \quad (3)
\]
\[
G = \frac{P}{256} \mod 256 \quad (4)
\]
\[
B = \frac{P}{65536} \quad (5)
\]

In the Equation (3)–(4), \(R\), \(G\), and \(B\) are integer type variables used to obtain the values of the three-prime colors value. “Mod” and “\(\div\)” are computational symbols for the Visual Basic programming language, representing remainder and divisibility, respectively.

- The brightness value \(Y\) can be calculated by Equation (6).

\[
Y = R \times 0.299 + G \times 0.587 + B \times 0.114 \quad (6)
\]

In the calculation brightness of a pixel, the proportion of red colour accounts for 29.9%, green colour accounts for 58.7%, and blue colour accounts for 11.4%.

- Convert the color image to black-white image according to the brightness value, and the implementation method is as shown in the Equation (7)

\[
\text{Picture1.PSet}(I, J), \text{If}(Y < T, \text{vbBlack, vbWhite}) \quad (7)
\]

In Equation (7), Pset is the function of drawing pixels in Visual Basic programming, and \(T\) is a control threshold variable. Equation (7) means that when the pixel’s brightness is less than \(T\), it is painted as black pixel, otherwise it is painted as white. “If” is a judgment function in Visual Basic programming. VbBlack and vbWhite are the black and white colour constants in Visual Basic.

- Each pixel in the fissure image is processed according to the above steps, and the processing is automatically completed by the programming. After the processing is completed, the colour image(Figure2 b) was transformed to a black-white picture (see figure3).

Based on the black-white color fissure image, Visual Basic programming is used to count the number of black and white pixels. If the number of accumulative black pixels is \(N_1\) and the number of white pixels is \(N_2\), and \(N_1 + N_2\) is the total pixels of the square in Figure 4. The shape of soil sample is circular so the white part around the sample should be deducted, Equation (8) is used to calculate the fissure density.
Figure 4. Fissure density calculation schematic diagram

\[
\delta_{fa} = \frac{N_1}{\pi\left(\frac{N_1 + N_2}{4}\right)} \times 100
\]

The calculation method of the actual area of the fissure \((A_s)\) on the sample can be calculated based on Equation (1) and Equation (8), as shown in Equation (9).

\[
A_s = A_2 \delta_{fa} = \frac{d^2 N_1}{\pi\left(\frac{N_1 + N_2}{4}\right)}
\]

Where \(A_2\) is the area of square in figure 4, \(d\) is the actual diameter of sample (unit mm).

4. Application of crack density calculation method based on Visual Basic

The brightness threshold \(T\) is very important in converting colour image to black-white image. Taking a fissure image of red clay soil sample after 6 dry-wet cycles as an example (see Figure 2), the first step is threshold selection. Too small \(T\) will cause the fissures to not be fully reflected (see Figure 5 a), and too large \(T\) will cause some non-fissure area to appear black (see Figure 5 b). A black-white image obtained when the brightness threshold \(T\) is set to 151 (see Figure 3), where the black portion can properly represent the fissures area. By comparing Figure 2 with Figure 3, the black part can better represent the distribution of fissures on the sample surface.

(a) The image when \(T\) is too small        (b) The image when \(T\) is too large

Figure 5. \(T\) value influence

Base on the Visual Basic programming, the fissure density of the soil sample in Figure 2 is obtained and which is 13.93%. The diameter of the sample is 152mm, and the actual fissure area is
3211.5 mm². If the image of each dry-wet cycle is counted according to this method, the variation of fissure density with the number of dry-wet cycles will be obtained.

5. Conclusions
Through the methods and practices, the following conclusions can be drawn:

- When using visual basic to convert colour image into black-white image, the threshold $T$ value plays an important role. Appropriate $T$ value only by trial calculation and comparison can be determined, and base on which the black part can better represent the distribution of fissures.
- By transforming the fissure area problem into the pixels statistical problem, the fissure density can be calculated, and the actual fissure area can be calculated conveniently by this proportion.

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