Discussion of the Generalized M-C Strength Criterion and Granite Three-axis Test

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Abstract. To verify the applicability and accuracy of the generalized M-C strength criterion, the glorious three-axis experimental data is used to calculate and verify the adherence and accuracy of the geotechnical material strength criteria. Experimental data comparison found: (1) the average error of the M-C strength standard = 0.17, and the average error of the general M-C strength criteria is lower. (2) broadly M-C strength criteria are equal to the root errors, and the broader M-C strength standard is lower. In summary, the accuracy of the broader M-C strength criteria for the applicability of geotechnical materials is better than the M-C strength criteria, which can be used for the calculation of the strength of geotechnical engineering.

Keywords: Strength criteria; M-C strength standard; Broad M-C strength criterion; Tri-axis test

1 Introduction

The accuracy of finite element analysis in geotechnical engineering is determined by its chosen strength theory. The M-C strength criterion considers the effects of maximum and minimum principal stresses on the material but does not consider the effects of intermediate principal stresses, which may not conform to the principle of the conservation of energy [1-4]. To solve these problems, this paper revises the generalized M-C.

Based on the broader M-C strength criteria of the first law of thermodynamics [5-7], the accuracy is relatively high, and it is more in line with the theory of energy conservation.

At this stage, many scholars have conducted related research on M-C amendments, such as Jiang et al. [8] modifying the π-plagiarism function of the broad M-C strength standards and using the Willian-WarNKE elliptical corner model point. It can directly embed the numerical software and improve the calculation accuracy. Based on the MOHR-COULOMB criteria, Deng et al. [9] introduce the Rhodes angle parameters and

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the Mohr-Coulomb standard graphic strain Mises standard, which derives the main stress formula of the material yielding under the plane strain conditions.

2 The generalized M-C strength criterion

The relationship between the soil is equivalent to the reaction law of the stress and the strain under the stress of the geotech and soil. However, in the conventional model and the various same-sex materials in geotechnical engineering, the strength criteria of same-sex dynamics can be represented by a unified expression (1).

$$\sqrt{J_2}=f\left(I_1,J_3,K_1,K_2,K_3...\right) \tag{1}$$

where I_1 is the first uninvited stress tension, J_3 is the third non-variable stress bias, and K_1、K_2、K_3 are the material parameters.

The M-C model is widely used, and it is more commonly used in most parts of the country. Many of the deepenings of this structure are deepened by the M-C structure, forming a modified M-C. The expression of the M-C strength guidelines is:

$$\sqrt{J_2}=\frac{(\frac{I_1\sin\varphi}{3}+c\cos\varphi)}{\cos\theta_\sigma+\frac{\sin\theta_\sigma\sin\varphi}{\sqrt{3}}} \tag{2}$$

where c and φ are the adhesive and internal friction angles of the material, respectively, which are determined by the M-C strength standard, and θ_σ is Rhodes.

The M-C model is reasonably expanded, and the general M-C model is used. The expression of the strength guidelines is:

$$\sqrt{J_{2g}}=\sqrt{J_2-\frac{1-2v}{3}I_2}=\frac{(\frac{I_1\sin\varphi}{3}+c\cos\varphi)}{\cos\theta_\sigma+\frac{\sin\theta_\sigma\sin\varphi}{\sqrt{3}}} \tag{3}$$

To fit the pine ratio, different from Ponsonby, the calculations are mainly obtained through the test data. Details can be seen in previous studies.

3 Granite three-axis test data verification

Calculating the strength and practical formula of the M-C model and the broad M-C model is effective in calculating the rock. This calculation is proposed to use the granite true three-axis test data, and the M-C strength standards and the broad M-C strength criteria are calculated. The theoretical value is compared with the actual test value.

The maximum primary stress is calculated according to Formula (4), and the elastic modulus E and Poson ratio (5) and (6) of the test parts in the three-axis stress state are calculated.

$$\sigma_1 = \frac{P}{A} \tag{4}$$

$$E = \frac{(\Delta\sigma_1 + 2\Delta\sigma_3)(\Delta\sigma_1 - \Delta\sigma_3)}{\Delta\sigma_3(\Delta\varepsilon_1 - 2\Delta\varepsilon_3) + \Delta\varepsilon_1\Delta\sigma_1} \tag{5}$$

$$\mu = \frac{3\Delta\varepsilon_1 - \Delta\sigma_1\Delta\varepsilon_3}{(\Delta\sigma_1 + \Delta\sigma_3)\Delta\varepsilon_1 - 2\Delta\sigma_3\Delta\varepsilon_3} \tag{6}$$

where P and A are the standard specimen limit load and area of the section, and σ is yield stress. The literature studied granite to yield and destroy the law under high-stress conditions and launched a true three-axis test, including granite-tested rock blocks, granite density, and average longitudinal waves.

In the true three-axis test environment, the experiment is performed on the strength yield test, and the strength of the strength yield is obtained. At the same time, the characteristic points calculate the main force value, adhesion, and friction angle of the geotechnical parameter. Obstacifically damaged conditions to terminate.

Table 1 shows the correction of the true three-axis test data. Taking the maximum primary stress as the vertical coordinate and the minimum main stress as the horizontal coordinates, the test data is drawn to the right-angle coordinate system, and the minimum daily method is used to draw the curve. The values in the function can be obtained by Formulas (7) and (8).

$$c = \frac{b(1-\sin\varphi)}{2\cos\varphi} \tag{7}$$

$$\varphi = \arcsin\frac{k-1}{k+1} \tag{8}$$

The curve slope in the first function is K, and the intercept of the one function on the vertical axis is B. The linear function is shown in formula (9). Curve fitting is shown in figure 1.

$$y = 7.83x + 258.23 \ (R^2 = 0.989) \tag{9}$$

Table 1. Granite triaxial test data fitting adhesion and friction angle

σ_1 / MPa	σ_2 / MPa	σ_3 / MPa	c / MPa	φ
327	10	10	46.14	50.67
512	30	30	46.14	50.67
640	50	50	46.14	50.67

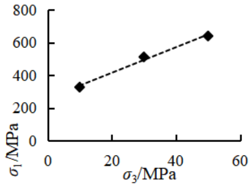

Fig. 1. Granite fit c and φ

The true triaxial test data were divided into two groups. The σ_2、 σ_3 and c, φ in the three-axis experimental data can calculate the first and second sets of data (the maximum main stress of the theoretical calculation of the i-i sample), respectively, it can be seen that Equation 10. We calculate the optimal fitting pine ratio of the corresponding first and second groups, ν_1=0.55 , ν_2=0.62 . We list the GM-C calculation value, M-C calculation value, and three-axis test values in Tables 2 and 3.

$$\sigma_1 = \sigma_3 \tan^2(45° + \frac{\varphi}{2}) + 2c \cdot \tan(45° + \frac{\varphi}{2}) \tag{10}$$

Table 2. Granite true three-axis test data first group

σ_1	σ_2	σ_3	M-C	GM-C
327	10	10	337	345
370	50	10	337	367
394	100	10	337	402
428	150	10	337	443
512	30	30	493	519
537	50	30	493	530
596	100	30	493	564
587	150	30	493	602
640	50	50	650	694
732	100	50	650	726
780	150	50	650	762

Table 3. Granite true three-axis test data second group

σ_1	σ_2	σ_3	M-C	GM-C
421	200	10	337	402
422	250	10	337	421
624	200	30	493	559
625	250	30	493	580
653	300	30	493	601
668	350	30	493	621
650	400	30	493	641
656	450	30	493	659
626	500	30	493	676
770	500	50	650	841

4 Test data verification error

After calculating the maximum primary stress according to the M-C strength criteria, the average error and average square root error are calculated separately (Table 4). The average errors and average square root errors can be calculated from Formulas (11), (12), and (13).

$$\Delta\chi_i = \frac{\sigma_{Ti} - \sigma_{CTi}}{\sigma_{Ti}} \times 100\% \tag{9}$$

$$\overline{\Delta\chi_i} = \frac{\sum_{j=1}^{n_i} |\Delta\chi_i|}{n_i} \quad (i=1,2,3) \tag{10}$$

$$\eta = \sqrt{\frac{\sum_i (\sigma_{Ti} - \sigma_{CTi})^2}{n}} \tag{11}$$

$\overline{\Delta\chi_i}$ in the formula is the calculation error of the theoretical value of the sample and the test value; $\overline{\Delta\chi_i}$ is the average value of the calculation error of the first sample theoretical value and the test value; σ_{Ti} is the maximum main force value of the three-axis test; σ_{CTi} is the maximum main stress calculated by different strength guidelines; η is the equalized square error root.

Table 4. The average root error and average error of the granite true three-axis test

	M-C	GM-C
$\overline{\Delta\chi_i}/\%$	16.76	4.99
η/MPa	116	39

The test data, M-C calculation data, and GM-C calculation data in Tables 3 and 4 are shown by scatter points and curves in Figures 2 and 3 respectively. The calculation results show that the $\overline{\Delta\chi_i}$ calculated by GM-C is 5%, far less than 17% of M-C, and η =39 of GM-C, far less than 116 of M-C, all achieving convergence of about 3 times. It is more accurate and reliable, and GM-C is more true and reasonable than M-C in the process of isotropic rock-soil constitutive calculation.

In summary, according to the results of the average root error and the average error result, it can be obvious. The broad M-C strength criteria on the granite true three-axis test data fix higher accuracy.

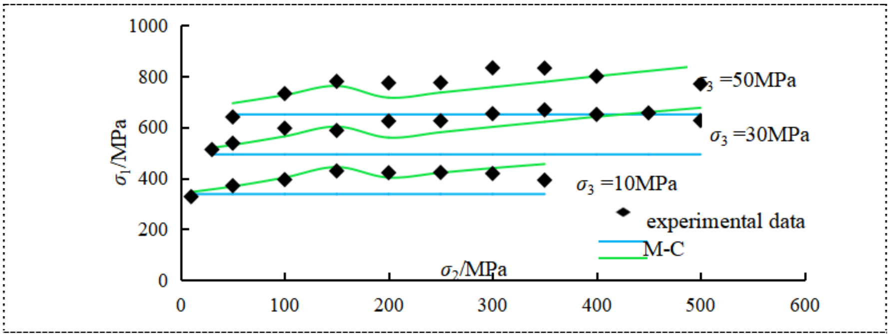

Fig. 2. Granite true three-axis test data and GM-C theoretical calculation value

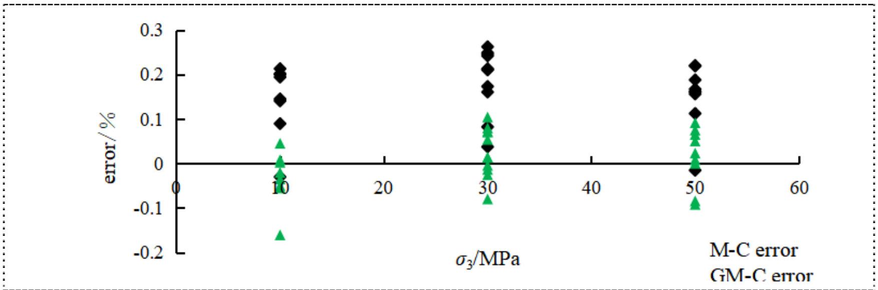

Fig. 3. Granite true three-axis test data GM-C and M-C calculation error

5 Conclusion

For the problem of the strength guidelines of M-C in this configuration, the average error is calculated with a large average error and a large amount of errors. This study specifically studies the content of this part. At the same time, the true three-axis test instrument is used. The more reasonable broad M-C strength guidelines are, the specific conclusions are:

According to the granite true three-axis test data, the accuracy of the broad M-C strength criteria is verified and compared with the accuracy of the M-C strength criteria. The average error of the M-C strength guidelines is $\overline{\Delta\chi_i}$ = 0.17 and the average root error η = 116; the average error of the broad M-C strength guidelines $\overline{\Delta\chi_i}=0.05$ and the average square root error $\eta=39$. The broad M-C strength criteria can be better applied to the maximum main stress and high accuracy. In summary, the generalized M-C strength criterion can be more accurate and superior in the application of geotechnical engineering and has higher application value.

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