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Experimental Investigation and Sensitivity Analysis for the Effects of Fracture Parameters to the Conductance Properties of Laterite

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***Abstract*—**This experiment discusses the effects of fracture parameters such as depth, length, width, angle and the number of the fracture to the conductance properties of laterite using the DUK-2B digital electrical measurement system combined with the method of simulating the fractures. The results of experiment show that the changes of fracture parameters produce effects to the conductance properties of laterite. There is a clear degressive period of the conductivity of laterite during increasing the depth, length, width, or the angle and the quantity of fracture gradually. When the depth of fracture exceeds the half thickness of the soil body, the conductivity of laterite shows evidently non-linear diminishing pattern and the amplitude of decrease tends to increase. The length of fracture has fewer effects than the depth to the conductivity. When the width of fracture reaches some fixed values, the change of the conductivity is less sensitive to the change of the width, and at this time, the conductivity of laterite maintains at a stable level. When the angle of fracture is less than 45°, the decrease of the conductivity is more clearly as the angle increases. But when angle is more than 45°, change of the conductivity is relatively gentle as the angle increases. The increasing quantity of the fracture causes the other fracture parameters having great impact on the change of conductivity. When moisture content and temperature were unchanged, depth and angle of fractures are the major factors affecting the conductivity of laterite soil; quantity, length, and width are minor influencing factors. The sensitivity of fracture parameters affect conductivity of laterite soil is: depth >angles >quantity >length >width.

***Keywords*—**laterite, fracture parameters, conductance properties, conductivity, uniform design, sensitivity analysis

I. Introduction

THE geo-materials in nature have different electrical properties due to the factors, such as kinds, composition, structure, moisture content and temperature are different. The electrical prospecting is used to identify the parameters of geo-materials based on the differences of electrical properties, from which an evaluation can be given to the fundamental characteristics of geo-materials. The resistivity method is one of the most important testing technologies in electrical prospecting. Since Archie [1] (1942) used resistivity method to study the relation between the resistivity and structure of saturated cohesionless soil and pure sandstones, many scholars have done beneficial attempts using resistivity theory on geotechnical engineering, such as physical and mechanical properties [2, 3], characteristics of soil and groundwater pollution [4, 5], improvement and strengthening of soil [6, 7], sand liquefaction [8] and microstructure of soil [9, 10].

The electrical conductivity of soil is mainly composed of soil particles surface conductivity and pore water conductivity, therefore, the resistivity of soil is closely related to the adsorption property of the ion on the surface of soil particles and the connection between soil particles. It is considered that the pore water, soil particles and soil structure determine the resistivity of soil. Due to the resistivity of soil is not only related to the mineral composition of soil particles, moisture content, saturation and the electrical conductivity of pore solution, but also related to the structure of pore within the soil. The results of many scholars are mainly concentrated on the research of moisture content, saturation, the electrical conductivity of pore solution and temperature, etc [1-3]. Preliminary experimental investigation for the effects of the microstructure characteristics of soil to the resistivity has been done also [9, 10], but most of them are confined to the effects of void ratio or porosity ratio to the resistivity. For the clay with fracture developing, the development of fracture which has a cutting function to the soil changes the microstructure characteristics of soil and produces noticeable effects to the intensity index and conductance properties of soil. Therefore, it will be of great importance to do the research on the effects of fracture parameters to the strength index and conductance properties of the soil.

Laterite is a kind of special soils which is widely distributed in Guizhou, Guangxi, Yunnan, Hunan and other provinces of China [11, 12].Because of the effects of climate change, laterite is under the action of dry-wet circulation which leads to the widespread development of fracture. The fractures not only damage the integrity of the soil and reduce the strength of soil which have bad effects to the stabilization and stress conditions of soil, but also open up channels for the deep soil to loss water and lead to the contraction of deep soil and then the original

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fractures will have a further development. At the same time, the fractures also cause the surface water infiltrating into ground easily. When the dried and contractive laterite is immersed in water again, it will easily get soaked and disintegrate causing problems such as slope instability. Actually, the development of soil fracture is an important precondition to the slope instability [13]. Based on the above, this paper systemically researches the effects of fracture parameters to the conductance properties of laterite through the artificial fracture experiments combining the resistivity testing method.

II. THE CONDUCTANCE PROPERTIES OF LATERITE

Soil is a kind of porous medium which is composed of solid framework, pore and the fluid filling inside the pore. The content of viscous particles in the solid framework of laterite is extremely high. The main mineral compositions of viscous particles are kaolinite and illite. These viscous particles have a negative charge through all kinds of adsorption. Under the effects of electrostatic attraction, the viscous particles will adsorb the cationic in the pore solution to their surface which causes the soil particles possessing conductance properties. The main content of the pore in the soil is air and water. Because the air conducts electricity far weaker than the water, the characteristic of pore water is considered only. Furthermore, the microstructure characteristics of connection between particles are also closely related to the conductance properties of soil. Therefore, it is considered that the soil particles, pore water and structure determine the conductance properties of soil together.

The resistivity of soil ρ is a measure of the conductive ability of the soil which is defined as the resistance of conductor with a unit of length and cross-sectional area. It is one of the soil intrinsic basic physical parameter. The reciprocal of it is the electrical conductivity σ, as shown in formula (1), (2).

$$\rho = RA/L \quad (1)$$

$$\sigma = 1/\rho \quad (2)$$

Where L (m) stands for the length of soil, A (m^2) the cross-sectional area of soil, R (Ω) the resistance of soil, ρ ($\Omega \cdot m$) the resistivity of soil and σ ($\Omega^{-1} \cdot m^{-1}$) the conductivity of soil.

The resistivity testing includes two aspects: in situ and indoor. They use the same testing principle. The current lines and current equipotent lines are shown in Fig.1, A and B are the power supplying electrodes, M and N are the measuring electrodes. When power is supplied by A and B electrodes, the supply current and potential difference between the M&N electrodes can be measured and then the resistivity can be calculated as shown in formula(3).

$$\rho = K\Delta V / I \quad (3)$$

Where ΔV stands for the potential difference between the measuring electrodes (mV), I the current intensity of circuit (mA), K the devices coefficient which is related to the distance between the power supply electrodes and measuring electrodes (m).

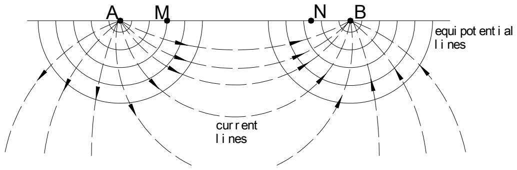

Fig.1 Electric fields of the electrical conductivity test

III. PROJECT BACKGROUND AND EXPERIMENTAL METHOD

A. Project background

At the Chenzhou sector of the highway from Xiamen to Chengdu (two cities of china) distributes a great amount of hard plastic to plastic laterite, mainly contained in the eroded valleys and slopes and featured with the upper in hard and the lower in soft and the thickness fluctuating drastically with the surface of underlying bedrock. Because of the effects of alternate humid and heat weather, the fractures of laterite developed in general under the dry-wet circulation of repeated water uptake and loss. The earth surface formed with vertical fractures, closing down gradually into the mesh shape. The surface of the fractures, generally smooth but with scratches, was tainted with materials of ferro and manganese or was filled with organic film. These fractures, on the one hand, destroyed the integrality of soil to the detriment of the intensity of soil, on the other hand, prompted the soil to contract and hence further fracturing. In raining days, surface water permeates downward through these fractures and causes the pore water pressure of soil increasing greatly, accelerating the partial slipping and leading to the problem of slope instability, as shown in Fig.2.

(a) (b)

(a)Fractures of laterite
(b) Shallow layer Landslide due to the dry-wet circulation
Fig. 2 Common problems of fracturing laterite

B. The basic physical property index of laterite

The soil samples of laterite were taken from the Chenzhou sector of the highway from Xiamen to Chengdu, tested based on Chinese code for the Test Method of Soils for Highway Engineering (JTG E40-2007)for the basic physical property index. The results were listed in Table I. According to the plasticity graph of special soil, the sample soil could be judged as MHR, namely high liquid limit laterite, after calculated as below line A and w_L >55%.

TABLE I
THE BASIC PHYSICAL PROPERTY INDEX OF LATERITE

Items		Value
Grain composition	0.074mm-0.005mm	68%
	<0.005mm	32%
Specific gravity		2.75
Liquid limit w_L (%)		65.15
Plastic limit w_P (%)		34.69
Plasticity index I_p		30.46
Optimum moisture content w_{opt} (%)		23.22
Maximum dry density(ρ_d / $g□cm^{-3}$)		1.656

C. The preparation of experiment

The saturated sample of laterite, 10cm in height, is put into an insulating cuboid vessel of glass, 30 cm internal length and 15cm in internal height. Copper electrodes with the uniform standard with dimension of 5cm×4cm×3cm are used. To make sure the better contact with the sample, copper electrodes set with 4 apertures 2mm in diameter, are arranged by way of four points. As shown in Fig.3. A&B are the power supplying electrodes, and M&N are the measuring electrodes. A&M electrodes and B&N electrodes are of 4cm in between and all the electrodes buried with the same depth. DUK-2B digital electrical measurement system is used to measure the conductivity. A&B are supplied by stable power source and the above design is able to measure out the voltage drop between M&N. The circuit diagram is shown in Fig.4. Use the artificial fracture made by pieces of insulative glass to simulate different fracture parameters. During this course, due to the short duration of test, the effects of moisture content and the temperature changes of laterite to the conductivity can be ignored, leading to the influence law of varying fracture length, fracture width, fracture depth, fracture distribution and the number of fractures on the conductivity of laterite.

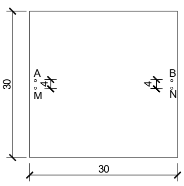

Fig. 3 Four electrodes layout

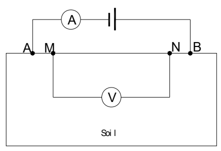

Fig. 4 The circuit diagram

To ensure the accuracy of experiment, the voltage of A and B electrodes should be kept stable. Upon tested, as shown in Fig.5, the deviation of the voltage measured during the experiment is below 0.01%, meeting the demand of experiment.

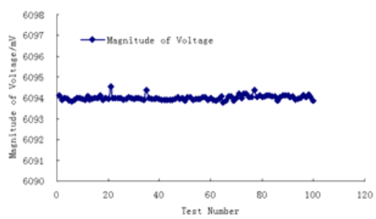

Fig .5 the distribution graph of measured voltage value

The layout of fractures is shown in Fig.6 to Fig.9, with cm as the scale, 0 degrees for fracture angle running parallel with A&B electrode line and 90 degrees for fracture angle perpendicular to A&B electrode line.

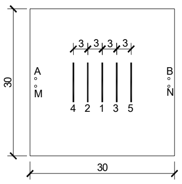

Fig.6 Layout of fractures (1)

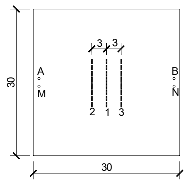

Fig.7 Layout of fractures (2)

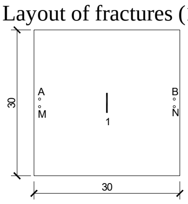

Fig. 8 Layout of fractures (3)

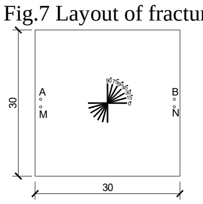

Fig.9 Layout of fractures (4)

IV. THE EFFECTS OF FRACTURE PARAMETERS TO THE CONDUCTANCE PROPERTIES OF LATERITE

A. The influence of the depth of fractures

To consider about the influence that the depth of the fracture has on the conductance properties of laterite, seven different fracture depths are used to test (8 cm in length, 0.4cm in width, at angle of 90°), the experiment steps are as follows: five parallel samples are set up and the setting of fractures are showed in Fig.6, the depth increases from 1cm to 7cm. The voltage and the electric current are tested three times when the depth adds 1cm. The conductivity is calculated by the average value of voltage and current. The parallel samples are set and numbered as Table II shows. As the initial conductivity of every experiment is not exactly the same, the conductivity data tested in experiments are normalized, that is, analyzing the ratios of tested conductivity and initial ones, to better embody how the fracture depths affect the conductivity of laterite. And the relation of the ratios and depths are shown in Fig.13.

TABLE II
THE FRACTURES LAYOUT AND NUMBERS

No. of the sample	layout of fractures	No. of the fracture	Depth range /cm
$d-1$	(1)	1	1-7
$d-2$	(1)	1,2	1-7
$d-3$	(1)	1,2,3	1-7
$d-4$	(1)	1,2,3,4	1-7
$d-5$	(1)	1,2,3,4,5	1-7

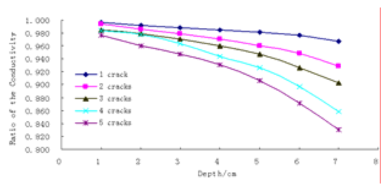

Fig. 10 The ratio of conductivity related to the depth of the fracture

As Fig.10 shows, the influence that depths have on conductivity is relatively large, that is, the deeper the fracture is, and the smaller the conductivity goes. Take the three-fracture sample as an example, the conductivity respectively decreases by 1.50%, 2.15%, 2.96%, 3.94%, 5.27%, 7.39%, 9.65% compared with no fracture situation as the depths increase. Because of the fractures emerging in the soil body, the current is blocked between two electrodes which causing the resistance value increases and the conduct capability decreases. And we can also see the conductivity is basically linear diminishing with increasing depth when it comes below 4 cm. When the depth goes deeper than 4 cm, the decrease of conductivity shows evidently non-linear diminishing pattern and the amplitude of decrease tends to increase. The reason of this atmosphere is that though the fractures which are shallow (8 cm in length, at an angle of 90°) block the electric current in some certain sense; they make more current conduct from electrode A to B through the bottom of the soil body forming a circuit. The conductivity ratios at this situation are linear to the depth of the fractures. When the depth exceeds the half thickness of the body, the existence of the fractures cuts too more current and the thickness of soil under the bottom of the fracture gradually decreases causing the effect fractures do to the conductivity is evidently increasing.

B. The influence of the length of the fractures

To consider about the influence that the length of the fracture has on the conductance properties of laterite, seven different fracture lengths are used to test (1 cm in depth, 0.4cm in width, at an angle of 90°), the experiment steps are as follows: Three parallel samples are set up and the setting of fractures are showed in Fig.7, the length increases from 2cm to 14cm. The voltage and the electric current are tested three times when the length adds 2cm. The conductivity is calculated by the average value of voltage and current. The parallel samples are set and numbered as Table V shows.

TABLE V
THE FRACTURES LAYOUT AND NUMBERS

No. of the sample	layout of fractures	No. of the fracture	Length range /cm
$l-1$	(2)	1	2-14
$l-2$	(2)	1,2	2-14
$l-3$	(2)	1,2,3	2-14

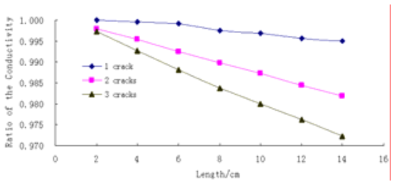

Fig. 11 The conductivity related to the length of the fracture

Fig.11 shows about the experiment curve graph of how the change of the length affects the conductivity. As it can be seen that the conductivity of laterite is decreasing as the length increases. Also take the three-fracture sample as an example, the conductivity decreases by 0.28%, 0.72%, 1.19%, 1.63%, 2.01%, 2.37%, 2.78% compared with the no-fracture situation as the length increases which is evidently in a linear pattern. It can be found that the 2 cm adding in length effects less than that in depth also.

C. The influence of the width of the fracture

To consider about the influence that the width of the fracture has on the conductance properties of laterite, eight different fracture widths are used to test (4 cm in depth, at an angle of 90°), the experiment steps are as follows: three parallel samples are set up and the setting of fractures are showed in Fig.8, The width increases from 2cm to 14cm. The voltage and the electric current are tested three times when the width adds 2 cm. The conductivity is calculated by the average value of voltage and current. The parallel samples are set and numbered as Table IV shows.

TABLE IV
THE FRACTURES LAYOUT AND NUMBERS

No. of the sample	layout of fractures	No. of the fracture	Length /cm	Width range /cm
$w-1$	(3)	1	2	2-14
$w-2$	(3)	1	4	2-14
$w-3$	(3)	1	8	2-14

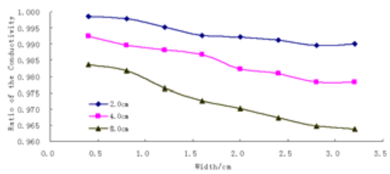

Fig. 12 The conductivity related to the width of the fracture

Fig.12 shows about the experiment curve graph of how the change of the width affects the conductivity. As it can be seen that the conductivity of laterite is decreasing as the length increases. Take the $w-2$ as example, the conductivity decreases by 0.75%, 1.03%, 1.17%, 1.34%, 1.77%, 1.91%, 2.17%, 2.17% compared with the no-fracture situation as the width increases. When the width reaches some fixed values, the change of the conductivity is relatively not sensitive to the change of the width. At the moment, the conductivity of laterite is basically maintaining stable when the width continues to increase.

D. The influence of the angle of the fractures

To consider about the influence that the angle of the fracture has on the conductance properties of laterite, seven different fracture angles are used to test (8 cm in length and 0.4 cm in width), the experiment steps are as follows: seven parallel samples are set up and the setting of fractures are showed in Fig.9, the angle of the fracture is set up as 0° first, then make the depth increases from 1cm to 5cm. Then the voltage and the electric current are tested three times when the depth adds 1cm. The conductivity is calculated by the average value of voltage and current. The other 6 parallel samples are set and numbered as Fig.9 shows, the angle of each fracture is set up as 15°, 30°, 45°, 60°, 75° and 90°, and the setting of the depth is the same with the fracture at the angle of 0°as Tab.V shows. The ratios of conductivity related to the angles are displayed in Fig.13.

TABLE V
THE FRACTURES LAYOUT AND NUMBERS

No. of the sample	layout of fractures	No. of the fracture	Width/cm	Angle/°
$a-1$	(4)	1	1,2,3,4,5	0
$a-2$	(4)	1	1,2,3,4,5	15
$a-3$	(4)	1	1,2,3,4,5	30
$a-4$	(4)	1	1,2,3,4,5	45
$a-5$	(4)	1	1,2,3,4,5	60
$a-6$	(4)	1	1,2,3,4,5	75
$a-7$	(4)	1	1,2,3,4,5	90

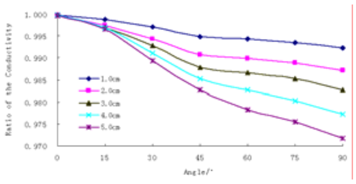

Fig. 13 The conductivity related to the angle of the fracture

As it can be seen that the conductivity is decreasing as the angles increase from Fig.13. And when the angle comes to 45° , the conductivity shows an evident turning point. That is, as the angle is less that 45°, the absolute value of the slope of the ratios and the angles is relatively large and the decrease of the conductivity is more clearly as the angle increases. On the contrary, when the angle is more than 45°, the absolute value of the slope of the ratios and the angles is relatively small and the change of the conductivity is relatively gentle as the angle increase. This is because the current lines are parallel to the fractures which causes no cutting when the fractures are set parallel to the line of A&B electrodes at the angle of 0° making no difference of the conductivity properties of laterite. At this situation, the ratio of conductivity approximates 1. When the angle increases, the fractures gradually cut the current line making more and more changing in the conductance properties of laterite. And the influence goes the most at the angle of 90° which means the setting of the fractures is absolutely vertical to the line of A&B.

E. The influence that the number of the fractures has on the conductance properties of laterite

As it can be seen from the experiment above, the conductivity properties are not only related to the depth and the length of the fractures, but also affected a lot by the number of the fractures. Fig.10 & Fig.11 show that the adding of the number makes a huge increase of the conductivity. The ratios of the conductivity related to the number of the fractures (8cm in length, 0.4cm in width, at the angle of 90°) are shown in Fig.14.

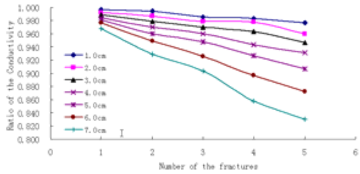

Fig. 14 The conductivity related to the number of the fracture

Fig.14 shows that the increasing of the fracture number causes the decrease of the conductivity of laterite. Take the 4cm in length-fracture as an example, the conductivity decreases by 1.54%, 2.96%, 3.94%, 5.63%, 6.93% compared with the no-fracture situation as the width increases which basically in a linear pattern. The reason that the increasing numbers cause the decrease of the conductivity is because the situation makes the current moving between A & B electrodes more difficult. As the fracture goes deeper, the number of the fractures affects more on the conductivity of laterite.

V. SENSITIVITY ANALYSIS FOR THE EFFECTS OF FRACTURE PARAMETERS

Fang Kaitai and Wang Yuan[14] (1978) proposed uniform design method based on uniform distribution in number theory: finding the set of points spread evenly in space with a deterministic method to replace the random number of Monte Carlo method. For test with m factors, each factor with n levels, the number of selected test points is only n, which means the amount of work may be reduced, all possible combinations of tests may be controlled. The advantage is: representative test points are generated in test range and distributed in test space, following the regression design ideas and not requiring excessive assumptions on models, stabilized with the change of models, test times increasing continually along with the increase of the levels. With this method, one factor may be arranged the most levels among all test designs. This design method has been involved in aerospace, chemistry, civil engineering and petrochemistry, remarkable achievements have been reached [15-18].

A. Test method

Analysis for sensitivity of conductivity of laterite soil to fracture parameters based on uniform design mainly includes the following contents: (1) Determination of test parameters. The conductivity of laterite soil is commonly measured by resistivity or specific conductance, in this paper, normalized specific conductance was the test index. (2) Selection of test factors. Factors such as depth, length, width, angle and the number of fractures were taken into consideration. (3) Determination of levels of factors. Numeric range of all factors based on test conditions was determined, shown as Table VI. (4) Selection of uniform tables and its corresponding control tables, arrangement of the test. To facilitate results statistics, test times took 2 times the number of factors, i.e. 10 levels. It was found out that minimum discrepancy of $U_{10}^{*}(U_{10}^{8})$ is 0.2414. The uniform design table and its corresponding table are shown as Table VII and Table VIII. (5) Modeling and combined calculation. Values of uniform design and test results are shown as Table IX. (6) Test results analysis. Regression analysis was used to analyze the test results.

TABLE VI
NUMERIC RANGE OF FRACTURE PARAMETERS

Depth /cm	Width /cm	Length /cm	angle /°	Quantity
1.0-10.0	0.4-4.0	2.0-20.0	0-90	1-10

TABLE VII
UNIFORM DESIGN TABLE

	1	2	3	4	5	6	7	8
1	1	2	3	4	5	7	9	10
2	2	4	6	8	10	3	7	9
3	3	6	9	1	4	10	5	8
4	4	8	1	5	9	6	3	7
5	5	10	4	9	3	2	1	6
6	6	1	7	2	8	9	10	5
7	7	3	10	6	2	5	8	4
8	8	5	2	10	7	1	6	3
9	9	7	5	3	1	8	4	2
10	10	9	8	7	6	4	2	1

TABLE VIII
CORRESPONDING TABLE OF $U_{10}^{*}(U_{10}^{8})$

Factors	1	2	3	4	5	6	Discrepancy
2	1	6					0.1125
3	1	5	6				0.1681
4	1	3	4	5			0.2236
5	1	3	4	5	7		0.2414
6	1	2	3	5	6	8	0.2994

TABLE IX
UNIFORM DESIGN TEST FOR EFFECTS OF FRACTURES PARAMETERS AND CONDUCTIVITY RATIO OBSERVATION

Test number	Depth /cm	Width /cm	Length /cm	Angle /°	Quantity	Specific conductance
1	1.0	1.2	8.0	40	7	0.988
2	2.0	2.4	16.0	90	9	0.957
3	3.0	3.6	2.0	30	5	0.992
4	4.0	0.4	10.0	80	3	0.975
5	5.0	1.6	18.0	20	1	0.990
6	6.0	2.8	4.0	70	10	0.930
7	7.0	4.0	12.0	10	8	0.955
8	8.0	0.8	20.0	60	6	0.921
9	9.0	2.0	6.0	0	4	0.991
10	10.0	3.2	14.0	50	2	0.919

B. Multiple regression analysis

Regression analysis is an effective tool in data analysis, it reveals the relationship among variables, for which it becomes the main analysis method in data analysis in uniform design. Multi regression model was used in this paper based on the 10 levels test, backward method was employed in regression analysis, significance level $\alpha = 0.05$, and the planned regression equation is:

$$y = b_0 + b_1 \times d + b_2 \times w + b_3 \times l + b_4 \times a + b_5 \times n \quad (4)$$

Where, regression coefficients $b_0 = 1.07$, $b_1 = -7.30\times10^{-3}$, $b_2 = -5.13\times10^{-3}$, $b_3 = -1.22\times10^{-3}$, $b_4 = -6.19\times10^{-4}$, $b_5 = -3.04\times10^{-3}$, multiple correlation coefficient $R = 0.9446$, significance test was taken to the regression equation, with sample size $N = 10$, significance level $\alpha = 0.05$, confidence level 95%, test value $F_t = 6.631$, critical value $F(0.05,5,4) = 6.256$, $F_t > F(0.05,5,4)$, regression equation was significant. The variables analytical statement was shown as Table X.

TABLE VI
VARIABLES ANALYSIS TABLE

Source of variation	Sum of squares	Degree of freedom	Mean square	Mean square ratio
Regression	$U = 7.14\times10^{-3}$	$K = 5$	$U/K = 1.43\times10^{-3}$	$F = 6.631$
Residue	$Q = 8.61\times10^{-4}$	$N-1-K = 4$	$Q/(N-1-K)$ $= 2.15\times10^{-4}$	
Sum	$L = 8.00\times10^{-3}$	$N-1 = 9$		

The obtained regression coefficient F test value were: $F(1) = 15.06$, $F(2) = 1.053$, $F(3) = 1.742$, $F(4) = 9.572$, $F(5) = 2.312$, sum of squares of partial regression and contribution (descending ordered by sum of squares of partial regression) to regression of each equation are listed as Table XI.

TABLE VI
VARIABLES ANALYSIS TABLE

Sum of squares of partial regression $U(i)$	Contribution to regression of each equation
$U(1) = 3.24\times10^{-3}$	$U(1)/U = 45.4\%$
$U(4) = 2.06\times10^{-3}$	$U(4)/U = 28.9\%$
$U(5) = 4.98\times10^{-4}$	$U(5)/U = 6.98\%$
$U(3) = 3.75\times10^{-4}$	$U(3)/U = 5.25\%$
$U(2) = 2.27\times10^{-4}$	$U(2)/U = 3.18\%$

As be learned from the regression analysis results, if moisture content and other factors were unchanged, depth and distribution angle of fractures are the major factors affecting the conductivity of laterite soil, quantity, length, and width are minor influencing factors, in conclusion, the fracture parameters affect the sensitivity of conductivity of laterite soil by the sequence relationship of depth of fracture d >angles of fracture a >quantity of fracture n >length of fracture l >width of fracture w .

VI. Discussions

The main effects to the engineering properties of clay caused by the fractures are the development of the internal fractures and the infiltration and evaporation of the water while the researches of most scholars to the fractures are mainly concentrated on the morphological analysis of surface fracture at present, such as Dasog[18] measured the overall length of the internal fracture 1m^2 in area with a string on the scence, Ringrose-Voase[19] measured the surface fracture with a combination of six half rings 1m in diameter, YI Shun-ming[20] used the fractal geometry to quantify the spread and development of the surface fractures, TANG Chao-sheng [21] studied the relation between the desiccation fracture of clay and the temperature through the experiment and made a description and quantitative analysis to the characteristics of surface structure of the desiccation fracture of clay produced under different temperature, MA Jia [22] reproduced the process of the generation, spread and expansion of fracture under the dehydrated situation through the laboratory tests and the digital image processing.

The theories can not direct practice if it merely study on the surface fracture of clay. How to establish the function relations between development degree of inner fracture and strength index as soon as possible is the research orientation of the fracture of clay. CHEN Zheng-han [23] made some useful exploration on inner fracture of expansive soil using CT scanning technology. But CT scanning technology is comparatively expensive and unsuitable for field test also. Electrical prospecting is more economical which has gained more experience in both laboratory and field[1-10].This paper discusses the effects of fracture parameters to the change of conductivity by using an artificial fracture method, on the contrary, puts forward another way that monitors the change of conductivity through electrical principle and combines with the statistics of the morphological characteristics such as the number, angle, width, etc of the surface fracture, ascertaining the depth of fracture indirectly and evaluating the degree of development of fracture within the clay, and then describing the relation between the fracture development of clay and the engineering reaction quantificationally.

VII. Conclusions

This paper, regarding the typical laterite of Chenzhou, Hunan Province as the research object, by setting the artificial fracture combining with the conductivity test to explore the law of the influence of fracture parameters to the conductivity of laterite, has the following main conclusions:

(1) Fracture depth, fracture length, fracture width, fracture angle and the number of fractures all impact the conductivity properties of laterite. With the increasing of fracture depth, elongation of fracture length, expansion of fracture width and the growth of fracture angle and numbers, the conductivity of laterite basically showed obvious linear decline phase.

(2) When the depth of fracture goes deeper than half the thickness of the soil sample, the decrease of conductivity of laterite shows evidently non-linear diminishing pattern and the amplitude of decrease tends to increase. The effect to the conductivity caused by the length of fracture is less than that by the depth of fracture. When the width of fracture reaches some fixed values, the change of the conductivity of laterite is relatively not sensitive to the change of the width and basically maintaining stable. When the angle of fracture is less that 45°, the decrease of the conductivity is more clearly as the angle increases. On the contrary, when the angle is more than 45°, the change of the conductivity is relatively gentle as the angle increase. The increasing number of the fracture causes the other fracture parameters having great impact on the change of conductivity.

(3)To demonstrate the combined effects of various fracture parameters on conductivity, testing program with ideal uniformity was designed based on uniform design principle in this paper, additionally, multiple regression analysis method was employed to analyze the sensitivity of conductivity of laterite soil to various fracture parameters. Uniform design performs well in analyzing the sensitivity of conductivity of laterite soil to fracture parameters, besides incarnating the features of testing system, uniform design may effectively reduce test times.

(4) As moisture content and other factors were unchanged, depth and distribution angle of fractures are the major factors affecting the conductivity of laterite soil, quantity, length, and width are minor influencing factors, in conclusion, the fracture parameters affect the sensitivity of conductivity of laterite soil by the sequence relationship of depth of fracture d >angles of fracture a >quantity of fracture n >length of fracture l >width of fracture w

(5) Put forward another way that monitors the change of conductivity through electrical principle and combines with the statistics of the morphological characteristics such as the number, angle, width, etc of the surface fracture, ascertaining the depth of fracture indirectly and evaluating the degree of development of fracture within the clay, and then describing the relation between the fracture development of clay and the engineering reaction quantificationally.

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