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The Consolidation Coefficient of Soil Is Calculated by Programming Based on Time Logarithm Method

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Abstract. The characteristics and difficulties of the time logarithm method for calculating the coefficient of consolidation have been analyzed. The VBA programming method for calculating T50 and coefficient of consolidation have been designed. A convenient method for calculating T50 and coefficient of consolidation is presented. Through the analysis of consolidation test cases, the veracity and convenience of VBA programming method are illustrated. It provides a reliable method for calculating the coefficient of consolidation in consolidation test. At the same time, the advantages, disadvantages and applicability of time logarithm method and time square root method are analyzed. Time logarithm method requires higher quality of the tail of the curve, and time square root method requires higher quality of the initial section of the curve. It is suggested that the time logarithm method be used to solve the coefficient of consolidation for the initial data collection of the deformation-time curve. It is suggested that the time square root method be used to solve the consolidation coefficient for the unideal consolidation test data collection of the tail data of the deformation-time relation curve..

Keywords. Time logarithm method, consolidation coefficient, programming, consolidation test, time square root method

1. Introduction

Under the action of loading, the pore water in the soil is discharged continuously, the pore water pressure dissipates gradually, and the volume of the soil decreases gradually, which is called consolidation of the soil. The coefficient of consolidation is an important index to reflect the speed of soil consolidation and an important parameter in the design of soft soil foundation treatment, the choice of foundation treatment method, construction period, drainage well spacing, preloading and project cost are closely related to the consolidation coefficient [1]. The coefficient of consolidation can be obtained by laboratory consolidation tests, but there are many factors that affect the

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accuracy of the coefficient of consolidation, for example, whether the undisturbed soil samples are drilled on site, whether the soil samples are disturbed, the calibration and precision of instruments and equipment, etc. In addition, the calculation of coefficient of consolidation is also affected by the errors caused by personnel, data processing and calculation methods.

At present, there are many methods to solve the coefficient of consolidation, among which the time square root method and time logarithm method are the most commonly used, the reverse bending point method proposed by Cour [2], the three-point method proposed by Sivaram [3], the Scott Method [4], the ASAOKA method [5], the two-point method proposed by Prasad [6], the rate method proposed by Parkin [7], the standard curve analogy method proposed by Li Jinxuan [8] and the method proposed by Zhang Yiping [9] to reduce the initial section of the time deformation curve and the influence of subconsolidation, etc., these methods are mainly based on the consolidation theory and the characteristics of time-strain curve, the appropriate approximate simplification, to solve the calculation of the coefficient of soil consolidation. Different methods are used to solve the coefficient of consolidation, the results may be quite different, and the above methods also have their own scope of application and conditions [10].

The coefficient of consolidation can be measured by the consolidation test, but not directly, but by the time-dependent curve of the deformation of the soil sample under a certain level of pressure, the method of time square root or the method of time logarithm is used to calculate the coefficient of consolidation. These two methods are recommended by the code. The law of time logarithm needs to solve t50, that is, the time required for the degree of consolidation to reach 50%, and then calculate the coefficient of consolidation, but it is not so easy to solve t50 accurately and quickly. This paper mainly introduces how to use the time logarithm method to solve t50 and then calculate the coefficient of consolidation.

2. Introduction to the Log-time Method

According to the results of consolidation test, the relation curve between deformation and time under a certain stage pressure can be drawn. The log-time method, as one of the most commonly used methods recommended in the code, takes d (mm) of soil sample deformation scale as the longitudinal coordinate for the time deformation data of one stage pressure applied, lgt (min) is the horizontal coordinate, draw d-lgt curve. At the beginning of the d-lgt curve, at any time t_1, the corresponding deformation is d_1, then at time t_2, $t_2 = t_1$ 1/4, the corresponding deformation is d_2, then, $2d_2$-d_1 is d_{01}; d_{02}, d_{03}, d_{04} and so on, can be obtained, and their average values can be taken as the theoretical zero point d_s, which prolongs the relatively straight line segment L1 in the middle of the d-lgt curve, and the intersection point with the Tangent L2 of the number points passing through the tail of the curve is the theoretical end point d_{100}, $d_{50} = (d_s + d_{100})/2$, corresponding to the time of d_{50}, which is t50 when the degree of consolidation of soil samples reaches 50% , the coefficient of consolidation can be calculated according to Formula (1):

$$C_v = \frac{0.197\bar{h}^2}{t_{50}} \tag{1}$$

In order to calculate C_v, it is necessary to solve t_{50}. According to the definition of time logarithm method, it is necessary to draw the curve of the relationship between deformation and time logarithm, which is relatively simple, then we get the mean as the theoretical zero point d_s, but the theoretical end point d_{100} is not so easy to find, because the line segment L1 in the middle of the d-lgt curve and the tangent L2 through the number of points in the tail of the curve are not easy to find exactly. Therefore, t_{50} is difficult to obtain.

3. VBA Programming Accurate and Fast Solution t50

The difficulty of calculating the coefficient of consolidation by time logarithm method lies in drawing the straight lines L1 and L2, thus obtaining t_{50}. Using coordinate paper to draw d-lgt curve by hand, then draw straight lines L1 and L2, we can get t_{50}. By using VBA MACRO program built in Excel, the d-lgt curve and the straight lines L1 and L2 can be drawn. The realization of VBA programming method is mainly divided into five steps:

First, draw the d-lgt curve, according to the corresponding deformation results of consolidation test, d-lgt curve can be drawn directly by using the chart tool in Excel.

Second, the bubble method is used to find the data segment with the highest fitting degree of the straight line segment, and the straight line L1. For the normal consolidation test d-lgt curve, the bubble method is used to fit the straight line segment of L1 with a high fitting degree, fitting 5-7 points, the fitting coefficient can be more than 0.99, of course, the fewer the fitting points, the higher the fitting degree is, the higher the accuracy of the test data is required when the fitting points are small.

Third, after establishing the best fitting straight line segment, the slope and the longitudinal coordinate intercept d_s of the straight line are obtained through the built-in function linest, and then the linear L1 function equation is established. In the same way, the quadratic function coefficients of 3-4 points at the end of d-lgt curve are fitted by function linest, and the slope and intercept of tangent L2 are calculated by taking derivatives.

Fourth, according to the method of time logarithm, select any time t_1 on d-lgt curve, then find the corresponding deformation value d_1, then select time $t_2 = t_1$ 1/4, get the corresponding deformation d_2, then $2d_2$-d_1 is d_{01}; similarly, we can get d_{02}, d_{03}, d_{04}, and take their average as the theoretical zero point d_s.

Fifth, $d_{50} = (d_s + d_{100})/2$, the time corresponding to d_{50} is calculated by interpolation method, which is t_{50} when the degree of consolidation of soil samples reaches 50%. The above provides the principles and methods of programming, programming in other languages can be applied, here only the most common office software based on VBA programming example. The specific program codes are no longer detailed.

4. Application and Analysis of VBA Programming Method

4.1. Calculation of Coefficient of Consolidation

The physical properties of undisturbed soil samples after vacuum preloading foundation treatment in xuwei port, Lianyungang are shown in table 1, and the

deformation at 100 kPa and 200 kPa pressure at different time are shown in table 2 and table 3. According to the results of consolidation test, the d-lgt curve can be drawn directly by using the chart tool in Excel. The bubble method is used to find the data segment with the highest fitting degree of the straight line segment, and the straight line L1. Through the built-in function linest, the slope and the intercept of the Linear L1 are obtained, and the Linear L 1 function equation is established. In the same way, the quadratic function coefficients of 3-4 points at the end of d-lg something T curve are fitted by function linest, and the slope and intercept of Tangent L2 are calculated by taking derivatives. According to the requirement of time logarithm method, the curves drawn by VBA program are shown in figure 1 and figure 2. The time square root method can also be used to plot the curve and solve the coefficient of consolidation. The fitting curve is shown in figure 3 and figure 4.

Table 1. The basic physical indexes of selected soil samples.

w/%	ρ/g/cm^3	e	w_L/%	w_P/%	I_P	I_L	Classification of soils
37.9	1.85	1.042	44.2	21.4	22.8	0.72	clay

Table 2. The corresponding deformation of soil samples at each time (P=100kPa).

time/min	0	0.1	0.25	1	2.25	4	6.25	9	12.25	16
deformation /mm	0.442	0.470	0.482	0.505	0.528	0.548	0.567	0.587	0.608	0.629
time/min	20.25	25	30.25	36	42.25	49	64	100	200	400
deformation /mm	0.648	0.666	0.681	0.700	0.714	0.725	0.743	0.772	0.813	0.840

Table 3. The corresponding deformation of soil samples at each time (P=200kPa).

time/min	0	0.1	0.25	1	2.25	4	6.25	9	12.25	16
deformation /mm	0.840	0.904	0.924	0.963	1.000	1.035	1.068	1.099	1.130	1.160
time/min	20.25	25	30.25	36	42.25	49	64	100	200	400
deformation /mm	1.187	1.213	1.236	1.257	1.276	1.292	1.317	1.348	1.387	1.410

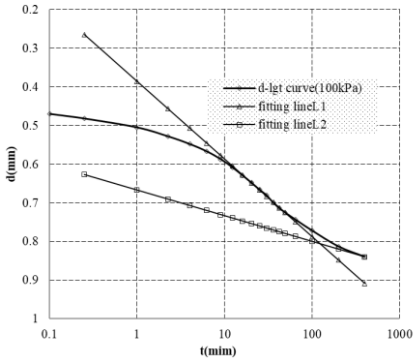

Figure 1. Fitting curves (P=100kPa).

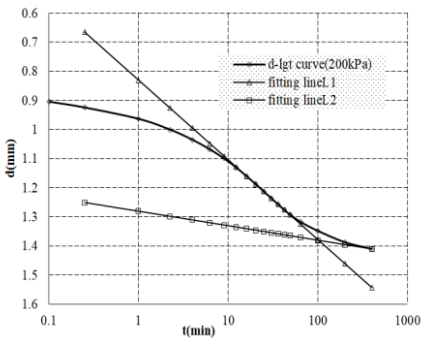

Figure 2. Fitting curves(P=200kPa).

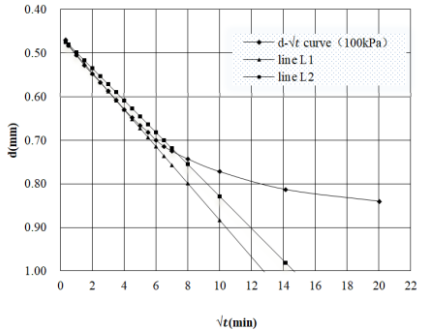

Figure 3. Time square root normal curve drawing (P=100kPa).

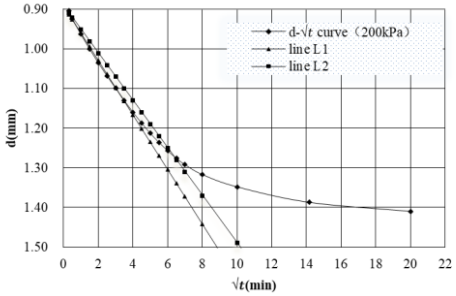

Figure 4. Time square root normal curve drawing (P=200kPa).

Table 4. t_{50} and consolidation coefficient obtained by different methods.

The results are calculated by three methods		Vba programming method	TWJ Business Software Law	The square root of time method
P=100kPa	t50/min	20	18	$t_{90=}$56min
	Cv/$10^{-4}cm^2/s$	1.54	1.74	2.35
P=200kPa	t50/min	19	302	$t_{90=}$42min
	Cv/$10^{-4}cm^2/s$	1.53	0.10	2.98

The maximum drainage distance of soil sample at 100 kPa pressure was H = (2-0.0442 + 2-0.0840)/4 = 0.9680 cm; the maximum drainage distance at 200 kPa pressure was H = (2-0.0840 + 2-0.1410)/4 = 0.9438 cm. From figure 1 and figure 2, we can find out the coordinate d100 of the intersection point of L 1 and L 2 quickly, then find out d_1, d_2, d_3, d_4 through d-lg something T curve, and calculate d_{01}, d_{02}, d_{03}, d_{04}, taking the average value as the theoretical zero point d_S, d_{50} = (d_S + d_{100})/2, the time t_{50} corresponding to d_{50} is found. It can be found and calculated manually and conveniently, and it can also be programmed to find and calculate t_{50} and consolidation coefficient C directly. The results are shown in table 4.

4.2. Comparative Analysis

Using semi-logarithmic coordinate paper, we can draw the curve by hand, find every point and calculate, and we can also get t_{50}, but when drawing L1 and L2, we need many times to draw it, and there will be error inevitably, different people draw the

curve is often different, and the drawing pencil must be cut very fine, otherwise, because of the thick line, there will be a larger error.

The TWJ commercial software method, using the time log method to calculate the coefficient of consolidation, has poor stability. As can be seen from table 4, the coefficient of consolidation under 100 kPa pressure is basically consistent with the result obtained by VBA programming method, but 200 kPa pressure consolidation coefficient and curve is very poor, there must be errors, here is not attached to the figure. The reason for the poor quality of curve fitting by commercial software method is that the number of points in d-lgt curve fitting by commercial software method is less, therefore, if the slope of the fitted straight line L1 is too large (which means the absolute value of the slope) , that is, the transverse coordinate intercept of the fitted straight line L1 is too small, the transverse coordinate of the intersection point of two fitted lines L1 and L2 is too small, the quality of curve tail fitting line L2 drawn by commercial software is poor, sometimes the error is very big. When the deformation is abnormal or the structure of soil sample is special, the commercial software may be limited, even the solution is not reasonable. Therefore, for the geotechnical testing personnel, the use of commercial software consolidation test data processing should pay attention to screening and analysis, can be further checked by VBA programming method.

Through the analysis, the VBA programming method to solve t_{50} and consolidation coefficient C, is accurate, fast and easy to use. In addition, by comparing and analyzing the time logarithm method and the time square root method, as well as the corresponding deformation relation curve and its fitting line, it can be seen that the time logarithm method requires higher quality of the tail of the curve, the time square root method requires higher quality of the initial section of the curve. Therefore, the time logarithm method can be used to solve the coefficient of consolidation for the initial data collection of the deformation-time curve, the time square root method can be used to solve the coefficient of consolidation, and it is relatively simple to use the time square root method.

5. Conclusion

(1) The importance and research status of the coefficient of consolidation in one-dimensional consolidation theory are first introduced, and the key and difficult points of the time logarithm method for calculating the coefficient of consolidation are mainly analyzed, the advantages and disadvantages of manual drawing curve method and commercial software processing method for calculating consolidation coefficient are pointed out. The drawback of the method of drawing curve by hand is that it has low efficiency and big error, and the disadvantage of commercial software is that the process of calculating the coefficient of consolidation is not clear, the drawing is easy to have problems, and the parameters and the basis are not known, it is difficult to eliminate outliers when processing data.

(2) According to the characteristics and difficulties of the time logarithm method, a specific program is designed, and the method and steps of solving t_{50} and consolidation coefficient C by VBA programming method are introduced in detail, a method for calculating t_{50} and coefficient of consolidation is presented.

(3) Through the comparison and analysis of VBA Programming Method and TWJ commercial software method, VBA programming method is clear in process, accurate

in drawing, accurate and convenient in obtaining t_{50} and C. TWJ commercial software method drawing is not accurate, mainly fitting the central line L1 and tail tangent L2 is not good, may lead to large errors, poor stability, or even errors.

(4) The time log method requires higher quality of the tail of the curve, while the time square root method requires higher quality of the initial segment of the curve, it is suggested that the time log method be used to calculate the coefficient of consolidation, and the time square root method be used to calculate the coefficient of consolidation.

(5) The VBA programming method based on time logarithm method can help geotechnical engineers deal with the consolidation test data and solve the coefficient of consolidation.

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