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Predicting Compression Index Influenced by Degree of Saturation and Consolidation in Silty-clay Formation, Ahoada East, Rivers State of Nigeria

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ABSTRACT

Stress in soil formation are caused by construction activities, these developments generate compression of soil layer in construction industries, the rate compression generates deformation of soil, relocation of soil including expulsion of water or air through void space in the formation, there are tendencies of void ratio changing due to increment in impose loading, therefore the developed model from the derived governing equation integrated this parameter in the system base on it rate of significant effect it has on compression index of soil, the deposition of silty clay were observed in other to determined it rate of compression through these pressured variables in the system, thus measure their level of roles in the compressibility of soil through the impose load, compressive index can be predicted through this derived model, experts in soil engineering will definitely apply this concept as a tool in predicting the compression index of silty clay.

Keywords: Predicting, Compression index, Degree of saturation, Consolidation, Soil, Clay.

1. Introduction

The study of Taylor and Merchant (1940) are known to be were the pioneers, the presentation a secondary compression model and since then has been a key of solving the consolidation problem. There are many other researchers that have recorded secondary compression when it occurs during the primary consolidation as well as after the end of primary consolidation. The literature on secondary compression is extensive and there is a brief review by Imai (1995) as well. In most recent studies, one-dimensional consolidation analysis is assumed to involve two processes, namely, primary consolidation and secondary compression. Both processes are also assumed to begin simultaneously with consolidation Toshihiko et al 2012. However, it is very difficult to differentiate the secondary compression behavior from the primary consolidation because of the total compression, namely, the sum of primary consolidation and secondary compression are recorded as one in the conventional IL oedometer test and the compressions are inseparable. Nevertheless, most studies by (Wahls 1962; Mesri 1974; Murakami 1980; Akaishi 1980; Feng 2010 and others) have focused on the characteristics of secondary compression during the stage of primary consolidation. The major areas of debate (Ladd 1976; Mesri 1985; Leroueil 1988) are to determine whether creep is significant during primary consolidation. Leroueil *et al.* (1985) pointed out that the constitutive equations in the form of $F(e, \sigma', t) = 0$ encounter a major difficulty when an origin for time must be defined although secondary compression decreases logarithmically with time. A unique constitutive equation in the form of $F(e, \sigma', \partial e / \partial t) = 0$ was used to avoid this difficulty (Sekiguchi 1976; Leroueil 1985; Imai 1992). However, none of the existing constitutive equations of clays for one-dimensional consolidation provides a clear explanation of secondary compression behavior during primary consolidation (Toshihiko et al 2012).

2. Theoretical Background

The compression index in soil were compared in formation characteristics to monitor influences in silty clay, this development has not been thoroughly examined in the behaviour of compression on impose or rolling load in civil and building engineering activities, this mathematical analysis were developed to predict the rate of pressure from this soil characteristics in deltaic environment, the study will definitely determine whether there is any significant influences on these parameter pressure on compression index in the study location. The study predict it rate of compression under the influences of these detailed parameter in the system, several soil engineers should have note the development of compression index in several construction activities, there change of void ratio in the system should affect the deposition of soil, precisely the rate of impose load on the soil that transmit through the foundation. Change of void ratio were part of the parameter in the system that should express various shear strength of the soil through compression index, the void deposition between the strata change with respect to the rate of disintegration of the any typed of rock deposited in the study area. The rate permeability of the soil through void ratio express another pressure in the compression rate of the soil for any impose load. More so shear strength, compressibility and permeability are observed to be the three most significant properties of a soil mass useful in most areas such as design and analysis of dams, including retaining walls, thus soil foundation systems and in other appliance pertaining to geotechnical engineering practice. Looking at these, compressibility is the most important parameter, while analyzing the settlement of soil under the load of an infrastructure constructed on that soil mass (Tiwari and Ajmera, 2012). Compressibility of a soil mass is its vulnerability to decrease in volume under force it also point out by soil characteristics like coefficient of compressibility, compression index and coefficient of consolidation. Although coefficient of volume compressibility is the most appropriate, and most popular on calculation for compressibility coefficients for direct settlement of structures, its variability with confining pressure makes it less useful when quoting typical compressibility's or when correlating compressibility with some other property. For this reason, the compression index of soils is generally preferred as its value does not change with the change in confining pressure for normally consolidated clays (Carter and Bentley, 1991; Gulhati and Datta, 2005). Nevertheless, the calibration of compression index in the labs is a difficult and time consuming process. Hence numerous effort have been prepared in the past to show a relationship the value of compression index of soils with index properties of soil, these identified to be relatively easier to determine and take lesser time (Gelatin, and Datta 2005).

3. Governing Equation

$$\beta \frac{d^2Cc}{dZ^2} - \Delta eo \frac{dCc}{dZ} + K \frac{dCc}{dZ} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (1)$$

The expression here is the governing equation for the study, this developed equation were generated through other parameters that has not been noticed in soil characteristics as significant parameter in soil mechanics, it has been observed that there is direct relationship in geotechnical investigation of soil in design and constructions of structural activities, the behaviour of these parameters were observed on there significant relationship with compression index in soil engineering. Base on these factors the governing equation were develop to see the rate of compression index as it can be predicted through this developed governing equation.

Nomenclature

Cc	=	Compression index	[-]
Δeo	=	Change of void ratio	[-]
K	=	Permeability	[LT^{-1}]
B	=	unconsolidated	[-]
Z	=	Depth	[L]

$$\beta \frac{d^2c}{dZ^2} = (\Delta eo - K)\frac{dCc}{dZ} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (2)$$

Let $Cc = \sum_{n=0}^{\infty} a_n Z^n$

$$Cc^1 = \sum_{n=1}^{\infty} n a_n Z^{n-1}$$

$$Cc^{11} = \sum_{n=2}^{\infty} n(n-1) a_n Z^{n-2}$$

$$\beta \sum_{n=2}^{\infty} n(n-1) a_n Z^{n-2} - (\Delta eo + K) \sum_{n=1}^{\infty} n a_n Z^{n-1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \quad (3)$$

Replace *n* in the 1st term by *n+2* and in the 2nd term by *n+1*, so that we have;

$$\beta \sum_{n=0}^{\infty} (n+2)(n+1) a_{n+2} Z^n - (\Delta eo + K) \sum_{n=0}^{\infty} (n+1) a_{n+1} Z^n \quad \ldots\ldots\ldots\ldots \quad (4)$$

i.e. $\beta (n+2)(n+1) a_{n+2} = (\Delta eo + K)(n+1) a_{n+1}$ ……………………….….….. (5)

$$a_{n+2} = \frac{(\Delta eo + K)(n+1)a_{n+1}}{\beta(n+2)(n+1)} \qquad \text{..........................} \qquad (6)$$

$$a_{n+2} = \frac{(\Delta eo + K)a_{n+1}}{\beta(n+2)} \qquad \text{......................} \qquad (7)$$

For $n = 0, \; a_2 = \dfrac{(\Delta eo + K)a_1}{2\beta}$ .... (8)

For $n = 1, \; a_3 = \dfrac{(\Delta eo + K)a_2}{2\beta} = \dfrac{(\Delta eo + K)^2 a_2}{2\beta}$ .... (9)

For $n = 2; \; a_4 = \dfrac{(\Delta eo + K)a_3}{4\beta} = \dfrac{(\Delta eo + K)}{4\beta} \bullet \dfrac{(\Delta eo + K)a_1}{3\beta \bullet 2\beta} = \dfrac{(\Delta eo + K)^3 a_1}{4\beta \bullet 3\beta \bullet 2\beta}$ ....(10)

For $n = 3; \; a_5 = \dfrac{(\Delta eo + K)a^4}{5\beta} = \dfrac{(\Delta eo + K)^4 a_1}{5\phi \bullet 4\phi \bullet 3\phi \bullet 2\phi}$ ....(11)

For $n; \; a_n - \dfrac{(\Delta eo + K)^{n-1} a_1}{\beta^{n-1} n!}$ ....(12)

$$C(Z) = a_0 + a_1 Z + a_2 Z^2 + a_3 Z^3 + a_4 Z^4 + a_5 Z^5 + ... + a_n Z_n \qquad \text{...............................(13)}$$

$$= a_0 + a_1 Z + \frac{(\Delta eo + K)Z^2}{2!\beta} + \frac{(\Delta eo + K)aZ^3}{3!\beta^2} + \frac{(\Delta eo + K)aZ^4}{4!\beta^3} + \frac{(\Delta eo + K)aZ^5}{5!\beta^4} + ... \; (14)$$

$$C(Z) = a_0 + a_1\left[Z + \frac{(\Delta eo + K)Z^2}{2!\beta} + \frac{(\Delta eo + K)^2 Z^3}{3!\beta^2} + \frac{(\Delta eo + K)Z^4}{4!\beta^3} + \frac{(\Delta eo + K)Z^5}{5!\beta^4} + \right] \text{..........(15)}$$

$$C(Z) = a_0 + a_1 \ell^{\frac{(\Delta eo + K)}{\beta}Z} \qquad \text{...(16)}$$

The derived model at this phase express the behaviour of the soil on the pressures of compression through some transition lithology, the expression did not monitor the derived solution in terms of limitation on the rate of compression in the formation, this also includes other parameters in the system, such development were considered in the phase were the compression index may not experiences limitation base on the pressure from its properties. Compressibility is the process where soil formation or soil mass are found in its susceptibility decreasing in volume under force indicated by soil characteristics, this includes coefficient of compressibility, compression index and coefficient of consolidation. These parameters expresses the behaviour of compression index and in some condition determinant the pressure that may be unassuming, therefore the developed model at this phase express the system on this unassuming condition.
Subject equation (16) to the following boundary conditions,

$$Cc(o) = 0 \; and \; C^1(o) = H$$

$$C(Z) = a_0 + a_1 \ell^{\frac{(\Delta eo + K)}{\beta}Z}$$

$$C(o) = a_0 + a_1 = 0$$

i.e. $a_0 + a_1 = 0$ .... (17)

$$C^1(x) = \frac{(\Delta eo + K)}{\beta} a_1 \ell^{\frac{(\Delta eo+K)}{\beta}Z}$$

$$C^1(o) = \frac{(\Delta eo + K)}{\beta} a_1 = H$$

$$a_1 = \frac{H\beta}{\Delta eo + K} \quad \text{......................} \quad (18)$$

Substitute (18) into equation (17)

$$a_1 = -a_0$$

$$\Rightarrow \quad a_0 = \frac{H\beta}{\Delta eo + K} \quad \text{......................} \quad (19)$$

Hence, the particular solution of equation (16) is of the form:

$$C(Z) = -\frac{H\phi}{\Delta eo + K} + \frac{H\phi}{\Delta eo + K} \ell^{\frac{(\Delta eo+K)}{\beta}Z}$$

$$\Rightarrow C(Z) = \frac{H\phi}{\Delta eo + K}\left[\ell^{\frac{(\Delta eo+K)}{\beta}Z} - 1\right] \quad \text{......................} \quad (20)$$

The behaviour of the strata has been observed to depend on some significant formation characteristics, but on this study, the developed system integrated other parameters, they are found unassuming in terms of it pressure in compression index of soil structures, such development were considered in the development of the derived governing equation for the study, several relationship has been expressed by several experts, but there is no thorough evaluation if any on the integration reflect change in void ratio including other parameter that make up the system, base on this factors it has express the relationship with other parameter on their various rate of effect, it observed to be imperative to monitor it through other express parameters in the system, these concept should predict compression index of soil through the developed model for the study

4. Conclusion

The compression index are known to be the slope of linear portion of the forces from void ratio of soil formation curve through a semi plot whereby the pressure are observed , these are done through log scale, this dimensionless parameter are found on two point of linear portion plot, these condition give way for coefficient of compressibility through it secant slope on a given pressure increment in effective pressure, this expression detailed the coefficient of compressibility volume thus litho unit of soil from original thickness, it is due to it expressed unit of pressure, it is through effective pressure from the expressed parameters like void ratio that decrease the formation to generate the rate of effective pressure.. The relations with other parameters has been applied from other experts in soil engineering, but this parameters has not been thoroughly considered influencing compression index in soil, therefore it is imperative that this study are carried out through this application to predict compression index in silty clay.

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