PRECONSOLIDATION STRESS OF RESIDUAL SOILS IN NORTH-CENTRAL NIGERIA

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ABSTRACT
Preconsolidation stress of residual overburden soil in North-central Nigeria was studied with depth variation. The results indicate variability of maximum stress on the undisturbed deposit which it has experienced in its geologic past. While at some location, the preconsolidation pressure increased with depth at some other points, the pressure decreased with depth of the residual soils. The observed trend in variability of the preconsolidation pressure conformed with other studies carried out on similar residual profile from other regions.

Keywords: *North-central Nigeria, Preconsolidation pressure, Residual profile, Undisturbed soil deposit.*

1 INTRODUCTION

Residual soils overlie parent rocks in most parts of Nigeria. The parent rocks could be either crystalline rocks (from Basement Complex) or of sedimentary origin (from Sedimentary Basins). These soils are widely employed as construction and foundation materials in most parts of the country. In Nigeria, sub-surface conditions at building sites, in some cases (especially within Sedimentary Basins) are such that bedrock is far beneath the ground surface, while at other sites (especially within Basement Complex Terrain), it can be close to the ground surface. In either of these cases, residual soils still constitute material on which the foundations are sited. Although, the most common residual soil profile in the tropics (Nigeria inclusive) is the lateritic weathering profile, they could also be laterite or non-lateritic soils, consisting of clay-sized particles. Depending on their mineralogical compositions, clay-sized particles are known to pose challenges to civil engineers during and after construction (Adebisi and Adeyemi, 2012). This is because they exhibit plasticity and compressibility characteristics. Compressibility is the ability of a clay soil to reduce in volume on application of structural load over a period of time, resulting in settlement. Compressibility of a soil deposit is influenced by preconsolidation stress of the deposit.

Preconsolidation stress of a soil deposit deals with stress history of the deposit. Stress history of soil is concern with the pressure an undisturbed deposit has ever experienced in its geologic past. This load (stress) has significant influence on the compressibility of a particular soil deposit, especially under structural loads (Das, 1999; Punmia et al., 2005; Ranjan and Rao, 2005). A soil deposit can be classified as under-consolidated, if the existing surcharge load is higher than the load the soil has ever experienced in its geologic past; normally consolidated, if the existing surcharge load is equal to the load the soil deposit has ever experienced in its geologic past, and over-consolidated or pre-consolidated, if the existing surcharge load is less than the load the soil has ever experienced in its geologic past. Nishimura et al (1999) states that, estimation of volume change and evaluation of shear strength of soils require information on the present in-situ stress state in a soil mass and possible future changes to the stress state. This needed information, can be gotten from the study of stress history of soil deposit.

Solanki and Desai (2008) defined preconsolidation pressure as the maximum vertical overburden stress that a particular soil deposit has sustained in the past (Das, 1999; Punmia et al., 2005; Ranjan and Rao, 2005). The ratio of this pressure and the present overburden pressure is known as overconsolidation ratio (Alhaji and Alhassan,2013). Based on overconsolidation ratio, soils deposits are classified as normally consolidated, over consolidated or under consolidated.

Preconsolidation pressure can be utilized in the determination of the maximum overburden pressure that can be exerted on a soil without irrecoverable volume change. This is important in understanding shrinkage behavior, crack and structure formation and resistance to shearing stresses of soils. Previous stresses and other changes in a soil's history are preserved within the soils structure. If a soil is loaded beyond this stress, it is unable to sustain the increased load and its structure breaks down. This therefore, makes it an important parameter in geotechnical engineering. Selection of consolidation parameters, such as compression index (Cc), recompression index (Cr) or coefficient of volume change (mv), used for computing consolidation settlement, are often based on overconsolidation ratio (Solanki and Desai, 2008).

Preconsolidation pressure is not usually measured directly, but estimated using a number of indirect methods from laboratory data. The stress history of a soil is commonly and classically determined from one-dimensional compressibility test on undisturbed samples (Józsa, 2003). In 1936, Casagrande (1936) evolved a graphical method for determination of preconsolidation stress of a clay deposit, using results of one-dimensional oedometer (compressibility) test, represented on a semi-logarithmic graph (Figure 1). Grozicet al. (2003), Grozicet al, (2005), Clementino (2005) and Boone (2010) presented detailed and graphical summaries of these approaches. The graph consists of a recompression curve with a slope called recompression index Cr, and a virgin compression curve whose slope is known as the compression index Cc. These indices are very essential as they are used mainly in the evaluation of magnitude of consolidation settlement, which accounts for most of the settlement in clay soils.

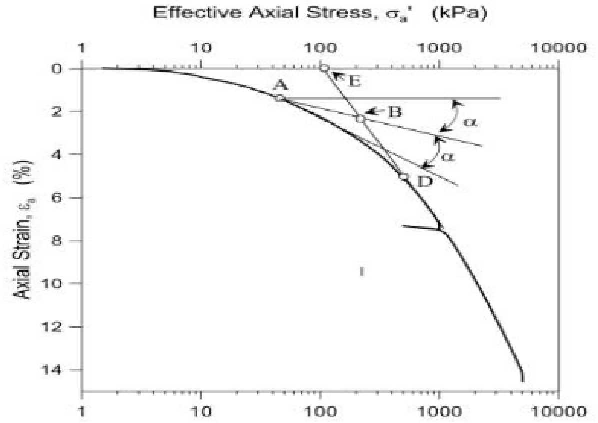

FIGURE 1: CASAGRANDE METHOD OF EVALUATING PRECONSOLIDATION PRESSURE P_C (SOURCE: HOLTZ AND KOVACS, 1981)

Although, many studies have been carried out on the properties of soils in Nigeria (Solanki, 2008; Józsa, 2013; Ola, 1987; Farrington, 1983; Ajayi, 1983; Madedor and Lal, 1985; Adesunloye, 1987; Omange and Aitsebaomo, 1989; Abolarinwa, 2010; Nwaiwu and Nuhu, 2006; Mustapha and Alhassan, 2012; Adebisi and Adeyemi, 2012), much attention has not been given to the study of preconsolidation pressure of these soil deposits. This work presents preconsolidation pressure of some residual soil deposits within North-central Nigeria, and hoped to serve as a preliminary guide for choice of design parameters for foundations of buildings and other structures with the studied area.

Casagrande (1936) method is still considered as the most commonly used method of determining preconsolidation pressure of soil deposits (Strokova, 2013). The method involves using empirical geometrical construction from the void ratio (e) vs logarithm of vertical effective stress, бv', curve to determine preconsolidation pressure (Figure 1). The method is therefore, employed in this study.

2 METHODOLOGY

To collect undisturbed soil samples for the study, sampling through boring was adopted. Six boreholes, drilled to bedrock, at six different locations, were used for the study. The Boreholes (BH) were tagged BH1, BH 2, BH 3, BH 4 BH 5 and BH 6, and were respectively sited as shown on Table I. From BH 1, samples were taken at 1.5, 3.0 and 4.5m, while from BH 2, samples were taken 1.5, 3.0, 4.5 and 6.0m. From BH 3, samples were taken at 1.5, 3.0, 4.5 and 6.0m, while from BH 4, samples were taken at 1.5, 4.5, and 6.0m. From BH 5, samples were collected at 1.5, 3.0, 6.0, and 9.0m, while from BH 6, samples were taken at 1.5, 3.0, 4.5 and 7.5 m. Collection of samples at the stated depths was informed by changes in strata of the soils in the respective bore holes. All the collected soil samples were carefully placed in labelled polythene sample bags, and transported to geotechnical laboratory of Civil Engineering, Federal University of Technology, Minna.

Although, preconsolidation stress, from one-dimensional consolidation test result is the main focus of this study, specific gravity and index properties tests were carried out. All the tests were conducted in accordance with BS 1377 (1990). From the resulting one-dimensional consolidation plot of void ratio (e) vs logarithm of vertical effective stress, бv, preconsolidation pressures for each of the tested samples were determined using Casagrande construction method. The method essentially involves (as shown on Figure 1): (i) choosing, by eye, the point of minimum radius (or maximum curvature) on the consolidation curve (point A in Figure 1); (ii) drawing a horizontal line from point A; (iii) drawing a line, tangent to the curve at point A; iv) bisecting the angle made by steps (ii) and (iii); (v) extending the straight-line portion of the virgin compression curve up to where it meets the bisector line obtained in step (iv). The point of intersection of these two lines is the most probable preconsolidation stress (point B of Figure 1). The maximum possible preconsolidation stress is shown as point D, while E represents the minimum possible value of the preconsolidation stress.

TABLE I: LOCATION OF BOREHOLES

Coordinate	**Borehole**					
	BH1	**BH2**	**BH3**	**BH4**	**BH5**	**BH6**
m E	274206	284829	285920	287974	288749	314080
m N	976278	1044052	1048996	1063179	1066811	1136448

3 RESULTS AND DISCUSSION

Figures 2 to 7 show variations of preconsolidation stress with depth for soils at BH I to BH 6. From the figures, it is observed that for BH 1 (Figure 2), within the studied overburden, maximum preconsolidation stress of 120 kN/m2 occurred at 1.5m depth. This stress was also experienced by soil at 3.0m depth. Soil at 4.5m depth, in this borehole, has 100 kN/m2 as preconsolidation pressure. For BH 2 (Figure 3), soil at 1.5m depth has preconsolidation pressure of 85 kN/m2. At 3.0 and 6.0m depth, the preconsolidation pressure reduces to 65 kN/m2 and 52 kN/m2 respectively. At 7.5m depth, the value increased to 220 kN/m2.

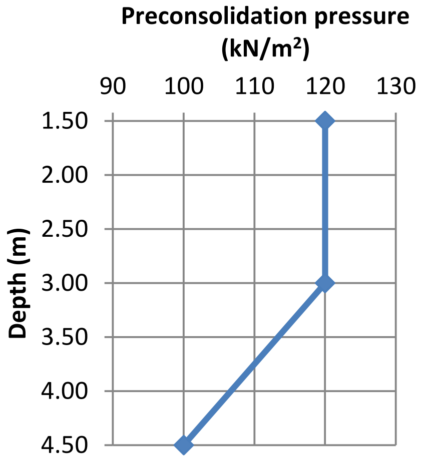

FIGURE 2: VARIATION OF PRECONSOLIDATION PRESSURE WITH DEPTH AT BH 1

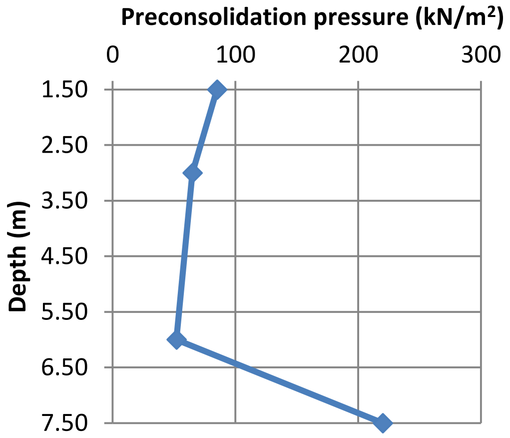

FIGURE 3: VARIATION OF PRECONSOLIDATION PRESSURE WITH DEPTH AT BH 2

Also from the results, it is observed that for BH 3 (Figure 4), within the studied overburden, minimum preconsolidation stress of 85 kN/m2 occurred at 1.5m depth. This stress increased to 130 and 170 kN/m2 at 3.0m and 4.5m respectively. The results from this borehole indicate gradual increase in preconsolidation pressure as depth of the soil increases. For BH 4 (Figure 5), the pattern of variation, observed from BH 1, where maximum preconsolidation stress was observed at the top layer, and increasing with depth, is also observed in this borehole.

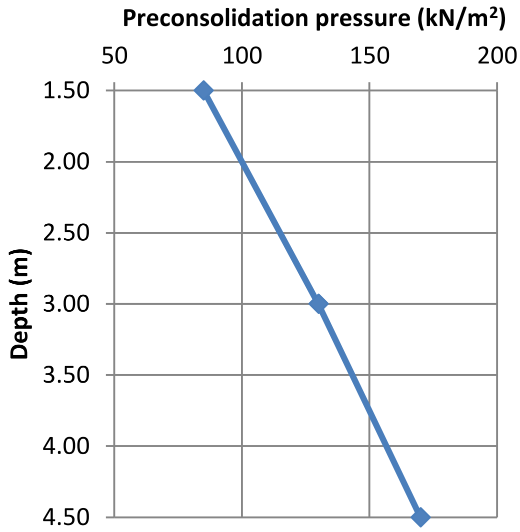

FIGURE 4: VARIATION OF PRECONSOLIDATION PRESSURE WITH DEPTH AT BH 3

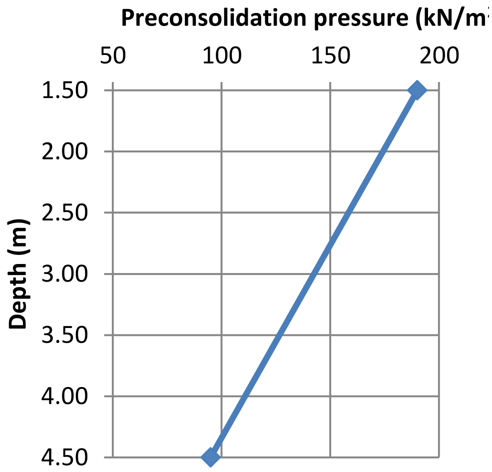

FIGURE 5: VARIATION OF PRECONSOLIDATION PRESSURE WITH DEPTH AT BH 4

Result from BH 5 (Figure 6) shows preconsolidation pressure varying from 102 to 150 kN/m^2 and 120 to 180 kN/m^2 at 1.5 to 3.0m and 6.0 to 9.0m depth respectively. For BH 6 (Figure 7), soil at 1.5m depth has preconsolidation stress of 180 kN/m^2, which reduces to 80 kN/m^2 at 3.0m depth. The preconsolidation pressure increased to 102 kN/m^2 and 104 kN/m^{2}at 4.5 and 7.5m depth.

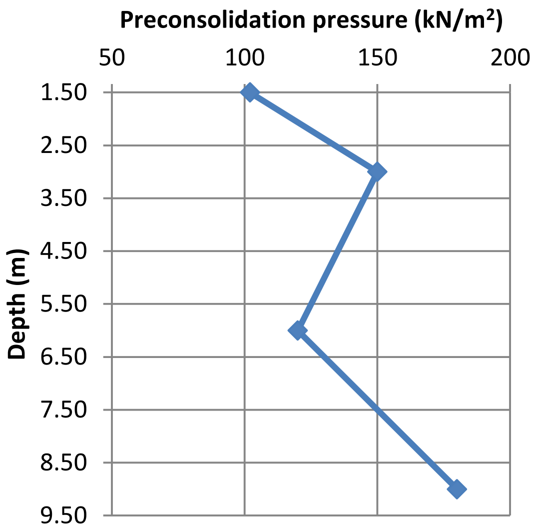

FIGURE 6: VARIATION OF PRECONSOLIDATION PRESSURE WITH DEPTH AT BH 5

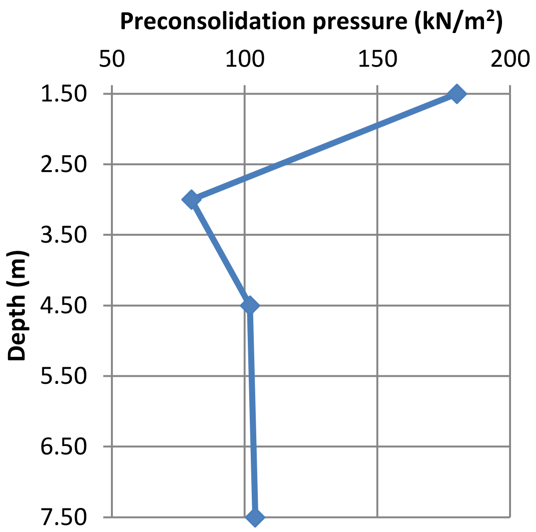

FIGURE 7: VARIATION OF PRECONSOLIDATION PRESSURE WITH DEPTH AT BH 6

The trend in variation of the preconsolidation stress with depth, observed in this studied, relatively conformed with study carried out by Alhajiand Alhassan (2013) on overconsolidation ratio of some selected soil deposits in Nigeria. Adebisi and Adeyemi (2012), in their study on assessment of compressibility characteristics of residual laterized soils in southwestern Nigeria, also reported variability of compressibility characteristics with depth. Carreón-Freyre*et al.*, (2015), in reporting analysis of the variation of the compressibility index of volcanic clays and its application to estimate subsidence in lacustrine areas, presented reported curves of void ratio (e) vs logarithm of vertical effective stress, which evidently indicated similar variation of preconsolidation pressure with depth.Józsa (2013) and Sohail*et al.*, (2012) also reported similar trend with overconsolidation ratio.

4 CONCLUSION

Preconsolidation stress of residual overburden soil in North-central Nigeria was studied with depth. The results indicate variability of maximum stress the undisturbed deposit has ever experienced in its geologic past. While at some location, the preconsolidation pressure increased with depth, at some other point, the pressure decreased with depth of the residual soil. The observed trend in variability of the preconsolidation pressure conformed with other studies carried out on similar residual from other regions.

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