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Research Article

Overconsolidation Ratio of Some Selected Soil Deposits in Nigeria

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Abstract: Undisturbed soil samples, collected at between 0.5 and 3.0 m depths, from 16 soil deposits across Nigeria, were subjected to Identification and one-dimensional consolidation tests. Using Casagrande method, preconsolidation pressures and subsequently, Overconsolidation Ratio (OCR) of the respective soil samples were determined. The results generally showed that the investigated soil deposits are overconsolidated. Although, the OCR of the studied soil deposits covers a relatively wide range, soils deposits from the same region shows relatively narrow range of OCR values. The highest OCR values of between 15.8 and 16.9 were observed with soil samples from deposits in the Northeastern part of the country, that is, from deposits of Vertisol (Black cotton soils). The OCR value of the soil deposit from the Northwestern region shows that the soil is under-consolidated.
Keywords: Clay deposit; Consolidation; Overconsolidation ratio; Preconsolidation pressure.

INTRODUCTION

Stress history deals with the pressure an undisturbed clay deposit has ever encountered in its geologic past. This pressure has very significant influence on the compressibility of a particular clay deposit on application of structural loads [1-3]. A clay deposit can be categorized as under-consolidated if the existing surcharge pressure is higher than the pressure the clay has ever encountered in its geologic history, normally consolidated if the existing surcharge pressure is equal to the pressure the clay has ever encountered in its geologic history, and over-consolidated or pre-consolidated if the existing surcharge pressure is less than the pressure the clay has ever encountered in its geologic history. Nishimura *et al* [4] states that, the prediction of volume change and the evaluation of shear strength require information on the present in situ stress state in soil mass and possible future changes to the stress state. This information can be obtained from the study of stress history of the soil deposit.

Preconsolidation pressure is the maximum vertical overburden stress that a particular soil sample has sustained in the past [5]. The ratio of preconsolidation pressure and present overburden pressure is known as Overconsolidation Ratio (OCR). Based on OCR, soils deposits are classified as normally consolidated, over consolidated or under consolidated. Preconsolidation pressure can be used in the determination of the maximum overburden pressure that can be exerted on a soil without irrecoverable volume change, which is important in understanding shrinkage behavior, crack and structure formation and resistance to shearing stresses of the soil. Previous stresses and other changes in a soils history are preserved within the soils structure. If a soil is loaded beyond this point, 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 (C_c), Recompression index (C_r) or coefficient of volume change (m_v), used for computing consolidation settlement, are often based on OCR [5].

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 oedometer test on undisturbed samples [6]. Casagrande in 1936 evolved a graphical method for determining the preconsolidation pressure of a clay deposit using the results of one-dimensional oedometer tests, represented on a semi-logarithmic graph. The graph consists of a recompression curve with a slope called recompression index C_r, and a virgin compression curve whose slope is known as the compression index C_c. 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.

Although, many studies have been carried out on the properties of soils in Nigeria [7-15], attention has not been given to the study of OCR of these soil deposits. This work presents OCR of some selected soil deposits in Nigeria, and is intended to serve as a guide for the preliminary choice of design parameters for foundations of buildings and other structures.

The Casagrande method is still considered the most commonly used method of determining

preconsolidation pressure of soil deposits [16], and as such was employed in this work.

GEOLOGY OF THE STUDY AREA (NIGERIA)

The geology of Nigeria is dominated by sedimentary and crystalline basement complex formations which occur in almost equal proportions all over the country [17-22] (fig. 1). The sediment is mainly Upper Cretaceous to recent in age while the basement complex rocks are thought to be Precambrian.

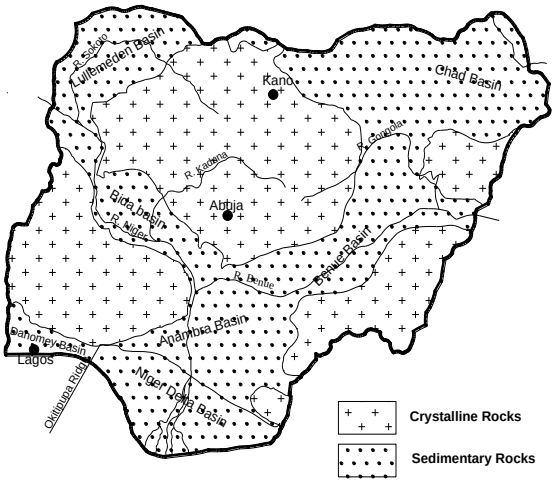

Fig.1: Geological formation of Nigeria

Generally, in Nigeria, the weathered in-situ rock overlies the unweathered bedrock except in areas of outcrops and in exceptional cases where the Quaternary deposits overlie the bedrock directly. The contact between the weathered and unweathered bedrock is known as the basal surface of weathering. The depth of the basal surface is highly variable depending on the type of rock. In sedimentary rock regions, the basal surface of weathering may not easily be discerned, especially when the rocks are not very consolidated. But on the crystalline rocks, this boundary is very distinct because of the remarkable transformation, involved in the chemical weathering of primary rock forming minerals, like feldspars and the ferromagnesians, into secondary clays and iron oxides [17]. Products of weathering in Nigeria are generally grouped into four main basic groups (fig. 2): the Ferruginous soils, the Ferrallitic soils, the weakly developed soils, and Vertisols, which is localized to the Northeastern part of the country [23].

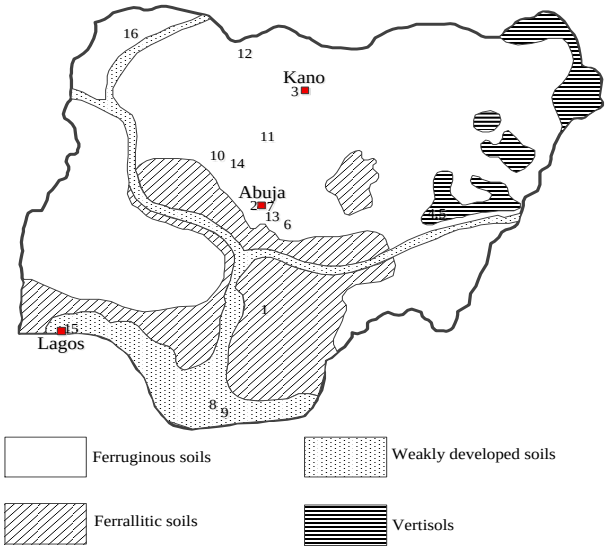

Fig.2: Soil groups in Nigeria (sample collection points are shown with numbers)

The Characteristic landforms on the crystalline Basement Complex and the Younger Granites of the Jos Plateau are the extensive dissected pedi-plains above which rise prominent steep sided residual hills, which range in height. The characteristic landforms on the sedimentary Basement Complex consist of extensive dissected flat to very gentle sloping plains of a lower pediment level, above which rise remnants of flat lateritic capped hills of a higher pediment level. These lateritic capped hills, dissecting the flat plains are of various heights, with height up to 300m been recorded [17].

METHODOLOGY

Undisturbed soil samples were collected from trial pits at depth ranging between 0.5 and 3.0 m. This depth range was informed by the depth of foundation bases for normal structures in the country. The distribution of the trial pits is as shown in fig. 2. Tests conducted on the samples included soil identification and classification tests in accordance with B. S. 1377-2 [24] with modifications where necessary, while consolidation test was conducted in accordance with B. S. 1377-5 [25]. All the tests were carried out in the geotechnical laboratory of the Department of Civil Engineering, Federal University of Technology, Minna, Nigeria.

The laboratory data from the consolidation test was used to plot graphs, commonly called the e-logp curve or the consolidation curve, i.e. semi-log curves of the effective stress verses the void ratio. From the e-logp graphs, using Casagrande method, preconsolidation pressures of the respective soil deposits were determined. Fig. 3 and 4 shows some of these plots. The resulting preconsolidation pressures

were then used in the determination, for the respective soil deposits OCR, which is expressed as:

$$OCR = \frac{P_c}{P_o} \quad (1)$$

where,

P_o is the current overburden effective stress; and P_c is the preconsolidation pressure.

The results are presented in table 1.

RESULTS AND DISCUSSION

Summary of the laboratory results and the resulting preconsolidation pressures and OCR are presented in table 1. From the results, it is observed that most (more than 90 %) of the studied soil deposits are generally over-consolidated soils. Although, the OCR of the studied deposits covers a relatively wide range, soils deposits from the same region shows relatively narrow range of OCR values, indicating relative homogeneity in their profiles. Soil sample 2 and 7, which were collected from deposits around Abuja, the country's capital city, has OCR between 1.62 and 1.65, while soil sample 8 and 9, with OCR values between 2.59 and 2.97, were collected from deposits around Rivers State, in the south-south region of the country. The highest OCR values of between 15.8 and 16.9 were observed with soil samples from deposits of Vertisol (Black cotton soils) in the Northeastern part of the country. The OCR value of 0.62, observed from soil deposit from the Northwestern region shows that the soil is under-consolidated.

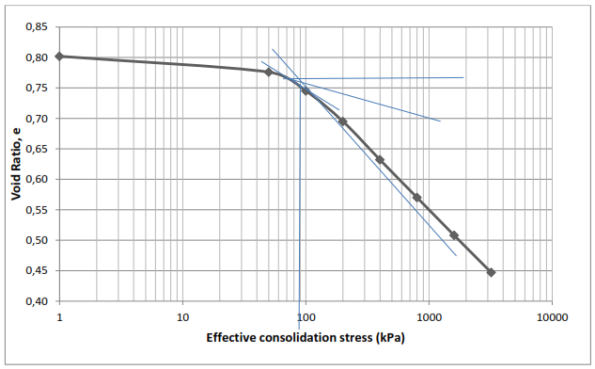

Fig. 3: e-log p curve for sample 1

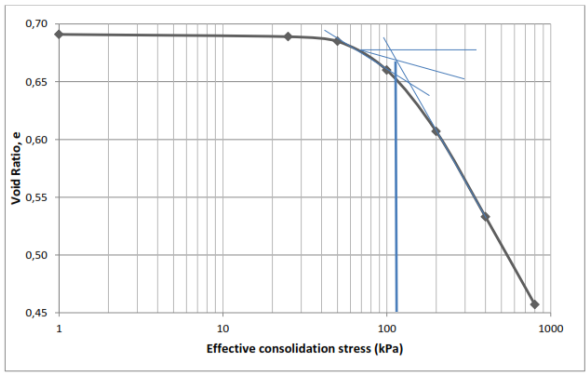

Fig. 4: e-log p curve for sample 9

Table1: Summary of results

Soil sample	Depth (m)	Specific Gravity	Bulk unit Weight (kN/m^3)	Soil Classification	Surcharge Pressure (σ_{vo}) (kN/m^2)	Preconsolidation Pressure, σ_p (kN/m^2)	OCR	Compressive Index (C_c)
1	3.0	2.60	19.3	CL	58	90	1.55	0.204
2	1.5	2.57	18.9	SC	28.4	46.0	1.62	0.188
3	1.2	2.52	21.2	SC	25.4	38.0	1.50	0.098
4	0.5	2.50	19.5	CL	9.8	155.0	15.8	0.193
5	1.0	2.53	19.5	CH	19.5	330.0	16.9	0.161
6	1.5	2.61	19.9	SC	29.9	74.0	2.47	0.189
7	1.5	2.59	18.2	SC	27.3	45.0	1.65	0.291
8	2.0	2.59	20.2	SC	40.4	120.0	2.97	0.163
9	2.5	2.57	19.0	SC	47.5	123.0	2.59	0.249
10	1.4	2.67	20.1	CH	28.1	100.0	3.56	0.224
11	1.1	2.66	18.1	ML	19.9	115.0	5.78	0.209
12	1.8	2.65	18.4	SC	33.1	34.0	1.03	0.145
13	1.5	2.69	16.2	CH	24.3	57.0	2.35	0.272
14	1.2	2.54	20.3	SC	24.4	42.0	1.72	0.143
15	2.0	2.58	18.1	ML	36.2	51.0	1.41	0.226
16	2.5	2.60	21.3	SC	53.3	33.0	0.62	0.080

CONCLUSION

Preconsolidation pressure and subsequent OCR of some selected soil deposits in Nigeria were investigated. Results of the study showed that the investigated soil deposits are generally overconsolidated, with exception of soil deposit from

Northwestern part of the country, which is under-consolidated. Although, the OCR covers a relatively wide range, soils deposits from the same region shows relatively narrow range of OCR values. The highest OCR values of between 15.8 and 16.9 were observed with soil samples from deposits in the Northeastern part of the country, that is, from deposits of Vertisol (Black cotton soils).

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