Predictive models for the determination of settlement parameters of cohesive soils in the Niger Delta Region of Nigeria.

Modèles prédictifs pour la détermination des paramètres de colonisation des sols cohésifs dans la région du delta du Niger au Nigeria.

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ABSTRACT: Settlement of cohesive soils has been a major problem hampering infrastructure development and building construction in the Niger Delta region of Nigeria. Owing to the difficulty in computing foundation settlement, an attempt is made in this research to develop predictive models for determining settlement parameters of cohesive soils in the Niger Delta to aide preliminary analysis and design of foundations placed on clayey soils. Compressibility tests were done in the laboratory on 150 soil samples from the study area which comprised of the nine states of the Niger Delta to determine the settlement parameters which included pressure, void ratio (e), modulus of compressibility (M_v), and compression modulus (E_c). Results of E_c increased with pressure while results of e, and M_v generally showed a decreasing trend with increase in pressure. Empirical relationships for various settlement parameters notably pressure, void ratio, modulus of compressibility and compression modulus were developed for use in studying Niger Delta clays. The models can be utilized for quick determination of settlement input parameters needed in deformation analysis of foundations placed in cohesive soils.

KEYWORDS: predictive model, void ratio, modulus of compressibility, settlement, compression modulus, cohesive soil, clay

1 INTRODUCTION. FIRST LEVEL HEADING

Compressibility and settlement of a soil mass reflect its susceptibility to decrease in volume under pressure and depend on soil characteristics like void ratio, modulus of compressibility, and compression modulus of the compressible soil mass under vertical stress. The void ratio of a soil is the ratio of the volume of voids to the volume of solids, while the coefficient of volume compressibility is expressed as the ratio of the strain increment to the stress increment in a specified direction caused by external or internal loading.

The determination of soil compressibility parameters in the laboratory is cumbersome and time consuming, especially the determination of undrained modulus, E_u required for evaluation of immediate settlement of shallow foundation placed in cohesive soils. Skempton (1951) and Smith (1982) presented a procedure for obtaining the undrained modulus directly from triaxial test results namely, the ratio of the strain corresponding to 65% of the maximum deviator stress to the corresponding vertical stress. It is also known that compression modulus, E_c, is the reciprocal of M_v and is analogous to Young's modulus. In order to mitigate the complexities in determining these settlement parameters of cohesive soils equations have been developed by many researchers to study the compressibility characteristics of the soils. Akpila (2013) developed predictive models for quick determination of settlement input parameters needed in the deformation analysis of foundation placed on clayey soils in selected areas of Port Harcourt, Nigeria. Jones and Rust (1995) and Kulhawy and Mayne (1990) suggested models for estimating compression modulus of clays using CPT data.

2 DATA ACQUISITION AND ANALYSIS

The studied soils consist of Clay and Silt, collected from Abia, Akwa Ibom, Bayelsa, Cross Rivers, Delta, Edo, Imo, Ondo and Rivers state in the Niger Delta region of Nigeria. The soils ranged from soft to firm greyish brown silty peaty clay. Consolidation test using the Rowe's oedometer was carried out on samples of clay from clay layers 1 metre deep to
22 metres deep to determine settlement parameters such as void ratio, coefficient of compressibility and compression modulus.

3 RESULTS AND DISCUSSION

3.1 Void Ratio and Pressure Variation

Figure 1 shows the variation of void ratio and pressure. There was a gradual decrease in void ratio with increase in pressure up to an overburden pressure of 800 kN/m^2 for all the states in the Niger Delta. Values of void ratio for the nine states within the study area ranged between 0.285 in Cross River indicative of medium compressibility clays to 0.985 in Bayelsa State indicative of highly compressible clays for pressure range of 0-800 kN/m^2.

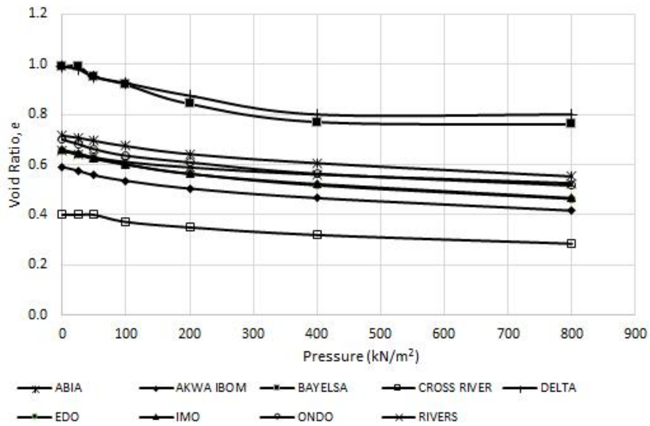

Figure 1. Variation of void ratio and pressure

The model equations expressing variation of void ratio versus pressure for each study area are given as follows:

Abia: $e = 2E\text{-}07p^2 - 0.0004p + 0.7132$; $R^2=0.9947$ (1)
Akwa Ibom: $e = 3E\text{-}07p^2 - 0.0004p + 0.5829$; $R^2 = 0.9888$ (2)
Bayelsa: $e = 7E\text{-}07p^2 - 0.0009p + 0.9973$; $R^2=0.9918$ (3)
Cross River: $e = 2E\text{-}07p^2 - 0.0003p + 0.4047$; $R^2=0.9862$ (4)
Delta: $e = 6E\text{-}07p^2 - 0.0007p + 0.9909$; $R^2 = 0.9974$ (5)
Edo: $e = 3E\text{-}07p^2 - 0.0005p + 0.6489$; $R^2 = 0.9949$ (6)
Imo: $e = 3E\text{-}07p^2 - 0.0005p + 0.6523$; $R^2 = 0.9901$ (7)
Ondo: $e = 3E\text{-}07p^2 - 0.0005p + 0.6898$; $R^2 = 0.9867$ (8)
Rivers: $e = 2E\text{-}07p^2 - 0.0003p + 0.6485$; $R^2 = 0.9847$ (9)

3.2 Coefficient of volume compressibility and Pressure Variation

Figure 2 shows the variation of coefficient of volume compressibility, m_v with pressure. There was a steep decrease in m_v through a pressure range of 0-100 kN/m^2, beyond which m_v had a gentle decrease as pressure increased. Values of mv for the nine states within the study area ranged between 0.03 m^2/MN in Cross River indicative of medium compressibility clays to 0.626 m^2/MN in Bayelsa State indicative of highly compressible clays for pressure range of 0-400 kN/m^2.

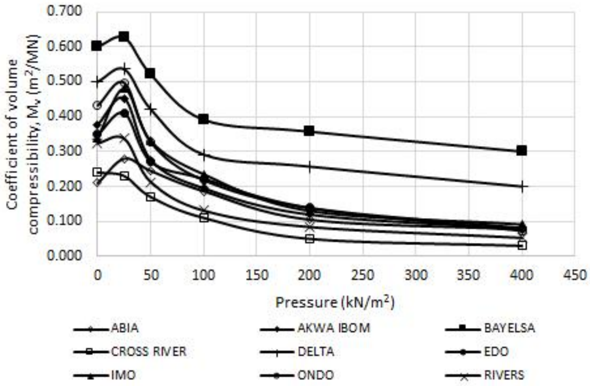

Figure 2. Variation of coefficient of volume compressibility and pressure

The model equations expressing variation of coefficient of volume compressibility versus pressure for each study area are given as follows:

Abia: M_v = 1E-06p^2 - 0.0009p + 0.2602; R² = 0.829 (10)
Akwa Ibom: M_v = 4E-06p^2 - 0.0023p + 0.4174; R² = 0.887 (11)
Bayelsa: M_v = 3E-06p^2 - 0.0021p + 0.623; R² = 0.9242 (12)
Cross River: M_v = 2E-06p^2 - 0.0015p + 0.2467; R² = 0.983 (13)
Delta: M_v = 3E-06p^2 - 0.0022p + 0.5267; R² = 0.9146 (14)
Edo: M_v = 2E-06p^2 - 0.0017p + 0.382; R² = 0.9089 (15)
Imo: M_v = 3E-06p^2 - 0.002p + 0.4207; R² = 0.9901 (16)
Ondo: M_v = 4E-06p^2 - 0.0025p + 0.4713; R² = 0.9164 (17)
Rivers: M_v = 3E-06p^2 - 0.0021p + 0.3354; R² = 0.9298 (18)

3.3 Compression Modulus and Pressure Variation

Figure 3 shows the variation of compression modulus E_c (also given as 1/m_v), with pressure. There was a gradual increase in E_c with increase in pressure up to an overburden pressure of 400KN/m^2 for all the states in the Niger Delta. Values of E_c for the nine states within the study area ranged between 2.6 MN/m^2 in Cross River to 23 MN/m^2 in Bayelsa State for pressure range of 0-400 kN/m^2.

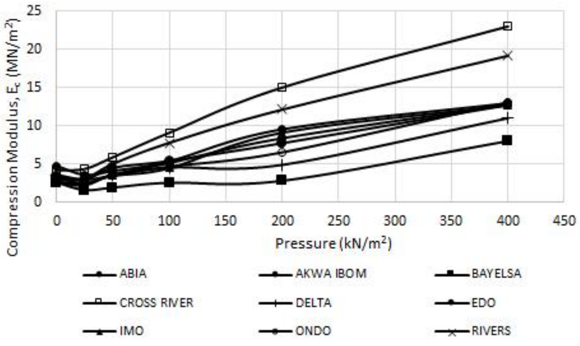

Figure 3. Variation of compression modulus and pressure

The model equations expressing variation of compression modulus versus pressure for each study area are given as follows:

Abia: E_c = -5E-06p^2 + 0.026p + 3.5271; R² = 0.9425 (19)
Akwa Ibom: E_c = -2E-05p^2 + 0.0339p + 2.029; R² = 0.989 (20)
Bayelsa: E_c = 5E-05p^2 - 0.0072p + 2.2667; R² = 0.9768 (21)
Cross River: E_c = -3E-05p^2 + 0.0625p + 3.3382; R² = 0.994 (22)
Delta: E_c = 5E-05p^2 - 0.0005p + 3.4232; R² = 0.9809 (23)
Edo: E_c = 3E-06p^2 + 0.0229p + 3.0295; R² = 0.9891 (24)
Imo: E_c = -2E-05p^2 + 0.0332p + 2.1689; R² = 0.9649 (25)
Ondo: E_c = 3E-05p^2 + 0.0157p + 2.5199; R² = 0.994 (26)
Rivers: E_c = -3E-05p^2 + 0.0531p + 2.5562; R² = 0.9949 (27)

4 CONCLUSION

Based on the study the following conclusions were drawn:

i. Input parameters of void ratio, coefficient of volume compressibility and compression modulus of medium to highly compressible clay soils can easily be accessed from the generated predictive models for purposes of preliminary foundation settlement analysis and design.
ii. The predictive models generated for the study areas show promising reproducibility of measured and predicted values.

5 REFERENCES

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