MedCrave
Step into the World of Research

Material Science & Engineering International Journal

Research Article

Modeling and simulation of heterogeneous moisture content influence on foundation settlement in silt clay

Abstract

In this paper, modeling and simulation techniques with experimental setup values were used to investigate the effects of foundation settlement on the heterogeneity of moisture content, formation characteristics, and ground water. The study was conducted at Obirikom in Rivers State's Ogba Egbema Local Government Area; the samples were subjected to the following laboratory tests: particle size analysis, Atterberg limit tests, compaction test, natural moisture content test, specific gravity, and consolidation test, which revealed that the soil was predominantly clay deposited. Modeling and simulation were used to predict how different soil conditions affected the settlement of a foundation. The study observed heterogeneous soil deposition as it reflected on soil properties, and the study on foundation settlement influence explained the heterogeneous impacts on moisture. Permeability, plastic and liquid limits, as well as other soil properties such as moisture content, water content, and dry density, was investigated. Significant parameters were observed in the study, such as dry density, which is directly proportional to plasticity as settlement increases in moisture until optimum moisture content is observed at the level where settlement decreases to a minimum. The moisture content of the settlement increased while exceeding the optimum moisture content.

Keywords: predicting, moisture content, foundation settlement, silt clay

Volume 7 Issue 1 - 2023

Nwaokezi EE, Eluozo SN, Ukpaka C
Department of Civil Engineering, College of Engineering, Gregory University, Nigeria

Correspondence: Eluozo SN, Department of Civil Engineering, Faculty of Engineering, University of Nigeria, Nigeria, Email ndusol2018@gmail.com

Received: February 10, 2023 | **Published:** March 30, 2023

Introduction

It is obvious that man-made or natural activities have an impact on the environment, as it affects soil and water. These conditions have been observed in several studies, and this could also be related precisely to different foundations of engineering structures. Such soil conditions reflect the variation in moisture content as significant in soil mechanics, as well as other important aspects in soil engineering. This stated condition in soil mechanics represents a significant change that has an impact on the mechanical behavior of partially saturated soils. The degrees of saturation are determined by the rates of differentiation between saturated and partially saturated soils; this condition will always cause significant changes in volume, shear strength, and hydraulic properties, resulting in bearing capacity. Furthermore, satisfactory foundations are known to develop two main characteristics: shear failure in the soil that supports the foundation and settlement within acceptable limits. It implies that, in this direction, the stability of shallow footings will be heavily reliant on keeping settlement values within a tolerable range. In terms of both analytical treatment and practical experimentation, the degree of soil saturation that it experiences orchestrates a decrease in the bearing capacity of shallow foundations. According to theory, only a few numbers of researchers have addressed this issue (Krishnamurthy and[1–5] Experimental research studies and similar examinations had some restrictions.[2–8] Using kinematic approaches of limit analysis[8–11] research study developed Influence on groundwater from the carrying capacity of shallow foundations. A method was put out by[4] that estimate the loss in bearing capacity caused by a static water table at any depth in any type of soil. According to[5,6] the air permeability was effectively zero for saturation levels beyond 85%. Buildings, bridges, highways, and other sorts of structures are all recognized to rest directly on the ground beneath them. The safety of these structures is dependent on the strength/bearing capacity of the soil on which they are built. That is why it is important to conduct a proper analysis of the soil properties, as well as the design of their foundations, to ensure that these structures remain stable and safe from collapse or unequal settlements. According to studies conducted in the upper region of Himalayan Rivers, large size pebbles exist in the soil. This means that when the river flows downstream, the particle size of the soil is always reduced.

Groundwater in the crust is an important natural resource and a component of the three-phase rock and soil. Groundwater seepage into pores or fissures of rock and soil has a significant impact on their engineering mechanical properties.[9,11] For example, seepage of groundwater will result in seepage deformation of rock and soil, which will have a negative impact on the stability and security of structures and their foundations; a change in groundwater level will result in a change in the effective stress field in the foundation soil, which will result in rebound or settlement of the foundation soil; a change in groundwater level will also result in a change in soil moisture content, which will change the mechanical performance of the foundation soil.[10]

Improving research into soil chemistry and mechanics during reservoir impoundment will be critical.[11–13] Researchers have investigated the negative effects of reservoir immersion on the foundation, as well as the factors that contribute to immersion and the impact of immersion.[10,13,14]

In order to analysis embankment settlement in soft clays in 1-D, 2-D, and 3-D, a number of constitutive models for soft soils have been created. This means that, unlike with manual calculations, it is not essential to oversimplify the soil layers beneath an embankment or other structure when calculating settlement. The numerical modeling also enables combined settlement and stability analysis, which provides a broad understanding of the behaviour of soft soil under embankments. In order to simulate the behaviour of soft clay soils, these constitutive models needed between 5 and 13 parameters.

Several stress-strain-time relationships have been used to model the behaviour of soft soils in a few documented cases. Some of the models that have been applied: (1) modified cam clay model with 5 soil parameters[14]; (2) soft-soil model with 8 parameters (no time effect)[14] (3) soft-soil creep model with 9 parameters; (4) hardening soil model (isotropic hardening) with 13 soil parameters[9,14] and (6) kinematic hardening models.[14,15] These models have been used in a variety of applications.[10]

Theoretical background

$$K_t\frac{\partial e}{\partial t}-K\frac{\partial e}{\partial z}-H_{\boldsymbol{\epsilon}}\frac{\partial e}{\partial z}=\beta \tag{2.1}$$

$$K_t\frac{\partial e}{\partial t}-K\frac{\partial e}{\partial z}-H_{\boldsymbol{\epsilon}}\frac{\partial e}{\partial z}+\beta \tag{2.2}$$

$$K_t\frac{\partial e}{\partial t}=\left(K+H_{cr}\right)\frac{\partial e}{\partial z}+\beta \tag{2.3}$$

$$K_t\frac{\partial e_1}{\partial t}=\beta \tag{2.4}$$

$$\frac{\partial e_1}{\partial t}=\beta K_t \tag{2.5}$$

$$e_1=\beta K_t+\gamma \tag{2.6}$$

$$K_t\frac{\partial e_1}{\partial t}=\left(K+H_{cr}\right)\frac{\partial e}{\partial z} \tag{2.7}$$

Let $e_2=ZT$ (2.8)

$$\frac{\partial e_2}{\partial t}=ZT^1 \tag{2.9}$$

$$\frac{\partial e_2}{\partial z}=Z^1T \tag{2.10}$$

Substitute (9) and (10) into (7)

$$K_tZT^1=\left(K+H_{cr}\right)Z^1T \tag{2.11}$$

$$K_t\frac{T^1}{T}=\left(K+H_{cr}\right)\frac{Z^1}{Z}=\gamma \tag{2.12}$$

$$K_t\frac{T^1}{T}=\gamma \tag{2.13}$$

$$\left(K+H_{cr}\right)\frac{Z}{Z}=\gamma \tag{2.14}$$

From (13), $\frac{T^1}{T}=\frac{\gamma}{K_t}$

$$LnT=\frac{\gamma}{K_t}t+e_3 \tag{2.15}$$

$$T=Ae^{\frac{\gamma}{K_t}t} \tag{2.16}$$

From (14) $\left(K+H_{cr}\right)\frac{Z}{Z}=\gamma$

$$\frac{Z}{Z}=\frac{\gamma}{K+H_{cr}} \tag{2.17}$$

$$LnZ=\frac{\gamma}{K+H_{cr}}Z+e_4 \tag{2.18}$$

i.e. $Z=Be^{\frac{\gamma}{K+H_{cr}}Z}$ (2.19)

Put (16) and (19) into (8), yields

$$e_2=Ae^{\frac{\gamma}{K_t}t}\bullet Be^{\frac{\gamma}{K+H_{cr}}Z} \tag{2.20}$$

Derived model $e_2=ABe^{\left(\frac{t}{K_t}t+\frac{\gamma}{K+H_{\boldsymbol{\epsilon}}}Z\right)^{\gamma}}$ (2.21)

Hence, general solution becomes

$$e(z,t)=e_1+e_2$$

$$e(z,t)=\beta K_t t+\gamma+ABe^{\left(\frac{t}{K_t}+\frac{Z}{K+H_{\boldsymbol{\epsilon}}}\right)\gamma} \tag{2.22}$$

Materials and methods

Experimental setup

The samples for this study were taken from three trial pits that are located in Obrikom's residential and commercial buildings in the Ogba/Egbema/Ndoni Local Government Area of Rivers State, and they range in depth from 1.0 to 1.6 meters. The three pits each had an A, B, and C label.

Laboratory tests conducted

The laboratory experiments conducted in this research work were done in accordance with the British standards (BS1377, 1990). The tests conducted include: particle size analysis, Atterberg limit tests, compaction test, natural moisture content test, specific gravity and consolidation settlement

Methodology

Laboratory investigation

This research's laboratory experiments were carried out in compliance with British standards (BS1377, 1990). Particle size analysis, Atterberg limit tests, a compaction test, a test for natural moisture content, a test for specific gravity, and a test for consolidation settlement are among the examinations done.

Result and discussion

The effect of soil characteristics such as plastic and liquid limit heterogeneity on soil settlement was explained in Figures 1–8 and Tables 1–8 respectively. The parameter ranged from 17.36 to 17.22, respectively, and the dry density of the soil expressed their reflection as there is gradual increase to the optimum level, but suddenly experienced decrease to the minimum rate recorded within. as it approached the point where the settlement fell to a minimum, experience increased with increased moisture content was observed, whereas beyond the optimal moisture level, the settlement increased with increased moisture content. The outcome demonstrated how the trend's rate of exponential growth changed as soil plasticity varied; the higher the plasticity, the lower the maximum density reached; this suggests that it may have something to do with the development of

Citation: Nwaokezi EE, Eluozo SN, Ukpaka C. Modeling and simulation of heterogeneous moisture content influence on foundation settlement in silt clay. *Material Sci & Eng.* 2023;7(1):32–36. DOI: 10.15406/mseij.2023.07.00200

more microspores in combination with the seasonal environmental conditions in a deltaic region. The soil particle tends to drift apart since this may have an impact on the soil as a whole. More so in settlement settings, the volume of the soil changes as a result of seasonal conditional deformation brought on by imposed loads, including mass movement brought on entirely by ground water. The failure of the soil's bearing capacity, which results in compression of the soil as a result of external forces, is the cause of the settlement state.

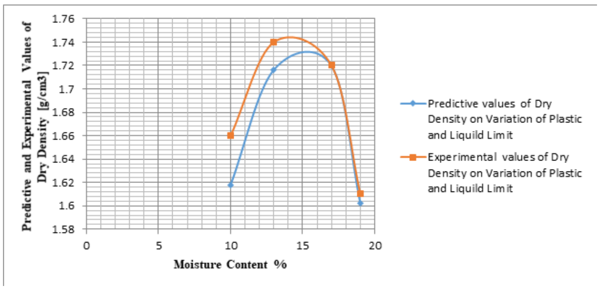

Figure 1 Predictive and experimental values of dry density at different moisture content.

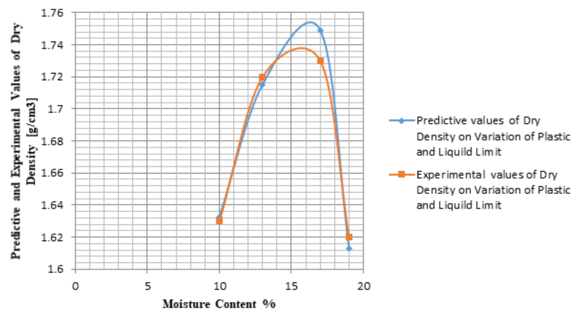

Figure 2 Predictive and experimental values of dry density at different moisture content.

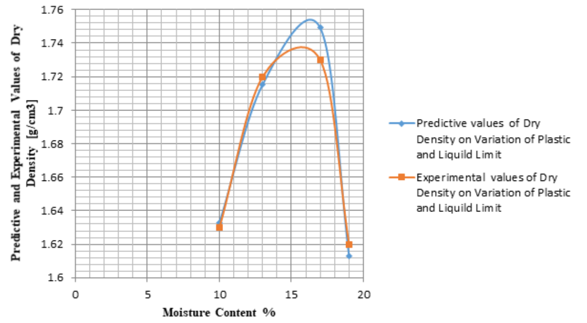

Figure 3 Predictive and experimental values of dry density at different moisture content.

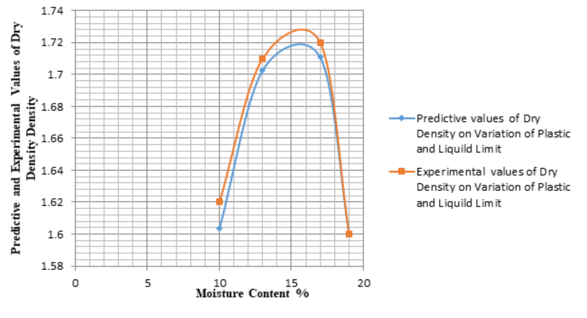

Figure 4 Predictive and experimental values of dry density at different moisture content.

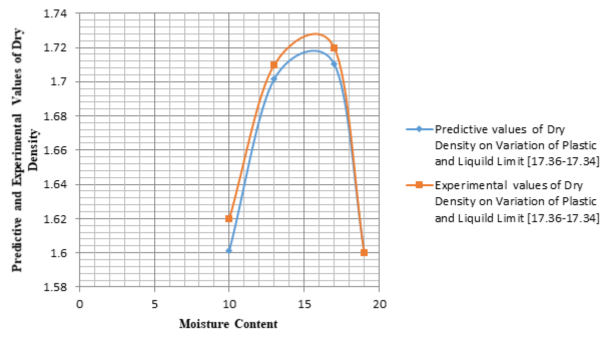

Figure 5 Predictive and experimental values of dry density at different pressure load.

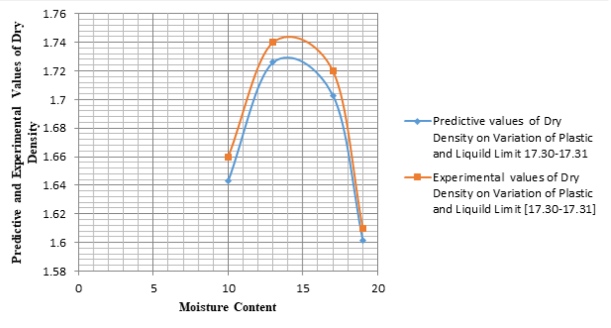

Figure 6 Predictive and experimental values of dry density at different moisture content.

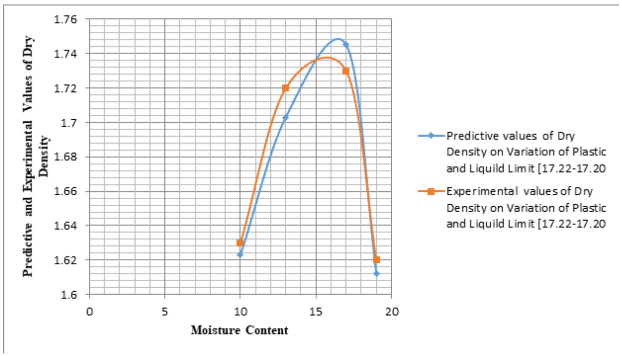

Figure 7 Predictive and experimental values of dry density at different moisture content.

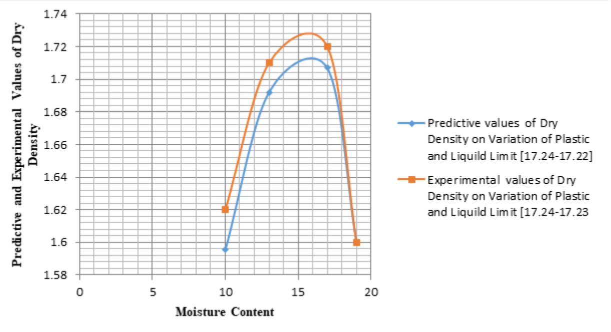

Figure 8 Predictive and experimental values of dry density at different moisture content.

Citation: Nwaokezi EE, Eluozo SN, Ukpaka C. Modeling and simulation of heterogeneous moisture content influence on foundation settlement in silt clay. *Material Sci & Eng.* 2023;7(1):32–36. DOI: 10.15406/mseij.2023.07.00200

Table 1 Predictive and experimental values of settlement at different pressure load

Average moisture content	Predictive values of dry density on variation of plastic and liquid limit	Experimental values of dry density on variation of plastic and liquid limit
10	1.688067931	1.68
13	1.770649961	1.76
17	1.745077214	1.74
19	1.646458258	1.63

Table 2 Predictive and experimental values of dry density at different moisture content

Average moisture content	Predictive values of dry density on variation of plastic and liquid limit	Experimental values of dry density on variation of plastic and liquid limit
10	1.618059596	1.66
13	1.716354156	1.74
17	1.719767257	1.72
19	1.601891148	1.61

Table 3 Predictive and experimental values of dry density at different moisture content

Average moisture content	Predictive values of dry density on variation of plastic and liquid limit	Experimental values of dry density on variation of plastic and liquid limit
10	1.632725596	1.63
13	1.715335604	1.72
17	1.749171019	1.73
19	1.613019165	1.62

Table 4 Predictive and experimental values of dry density at different moisture content

Average moisture content	Predictive values of dry density on variation of plastic and liquid limit	Experimental values of dry density on variation of plastic and liquid limit
10	1.603393596	1.62
13	1.70254804	1.71
17	1.710770962	1.72
19	1.600855656	1.6

Table 5 Predictive and experimental values of dry density at different moisture content

Average moisture content	Predictive values of dry density on variation of plastic and Liquid Limit (17.36-17.34)	Experimental values of dry density on variation of plastic and Liquid Limit (17.36-17.34)
10	1.601366038	1.62
13	1.70166672	1.71
17	1.710466685	1.72
19	1.600766481	1.6

Table 6 Predictive and experimental values of dry density at different moisture content

Average Moisture Content	Predictive values of Dry Density on Variation of Plastic and Liquid Limit 17.30-17.31	Experimental values of Dry Density on Variation of Plastic and Liquid Limit (17.30-17.31)
10	1.643184414	1.66
13	1.725928816	1.74
17	1.702925362	1.72
19	1.601665229	1.61

Table 7 Predictive and experimental values of dry density at different moisture content

Average Moisture Content	Predictive values of Dry Density on Variation of Plastic and Liquid Limit (17.22-17.20	Experimental values of Dry Density on Variation of Plastic and Liquid Limit (17.22-17.20
10	1.623027112	1.63
13	1.702949668	1.72
17	1.745063064	1.73
19	1.612286646	1.62

Table 8 Predictive and experimental values of dry density at different moisture content

Average Moisture Content	Predictive values of Dry Density on Variation of Plastic and Liquid Limit (17.24-17.22)	Experimental Values of Dry Density on Variation of Plastic and Liquid Limit (17.24-17.23
10	1.595283366	1.62
13	1.691972199	1.71
17	1.706815367	1.72
19	1.600276019	1.6

Citation: Nwaokezi EE, Eluozo SN, Ukpaka C. Modeling and simulation of heterogeneous moisture content influence on foundation settlement in silt clay. *Material Sci & Eng.* 2023;7(1):32–36. DOI: 10.15406/mseij.2023.07.00200

Conclusion

Because water that is present in soil is through the permeability in the Litho-structure of the soil formation, these are through it flows in pores. The study was able to observe it rates of settlements influences on stability that reflect the bearing capacity of the soil. It also experienced certain levels of heterogeneity in phreatic surface, which are known to be major factors that affect settlements. The study considered quantifications of permeability as it created substantial, useful tools for rectifying the technicalities of safe foundation design in geotechnical projects. Unexpected settling has been caused by large variations in moisture content beneath foundation soil. These are based on the generated values from the study area due to the high rate of saturation in the foundation soil. The study also shows the level of reduction in the soil's bearing capacity on foundation settlement because the amount of water that settles in the soil is proportional to the amount of solid in the soil. Based on these circumstances, the rate of soil heterogeneity affects the moisture through the soil's macrospores. This also represents the variation in moisture content across different soil profiles; above the ideal moisture level, the settlement rises as moisture content increases. The study found that water content increases to a higher percentage than necessary, which will undoubtedly result in a noticeable change in the amount and its distribution pattern for shear force, of which it is also includes bending moments. The result generated explained the exponential growth from the trend, as the plasticity experience increase with variation in plastic, the higher the plasticity the lower the maximum density attained.

Acknowledgments

None.

Conflicts of interest

There are no conflicts of interest.

Funding

None.

References

1. Krishnamurthy S, Kameswar Rao NSV. Effect of submergence on bearing capacity soils and foundations. *Japanese Society of Soil Mechanics and Foundation Engineering*. 1975;15(3):62–66.
2. Murtza G, Mohd Athar, Khan SM. Influence of submergence on settlement of footing on sand Institution of Engineers. *India Journal CV*. 1995;75(6).
3. Earnesto Ausillo, Enrico Conte. Influence of groundwater on the bearing capacity of shallow foundation. *Canadian Geotechnical Journal*. 2005;42(2):2–7.
4. Shenbaga R, Kaniraj. Design aids in soil mechanics and foundation engineering tata mcgraw hill education private limited.
5. Fang Hsai-Yang. Foundation Engineering Hand Book, New Delhi: CBS Publishers & Distributers Pvt Ltd; p.152–157.
6. De Simone P, Zurlo R. The effect of groundwater table on the bearing capacity of shallow foundation. In proceedings of the 9th European Conference on SMFE: Dudlin; 1987.
7. Pande PB, Bajad SP, Khandeshwar SR. The effect of degree of saturation on the bearing capacity of shallow foundation. *International Journal of Innovative Research in Science Engineering and Technology*. 2014;3(7):1–6.
8. Xie L. Experimental study on the influence of water level rise and fall on bearing capacity and settlement of coarse sand foundation. *J Journal of engineering geology*.2013;21(6):871–877.
9. Xu DS, Chen W, Fan X. Experimental investigation of particle size effect on the self-healing performance of microcapsule for cemented coral sand. *Constr Build Mater*. 2020;256:119343.
10. Xu DS, Liu Q, Qin Y, et al. 2020 Analytical approach for crack identification of glass fiber reinforced polymer–sea sand concrete composite structures based on strain dissipations. *Struct Health Monit*. 2020;20(5):25–27.
11. Ying C, Hu, X, Zhou C, et al. Analysis of chemo-mechanical behavior of silty soil under long-term immersion in saline reservoir water. *Bull Eng Geol Environ*. 2020;80:627–640.
12. Chen J, Huang Y, Yang Y, et al. Evaluation of the influence of Jiangxiang reservoir immersion on corp and residential areas. *Geofluids*. 2020;2018:9720970.
13. Plomteux C, Porbaha A. CMC Foundation System for Embankment Support - A case history. Geo-Support. 2004.
14. Rouainia M, Muir Wood. A kinematic hardening constitutive model for natural clays with loss of structure. *Géotechnique*. 2000;50(2):153–164.
15. Yanhouidé JAG. Consolidation parameters for embankment settlement on soft clay soils in houston area master of science in civil engineering, faculty of the department of civil and environmental engineering cullen college of engineering university of Houston.

Citation: Nwaokezi EE, Eluozo SN, Ukpaka C. Modeling and simulation of heterogeneous moisture content influence on foundation settlement in silt clay. *Material Sci & Eng*. 2023;7(1):32–36. DOI: 10.15406/mseij.2023.07.00200