RESEARCH ARTICLE

European Journal of Environment and Earth Sciences
www.ej-geo.org

Determination of Swell Potential of Soils using Cole in Panyam, North – Central Nigeria

A. A. Umbugadu, M. I. Ancho, and Nghargbu K'tso

ABSTRACT

Swell potential of soils from parts of Panyam, North – Central Nigeria were investigated covering 72 square kilometres within latitudes N9021′ and N9026′ and longitudes 9011′E and 9015′30″E. With the increase of civil engineering constructions and the scramble for limited portions of competent soils for such constructions, there is an urgent need in a developing nation to study and characterize such soils based on its geotechnical properties. The geotechnical studies include twenty soil samples taken within the 1.5m depth with the aim of determining the swell potential in order to give appropriate guide to any civil engineering design and construction. The direct method of soil analysis which is the coefficient of linear extensibility (COLE), which ranges from 0.02–0.17 was used for the study. COLE Values greater than 0.06, were considered to be critical for most civil engineering design and constructions. Most of the samples studied were considered not safe for bungalows and some infrastructure without proper safety measures carried out to improve upon it.

Keywords: Constructions, shrinkage, soil, swell.

Published Online: September 13, 2021

ISSN: 2684-446X

DOI :10.24018/ejgeo.2021.2.5.164

A. A. Umbugadu*
Department of Geology & Mining, Nasarawa State University, PMB 1022, Keffi, Nigeria.
(e-mail: umbugaduallu@nsuk.edu.ng)
M. I. Ancho
Department of Geology &Mining, Nasarawa State University, PMB 1022, Keffi, Nigeria
(e-mail: mozisbubo@gmail.com)
Nghargbu K'tso
Department of Geology &Mining, Nasarawa State University, PMB 1022, Keffi, Nigeria
(e-mail: nghargtbu@gmail.com)

Corresponding Author

I. INTRODUCTION

Moisture content determines the amount by which the ground can shrink and/or swell near the surface [1], [2]. Clay soils have the tendency to absorb large quantities of water and they can also release water depending on the climate (especially in the tropics) causing shrink – swell behaviour.

Expansive soils cause problems to geotechnical designs and constructions [3]. This is as a result of their ability to absorb and release water at certain environmental conditions (Fig. 1). They can increase in volume beyond the perceptible or threshold limits and as such can cause damages to mostly buildings and roads. Because of the changes in behaviour, this normally results in differential settling causing cracks to shallow foundations, pavements etc. This study becomes useful because of the extent of damage of engineering structures constructed on such soils.

Reference [4] Posited that Coefficient of Linear Extensibility (COLE) of soil can be used to describe the shrink or swell potentiality of soils clod giving the relative potentials of soils to either shrink or swell.

Most soils in the area are problematic and engineering constructions are founded on such clay – rich soils which are of significant hazard due to their ability to shrink or swell with changes in moisture content. This study is important particularly in the area studied because of infrastructural development and other environmental factors like global warming, deforestation, desertification, etc, access to land for both domestic and industrial uses become difficult because the area is a rural agrarian community with poor infrastructural development and hence frequent clashes about land ownership in such parts of the country becomes imminent. With the lack of technical know – how to improve on the problematic soils, the available 'suitable' soil is limited and often not always suitable for high quality engineering design and construction, hence the need to improve on its properties.

Fig. 1. Nature of soil in the study area showing extension of crack as a result of swelling.

The study area is in Panyam village, north-central Nigeria. It is located between latitudes N9º21′ and N9º26′, longitudes 9º11′E and 9º15′30″E and falls within the Basement Complex of Nigeria (Fig. 2).

European Journal of Environment and Earth Sciences
www.ej-geo.org

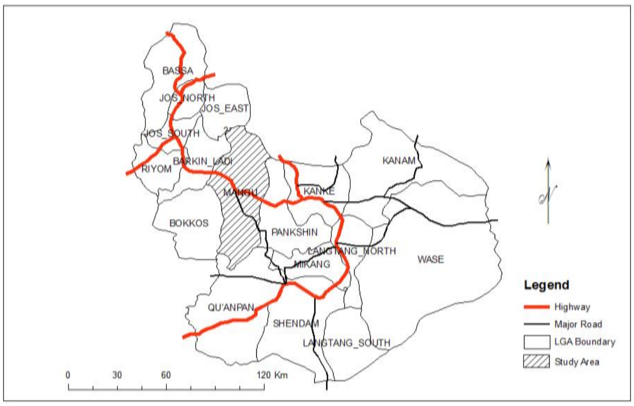


Fig. 2. Location map of the area.

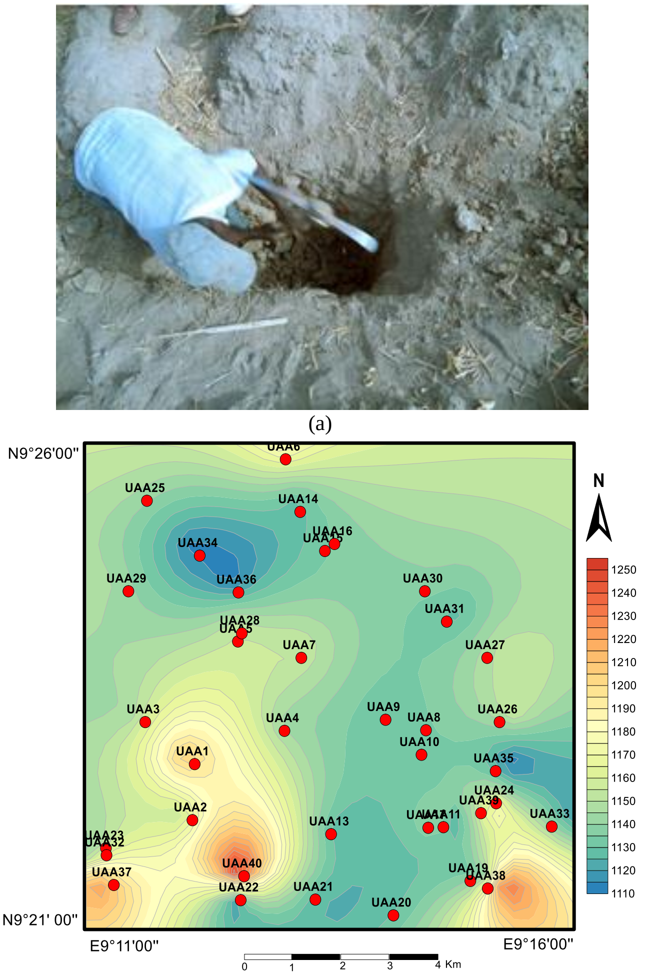
Samples of soils of the Quaternary period from Mangu, Central Nigeria were taken from highway construction sites and near residential buildings to study the effect of the property on such engineering construction. These materials as presented in Table I, with liquid limit of up to 80% and plastic limit up to 43% were as a result of the presence of some clay minerals particularly smectite and swelling chlorite in the samples.

The measure of the swell behaviour of the soils given as; Coefficient of Linear Extensibility (COLE) was measured using the method adopted by [7] from where the Volumetric Shrinkage (VS) was calculated from the equation below:

$$VS = [(COLE\ value + 1)^3 - 1] \times 100$$

II. Methodology

Soil samples derived from the weathering of granites and basalts were collected in the study area; Mangu, North central Nigeria. Sampling sites was carefully selected based on physiographic zones/features of the area; high ground and plains [5] with forty (40) disturbed samples collected at 1.5 m depth over 72 square kilometres to properly represent a wide variation in swelling properties and different parent materials that would constitute mainly of volcanic and basement rocks (Fig. 3a & b). The samples were collected by random sampling adhering to the [6] method of sampling.



(a)

(b)

Fig. 3. (a) Sampling of disturbed soil in the study. (b) Sampling location map.

III. Results

Geologically, the area is composed of four major rock units, which chronologically can be listed as Granite gneiss, fine/medium grained biotite granite, older and newer basalts (Fig. 4). Spatially, the newer basalt occupies about 85% of the area covering the Northern portion of the studied area. The fine to medium grained biotite granite occupies about 10% of the area occurring along the entire southern portion of the studied area. The granite gneiss which covers about 4% occurs along the southwestern part of the area while the remaining 1% of the area far north is occupied by the older basalt.

The older and younger basalts are Tertiary and Quaternary volcanics, respectively. The basalts are distinguished on the basis of their period of emplacement and textural differences [8]. The older basalts occur as decomposed boulders, plugs or dome-like outcrops, while the newer basalts occur as cones and lava flows.

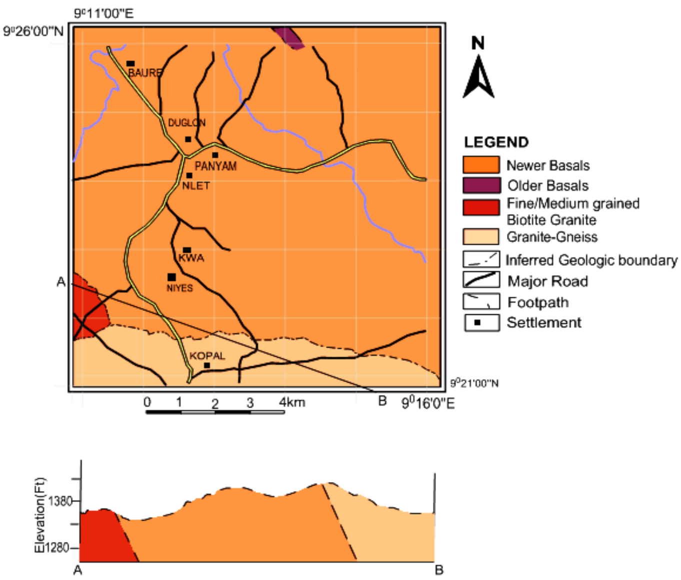


Fig. 4. Geological Map of the Area.

Soil samples constitute chiefly of kaolinite and smectite. The samples have wide range of swelling potentials due to the varying minerals contained in them and the areas it was sampled. Table I below gives a summary of the swelling characteristics, coefficient of linear extensibility and volumetric shrinkage. Atterberg limits with liquid limit (LL), plastic Limit (PL). Particle size distribution and compaction characteristics with optimum moisture content (OMC) and maximum dry density (MDD).

Coefficient of Linear Extensibility (COLE), Volumetric Shrinkage (VS), Optimum Moisture Content (OMC), Maximum Dry Density (MDD), Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI)

Researchers like [3], [9] have discussed extensively linking the swell/shrink behaviour of such soils with mineralogy, water content, and clay content. Reference [10] was of the opinion that the increase in COLE values with depths at surface horizons was as a result of the decrease in organic matter. According to [11], strong and reliable correlation based on linear relationship, has been found connecting swell percent with initial state factors like clay content and COLE.

TABLE I: SWELLING CHARACTERISTICS, ATTERBERG LIMITS AND PARTICLE SIZE DISTRIBUTION OF SOIL TYPES OF THE AREA

Sample ID	Swelling Characteristics		Consistency Limits			Particle Size Analysis			Compaction	
	COLE	VS	LL (%)	PL (%)	PI (%)	Sand (%)	Silt (%)	Clay (%)	OMC (%)	MDD (g/M^3)
UAA 2	0.040	12.486	40	24	16	20	47	33	20.0	1.54
UAA 3	0.021	06.433	37	25	12	08	68	24	24.5	1.54
UAA 4	0.039	12.162	42	21	21	11	57	31	22.5	1.52
UAA 5	0.034	10.550	54	41	13	16	61	23	21.5	1.56
UAA 6	0.036	11.257	30	20	10	14	62	20	15.0	1.80
UAA 9	0.130	06.120	65	46	19	10	33	57	28.5	1.44
UAA 14	0.152	42.003	65	33	22	08	21	70	31.0	1.43
UAA 15	0.166	58.524	70	45	25	10	18	72	30.0	1.40
UAA 16	0.022	59.341	66	39	27	12	65	25	20.0	1.62
UAA 24	0.168	59.341	40	20	20	09	15	76	25.7	1.47
UAA 25	0.082	26.672	46	26	20	10	46	44	26.0	1.46
UAA 26	0.079	25.621	60	44	16	12	45	43	28.0	1.47
UAA 27	0.147	50.900	47	26	21	08	27	65	32.5	1.44
UAA 29	0.079	25.621	43	22	21	07	50	43	26.0	1.44
UAA 30	0.108	36.025	49	26	23	10	38	52	27.1	1.44
UAA 31	0.108	36.025	50	34	26	10	38	52	13.8	1.84
UAA 33	0.036	11.193	42	20	22	13	58	29	19.8	1.55
UAA 34	0.085	27.728	52	31	21	06	45	45	16.2	1.77
UAA 35	0.018	05.497	62	44	18	12	70	18	26.8	1.45
UAA 36	0.080	25.971	54	32	22	06	49	43	25.80	1.48

IV. DISCUSSION

COLE is a good indicator of field behaviour of soils which is used for characterization in terms of volume and shrink – swell potential. Table II categorized soils shrink – swell behaviour based on their COLE values.

TABLE II: SCHAFER AND SINGER COLE RATING

COLE	Rating
0.00 – 0.03	Slight
0.03 – 0.06	Moderate
0.06 – 0.09	Severe
>0.09	Very severe

Soils within the study area reflect the different ratings as outlined by [9]. Three soil samples, UAA3, UAA 16 and UAA 35 fall under the slight with minimum or no impact to infrastructure that were constructed around the vicinity. Samples UAA2, UAA4, UAA5, UAA6 and UAA 33 have moderate impact on infrastructures of the area according to the COLE values and rating in Table II. The most intense impact are those infrastructures constructed on areas where the soils are gotten from UAA25, UAA26, UAA29, UAA34, UAA 36, UAA 9, UAA 15, UAA24, UAA 27 and UAA 30 where the rating is severe and very severe. The COLE values as plotted shows a good correlation with the clay content. The higher the clay content the higher the value of COLE (Fig. 5).

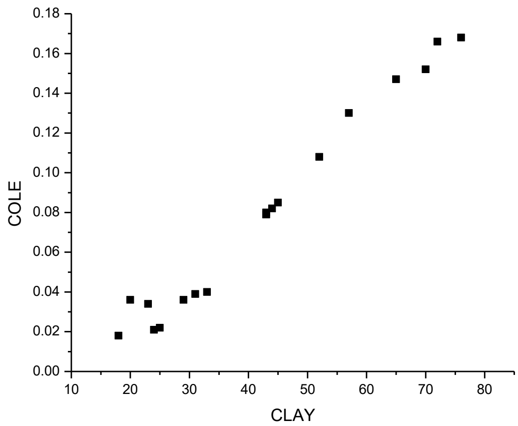


Fig. 5. Plot showing the relation of clay fraction with COLE of soils in the study area.

Fig. 6. Impact of COLE on shrink – swell behaviour of soils in the area.

V. Conclusion

COLE, which is a direct method, used to predict soil swell – shrink behaviour of soils, was analysed for soils of the area.Ten out of twenty samples analysed, showed severe to very severe rating as impact to infrastructure in the area, and hence linked to the infrastructural collapse of foundation in such areas. Even though most of the southern portion of the area was mostly clay, the COLE values correlate with the nature of clay minerals found within the area. Areas outlined as having swelling clays like Illite fall under the very severe and severe swelling category while those clays that occupied predominantly the southern portion of the area which are kaolinite, are the ones that fall under the moderate swelling category.

References

[1] P.G. Biddle. Tree roots and foundations, Arboriculture Research and Information Note 42/98/EXT, 1998.
[2] R. Driscoll. The influence of vegetation on the swelling and shrinking of clay soils in Britain. *Geotechnique*, 1983, (33) 93-105
[3] F. H. Chen. (1988). Foundations on Expansive Soils. Elsevier, Amsterdam, the Netherlands.
[4] M. M. E. Zumrawi. Swelling Potential of Compacted Expansive Soils. *International Journal of Engineering Research and Technology*. 2013, Vol. 23) 1-6.
[5] Food and Agricultural Organization, 1977. Guidelines for soil profile Descriptions (2nd edition). Rome, 66.
[6] R. Driscoll&M. Crilly. Subsidence damage to domestic buildings. Lessons learned and questions asked. Building Research Establishment, London, 2000.
[7] W. G. Holtz & H. J. Gibbs. Engineering Properties of Expansive Clays. Transactions of the American Society of Civil Engineers, 1956, (121), 641-663.
[8] D. E. McCormack, L. P. Wilding. Soil Properties Influencing Swelling in Cranfield and Geeburg soils. Soil Sci. Soc. Am. Proc. 1975, 39, 496-502.
[9] P. J. Thomas, J. C. Baker, L. W. Zelazny.An expansive soil index for predicting shrink – swell potential. *Soil Sci. Soc. Am. J.*2000, 64, 268-274.
[10] F. H. Chen. The use of pies to prevent the uplifting of lightly loaded structure founded on expansive soil. Concluding proceedings engineering effects of moisture change in soils, *International Research and Engineering Conference on expansive clay soils. A and M. Texas*, 1965, 152-171.
[11] A. Sridharan & Y. Gurtug. Swelling Behaviour of Compacted Fine – grained soils. *Engineering Geology Journal*, 2004, 72, 9-18.

A. A. Umbugadu holds a PhD in Engineering Geology from the University of Nigeria, Nsukka. He is currently a Lecturer at the Department of Geology and Mining, Nasarawa State University, Keffi, Nigeria.

M. I. Ancho holds a Masters Degree in Hydrogeology from the Federal University of Technology Minna, Nigeria. He is currently a Lecturer with the Department of Geology and Mining, Nasarawa State University, Keffi, Nigeria.

Nghargbu K'tso holds a PhD in Medical Geology from the Ahmadu Bello University, Zaria, Nigeria. He is currently a Lecturer with the Department of Geology and Mining, Nasarawa State University, Keffi, Nigeria.