International Journal of Advanced Geotechnic and Impact Engineering (IJAGIE), ISSN (Online): 2545-5559
A. J. OLAREWAJU & S. S. OMOPARIOLA
Open Access Accepted: May. 2022 Vol. 2, Issue 1, July. 2022 , Pp 1-6

Coefficient of Consolidation of Saturated and Unsaturated Eggshell Powder Stabilized Lateritic Soil of Part of South-Western Nigeria

[1] Akinola Johnson OLAREWAJU and [2] Sunday Samuel OMOPARIOLA
Civil Engineering Department, Federal Polytechnic Ilaro, Ogun State, Nigeria

E-mail: [1] akinolajolarewaju@gmail.com and [2] hfeforchrist@yahoo.com

Abstract: *Eggshell is an agricultural waste which has been found to possess pozolanic property and has been used as partial replacement of cement in other materials. It is against this background that it is been used as a stabilizing agent on problematic lateritic soil. The laterite soil was obtained from a borrow pit at Ajegunle along Ilaro-Papalanto road, Yewa South Local Government Area in Ogun State, Nigeria. The borrow pit site lies within the coordinates 6°53'11.81''N and 3°7'44.88''E.The eggshells were obtained from Obasanjo Farms Nigeria Limited, Ota, Ogun State, Nigeria and grounded to powder. In line with BS 1377 (1990) and other relevant codes of practice, consolidation tests on 1hour and 24hours soaked samples were conducted to determine the relevant consolidation parameters and settlement indices. Eggshell powder was substituted in the lateritic soil (sedimentary formation) in range of 0% to 50% with 0% serving as control experiment for both the 1-hour soaked and 24-hour soaked samples. The results indicated that for the 1hour soaked sample, the value of the coefficient of consolidation is within the range of 1.22 at 50% substitution to 1.68 at 10% substitution, while the range is 0.63 at 50% substitution to 1.60 at 20% substitution. Finally, from the results, coefficient of consolidation reduces as the percentage eggshell powder substitution increases.*

Keywords: *Coefficient; Consolidation; Stabilization; Lateritic; Soil; Settlement; Eggshell Powder*.

Introduction

The role of the engineering properties of soils in civil engineering construction works is very significant. According to Akintayo et al. 2021, the stability and serviceability potential of the intending civil engineering structure can be affected substantially by the deficiencies in the properties of soil. Omotoso et al. (2012) further stated that the stability, serviceability and durability of such construction works such as buildings, road, embankments, dams etc. is greatly influenced by the characteristics of the soils upon which they are founded. It is therefore imperative that the properties of soils should be carried out before embarking on such construction works so as to determine whether it is geotechnically suitable as a construction material Ikeagwuani and Nwonu (2019) attested to the use of various kinds of soil for civil engineering construction. It was further noted that while some soils are suitable for use in their natural states, others needed to be treated or modified before they can be suitable for use. The persistent search by geotechnic engineers to provide means of militating against this unpleasant development was equally highlighted. The means of modification posited includes excavation and replacement of the materials or modifying their properties by the addition of additives so that they can support the applied loads by the structures. Such soils which are termed problematic soils if not treated have the tendency to cause collapse of structures as a result of its susceptibility to high rate of volume changes. According to NBRRI (1983), the strength and stability of lateritic soils under service load may be unpredictable and undependable due to the presence of considerable quantity of clay minerals that possesses traces of Kaolinite, Illite and traces of Montmorrrilonite. Amadi (2010) posited that such lateritic soils possessing such minerals tend to swell thereby posing a lot of problems in the engineering properties of soil resulting in failure of highway and other engineering structures. According to Aizebeokhai et al. 2016 and Adeola and Olaleye (2018), Ilaro fall within the range of the Benin/Dahomey basin which is a sedimentary formation. This basin lies along the continental gulf of Guinnea, stretching through Southern Ghana, Togo, the Republic of Benin and extending to South Western Nigeria. This formation includes Abeokuta formation, Ewekoro formation, and Ilaro formation all in South Western Nigeria among others.

Background Study

Consolidation is the process of drainage of pore water from a soil of low permeability that is fully saturated so as to cause gradual reduction in volume. It is a continuous process of dissipating the total stress set up as a result of the excess pore water pressure (Bolarinwa et al. 2017). Bolarinwa et al. (2017) opined that the in – situ geotechnical properties of most lateritic soils are not suitable for civil engineering constructions. The option of burrowing or replacement is uneconomical, hence the need to modify the soil properties through the process of soil stabilization In the opinions of Bolarinwa et al. (2017) consolidation has to do with the way a saturated soil in compression will respond when steady static pressure is imposed on it with respect to predicting the stresses and displacement of the loaded soil as a function of space and time. The process involves setting up a model test in which soil sample is loaded systematically so as to predict the type of deformation that will take place in a soil stratum under similar loading on ground (Crawford,1986). The result obtained coud then be used in predicting the settlement of soil subjected to static loading. The result of consolidation model test is of immense benefit in the design and construction of civil engineering infrastructures (Schiffman et al. 1984). Shiva and Darga (2016) stressed the importance of consolidation in forecasting the possible future settlement that can emanate from imposed load of a structure on the soil through its foundation. It was further stated that there are induced changes in consolidation coefficient as a result of permeability and compressibility of soils. Even though the macro-structure characteristics of soil stratum, its thickness as well as the drainage condition may result in exaggerated in-situ settlement, the discrepancies in the observed behavior and the actual behavior can still be anticipated.

IRC:SP:89 (2010) and Latifi (2014) defined soil stabilization as the process of blending and mixing soil with some other materials for the purpose of obtaining a soil with considerable improvement in some of its physical and engineering properties. This process results in the alteration of such properties as gradation, texture, and plasticity, workability, tendency to swell or change in volume, compressibility strength and consolidation parameters. The aim of soil stabilization is to obtain a soil with an improved gradation, increased durability, increased strength, reduced plasticity index and reduced tendency to swell. When these are achieved, the properties of soil as construction materials are improved. According to Buhler and Cerato (2007) and Hussey et al. (2010), modifying the characteristic of the soil in situ is a preferred method of soil stabilization because of the high cost of the traditional method of soil replacement. The process of soil stabilization is an ancient practice whereby lime was used as stabilizer for earth road construction in Egypt, Mesopotamia, Greece and Rome. This according to McDowell (1959) has been in existence for about 5,000 years ago. According to Firoozi et al. (2017) the benefit of soil stabilization is the improvement of the performance of insitu subsoils. These benefits include reduction in volume change tendencies, soil plasticity and swelling/shrinkage capabilities. Other befits are increase of the dry unit weight, soil strength, durability, and stiffness. There are several methods of soil stabilization adopted to improve the geotechnical properties of such soils so that the stability and serviceability requirements can be met. Some of these methods are mechanical, Chemical, Thermal, Electrical and use of additives (Habiba, 2017). The additives reportedly used for soil stabilization includes Cement, Bitumen, Geo-textile and Fabrics, Recycled and Waste Products Fly ash, Rice Husk ash etc.

According to Muntohar (2009) coefficient of consolidation (Cv) is the primary parameter controlling the settlement rate of soils. It is computed from test data obtained from the laboratory or on the basis of in situ measurements. It is very essential to ensure that it is properly determined so as to make the right prediction of true time rate of the settlement. There are several curve fitting methods that can be used to evaluate the coefficient of consolidation (Cv) from the laboratory oedometer test based on Terzaghi's one-dimensional consolidation theory (Shiva and Darga, 2016). There are several methods that have been used by many researchers in computing the coefficient of consolidation. The followings are some methods highlighted by Shuklar et al. (2009) Casagrande logarithm of time method and Taylor square root of time method, inflection point method, analytical method, velocity method, rectangular hyperbola fitting method, revised logarithm of time fitting method, Naylor and Doran method of successive approximations. However, Robinson and Soundara (2008) stated that although there are several methods for evaluating Cv from time–deformation (t – d) data, not many literatures are available.

Eggshell is an agricultural waste that is scattered around the environment. They are waste products of poultry farms, restaurants, food industry and bakeries. Its disposal poses an enviromental challenge due to its potential to cause environmental pollution (Shah et al. 2013; BashirandManusamy2015;Raji and Samuel2015).Afolayan et al. (2007) described eggshell as a widely accepted agricultural waste pozollan. According to Mohamad (*2016),* they consist of a thinoutermostcoating, the outer shell, inner shell and the inner membrane. The outer most coating is made up of the cuticle, while the outer and inner shell membranes are made up of keratin. The major chemical composition of egg shell is calcium carbonate accounting for about 93.70% (Winton, 2003; Mohammed, 2016; Okonkwo et al. 2012). Similarly, calcium compounds the major component of Ordinary Portland Cement is composed of dicalcium silicates, (C2S), tricalciumsilicate, (C3S), tricalcium aluminate, (C3A),and tetra-calcium aluminoferite, (C4AF) (Shirley, 1980). It is therefore, indicated that cement and eggshells have the same primary composition in calcium compounds. The calcium trioxocarbonate (IV) which has been established to be common to eggshell and cement is a naturally abundantly available mineral. On the basis of the common compositional characteristics of cement and eggshells, with respect to the high percentage of calcium carbonate eggshell has been recommended as a prospective alternative to cement in view of the rising cost of cement (Asman et al. 2017).

Methodology

The laterite soil was obtained from a borrow pit at Ajegunle along Ilaro-Papalanto road, Yewa South Local Government Area in Ogun State, Nigeria. The borrow site lies within the coordinates 6°53'11.81"N and 3°7'44.88"E.The eggshells (Figure 1a) were obtained from Obasanjo Farms Nigeria Limited, Ota, Ogun State, Nigeria and grounded to powder as shown in Figure 1b. In line with BS 1377 (1990) and other relevant codes of practice, consolidation tests on 1 hour and 24 hours soaked samples were conducted to determine the relevant consolidation parameters and settlement indices. Eggshell powder was substituted in the lateritic soil (sedimentary formation) in range of 0% to 50% with 0% serving as control experiment for both the 1-hour soaked and 24-hour soaked samples.

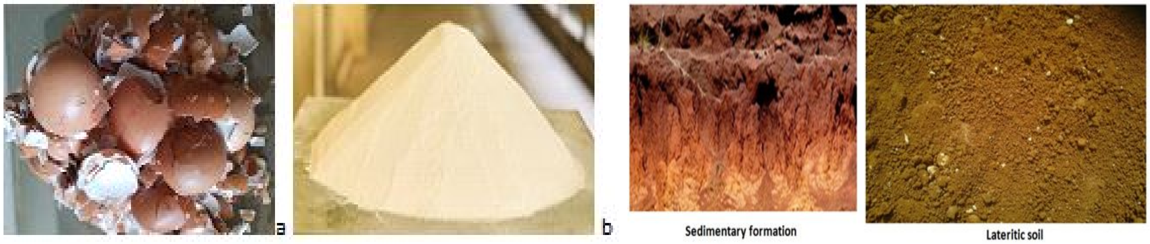

Figure 1: (a) Eggshell; (b) Eggshell Powder; (c) Sedimentary Formation (Lateritic Soil)

Results and Discussion

The results of coefficient of consolidation of eggshell powder stabilized sedimentary formation for composite materials for 1hour soaked and 24hour soaked samples for percentage substitution ranging from 0% to 50% with 0% serving as control experiment are graphically presented in Figures 2 to 3 respectively. The results of representative of pressure (log) against void ratio of eggshell powder (20%) stabilized sedimentary formation for 1hour soaked samples as well as the results of pressure (log) against dial gauge reading of eggshell powder (20%) stabilized sedimentary formation are graphically presented in Figures 4 and 5 respectively.

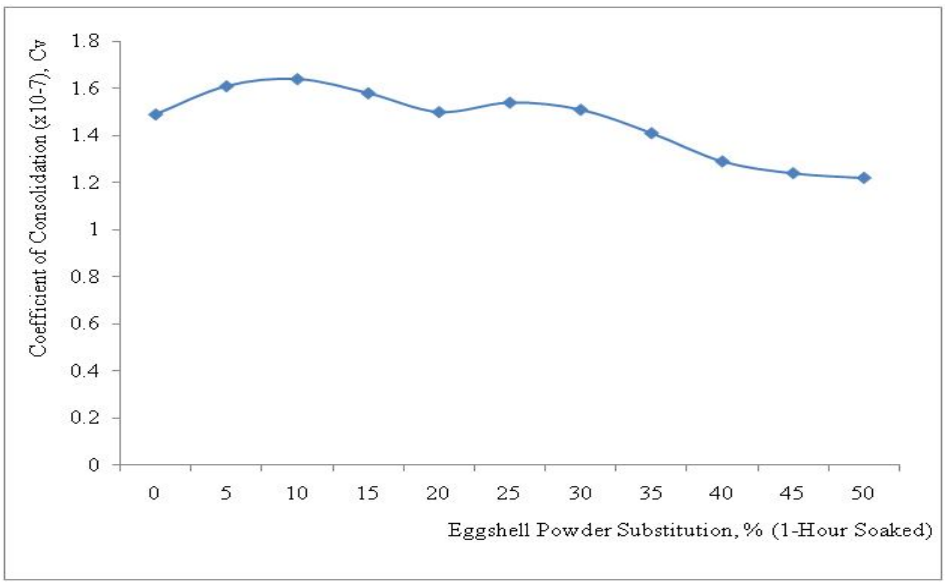

Figure 2: Results of coefficient of consolidation of eggshell powder stabilized sedimentary formation for 1hour soaked samples

Test results on the coefficient of consolidation of eggshell powder stabilized sedimentary formation for 1hoursoaked samples as presented in Figure 2 indicates a steady increase in value from 1.49 at 0% substitution level to 1.64 at 10% substitution level. From 15 % substitution of ESP, the value of the coefficient of consolidation begins to decrease steadily from 1.54 to 1.22 at 50% substitution. It can thus be inferred that the optimum level of the substitution of ESP for a 1hoursoaked sample occurs at 10% with a coefficient of consolidation (Cv) of 1.64

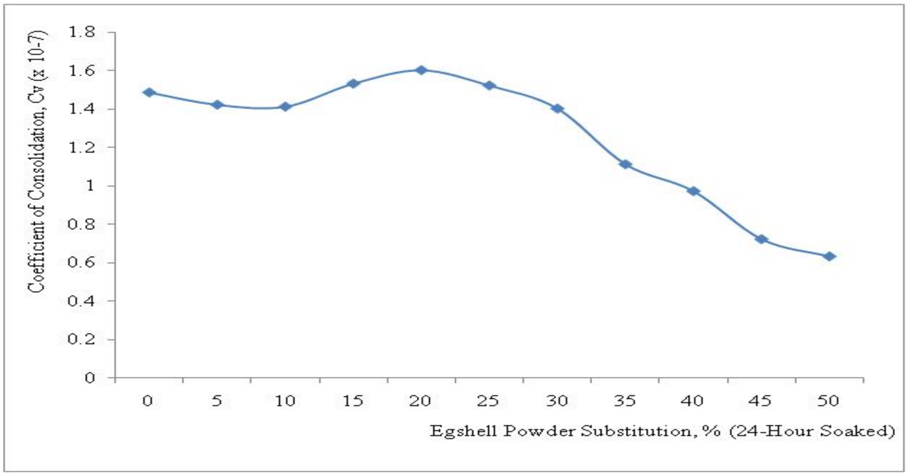

Figure 3: Results of coefficient of consolidation of eggshell powder stabilized sedimentary formation for 24hoursoaked samples

From the result of the coefficient of consolidation of eggshell powder stabilized sedimentary formation for 24hour soaked samples presented in Figure 3, there was a decrease in value of the coefficient of consolidation (Cv) from 1.48 at 0% substitution of ESP to 1.42 and 1.41 at 5% and 10% substitution respectively. From 15% substitution, the value increases to 1.53 and 1.6 at 20% substitution. Thereafter, there was a steady decrease from 1.6 at 20% substitution to 0.63 at 50% substitution of ESP. This implies that the optimum coefficient of consolidation for the 24hour soaked sample is 1.6 at 20% substitution level.

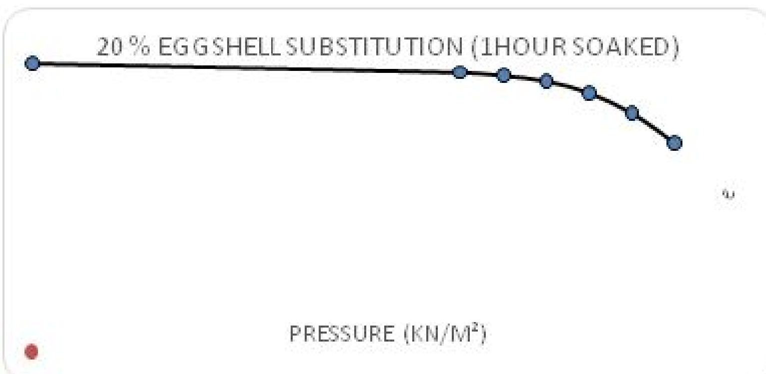

Figure 4: Results of pressure (log) against void ratio of eggshell powder (20%) stabilized sedimentary formation for 1-hour-soaked samples

The graph of pressure (log) against void ratio of ESP substitution at 20% stabilized sedimentary formation as presented in Figure 4 decreases steadily from 0.4 to 0.25, while the graph of pressure (log) against dial gauge reading of ESP substitution at 20% stabilized sedimentary formation as presented in Figure 5 increases steadily from 78 to 90.

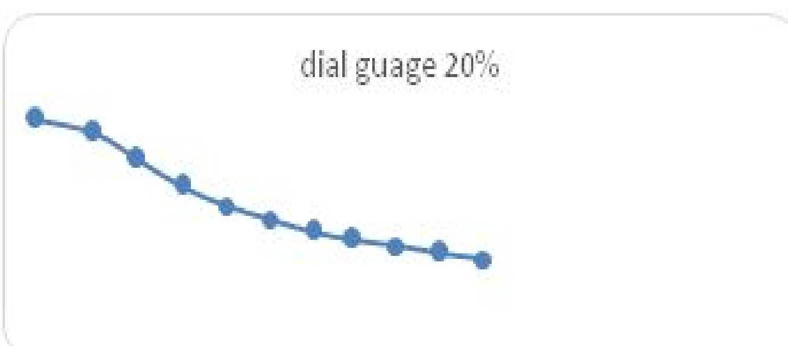

Figure 5: Results of pressure (log) against dial gauge reading of eggshell powder (20%) stabilized sedimentary formation

Conclusion

In this study, the impact of underground accidental explosions occurring below the ground surface and directly above buried pipes This study has presented the results of various coefficient of consolidation of eggshell powder stabilized sedimentary formation from oedometer test. Eggshell powder was substituted in the lateritic soil (sedimentary formation) in range of 0% to 50% with 0% serving as control experiment for both the 1-hour soaked and 24-hour-soaked samples**.** The result implies that the optimum substitution level of eggshell powder is at 10% for the one hour soaked and 20% for the 24hour soaked sample. Finally, from the results, coefficient of consolidation reduces as the percentage eggshell powder substitution increases.

Acknowledgement

The author acknowledges the contributions of OGUNSANYA Michael Oluwasegun, MULERO Mujeeb Opeyemi, SUNDAY Emeka, AIYEDUN Isaac Omohkowa, ADEWALE Jeremiah Olamide and OYETUNJI Sheriff in data collection as well as Oderinde, S. A. for technical assistance in the Geotechnical and Material Laboratories of the Federal Polytechnic Ilaro, Ogun State, Nigeria.

References

Adeyeri, J. B., Bolarinwa, A. and Okeke, T. C. (2017): "Geotechnical Properties of Soils in Ikole – Ekiti Area, Southwestern Nigeria", *Electronic Journal Geotechnical Engineering*, Vol. 22, No.1, Pp 21-32. Available at ejge.com, 06/02/2017, 12.00pm.

Afolayan J. O, Oriola F.O.P, Moses G and Sani J.E, (2017): Investigating the Effect of Eggshell Ash on the Properties of Sandcrete Block International Journal of Civil Engineering, Construction and Estate Management Vol.5, No.3, pp.43-54, August

Akintayo O. Ojo, Opeyemi O. Ogunyinka, Oluwatoyin O.Daramola, Felix A.Olaoye (2021): Hydro-chemical and microbial assessments of water resources around cassava mills in a sedimentary formation of Ilaro, Southwest Nigeria Applied Water Science 11:62 https://doi.org/10.1007/s13201-021-01384-7

Amadi, A. (2010). Evaluation of Changes in Index Properties of Lateritic Soil Stabilized with Fly Ash. *Leonardo Electronic Journal of Practices and Technologies*. *9*(17): 69-78.

Asman Nurul Shahadahtul Afizah, Dullah Salinah, Ayog Janice Lynn, Amaludin Adriana, Amaludin Hassanel, Lim C. H, and Baharum Aslina, (2017).Mechanical Properties of Concrete Using Eggshell Ash and Rice Husk Ash As Partial Replacement Of Cement, MATEC Web of ConfereAnces103, 01002*ISCEE*

BashirASMandManusamyY(2015).Characterizationofraweggshellpowder(ESP)asagood bio - filler *Journal of Engineering Research and technology* **2**(1)56–60.

Buhler R, Cerato A. Stabilization of Oklahoma expansive soils using lime and class C fly ash. In: Geo-denver (2007): new peaks in geotechnics. ASCE; 2007. https://doi.org/10.1061/40906(225)1.

Crawford C. B. (1986). State of the art: Evaluation and interpretation of soil consolidation tests, consolidation of soils: Testing and evaluation,

Firoozi Ali Akbar, Olgun C. Guney, Firoozi Ali Asghar and Baghini Mojtaba Shojaei, *(2017).* Fundamentals of soil stabilization International Journal of *Geo-Engineering, pp8 – 26*

Habiba Afrin (2017). A Review on Different Types Soil Stabilization Techniques. *International Journal of Transportation Engineering and Technology.* Vol. 3, No. 2, pp. 19-24.

Hussey N, Cerato A, Grasmick J, Holderby E, Miller G, Tabet W (2010). An assessment of soil parameters governing soil strength increases. In: Geo Florida: advances in analysis, modeling & design. ASCE; 2010. https://doi.org/10.1061/41095(365)274

IkeagwuaniChijioke Christopher, Nwonu Donald Chimobi (2019).Emerging trends in expansive soil stabilisation: Areview, Journal of Rock Mechanics and Geotechnical Engineering 11, 423e440

IRC: SP: 89-(2010),"Guidelines for Soil and Granular Material Stabilization Using Cement, Lime and Fly ash", Indian Road Congress, New Delhi.

Macchechnie, W. R. (1967). Some Consolidation Characteristics of a Residual Mica Schist. *In Proceedings of the Regional Conference for Africa—Soil Mechanics and Foundation Engineering. 44(2): pp.135-139).*

McDowellC(1959),Stabilizationofsoilswithlime,lime-flyash,andotherlimereactivematerials.HighwayResBoard Bull231:60–66

Mohamed Ansari M, Dinesh Kumar M, Milan Charles J and Vani G (2016). Replacement of Cement using Eggshell Powder *SSRG International Journal of Civil Engineering* **3**1–3.

NIBBRI (1983). 'Engineering properties of black cotton soils of Nigeria and related Pavement design'. Nigerian Building and Road Research Institute, Research Paper, 1- 20

Okonkwo U.N., Odiong I.C., and Akpabio E.E. (2012). The effects of eggshell ash on strength properties of cement-stabilized lateric, Int. J. of Sustainable Construction Engineering and Technology, **13**(1),18-25

Omotoso O A, Ojo O J and Adetolaju F.T, (2012). Evaluation of some Engineering properties of Lateritic soils around Dall Quarry, Sango Area, Ilorin, Nigeria. NTDJ, 9(1) 37.59 Faculty of Engineering & Technology University of Ilorin.

Raji S A and Samuel A T (2015). Egg shell as a fine aggregate in concrete for sustainable construction *International Journal of Scientific and Technology Research* **4**(09) 8–13.

Schiffman R. L., Pane V. & Gibson R. E. (1984). The theory of one- dimensional consolidation of saturated clays IV. An Overview of non- linear finite strain sedimentation and consolidation. Proceedings, ASCE Symposium on Sedimentation/Consolidation Models, San Francisco, pp. 1-29.

Shah C J, Pathak V B and Shah R A (2013). A Study of future trend for sustainable development by incorporation of supplementary cementitious materials *International Journal of Inventive Engineering and Sciences* **1**(11)19–26.

Shirley, D.C (1980). Introduction to concrete. Cement and Concrete Association, Wexham Springs, Slough SL3 6PL.

MuntoharAgusSetyo, (2009), Reliability of the Method for Determination of Coefficient of Consolidation (cv), 13th Annual Scientific Meeting Denpasar, Bali, 5-6 November

Shiva Prashanth Kumar K. and Darga Kumar N. (2016) Evaluation of Coefficient of Consolidation in CH Soils, J*ordan Journal of Civil Engineering*, Volume 10, No. 4, pp 515 - 528

ShuklaS. K., Sivakugan N. and Das B. M., (2009) Methods for determination of the coefficient of consolidation and field observations of time rate of settlement — an overview, International Journal of Geotechnical Engineering 3: pp89 – 120