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Critical Appraisal of Shear Strength Parameters of Contaminated Soils and Evaluation of Sub-Surface Remediation Processes

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ABSTRACT: *The purpose of the report is to undertake a shear box testing on two soil samples to gain knowledge of possible source and direct effects of contamination of sites and evaluate remediation processes.* *This is to enable a deeper understanding of site contamination, as found in many brownfield sites, and critically appraise remediation solutions to produce a decontaminated site. The basis of analyzing shear strength is to understand soil stability problems such as lateral pressure on earth retaining structures, slope stability and soil bearing capacity. The experiments cover determination of consolidated drained shear strength of the two types of soil materials. The specimen is deformed at controlled rate on single shear plane relative to the configuration of the apparatus. Non-uniformity usually exists in the distribution of shear stresses and displacements within the specimen, and also the height may not be necessarily defined for the determination of shear strains. The shear strength parameters obtained of the sediments were cohesion of 35 KPa, and friction angle of 60° which are important because strength of the soil determines its safety in relation to loading in any geotechnical designs and analyses. The implication is that failure in the soil would mean the eventual collapse of mechanical and related loads or structures founded upon it.*

Keywords: *shear box test, shear strength, cohesion, friction angle, contaminated sites, remediation.*

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I. INTRODUCTION

The release or eventual presence of contaminants in whatever form in soils can easily be acted upon by several environmental factors. These factors could be in the form of driving mechanisms or forces, for instance contaminants in soils can be influenced by the force of gravity. When once exposed to such driving mechanisms, the contaminant could migrate into other compartments of the soil. Several studies are available (Newell et al., 1995; Itugha, 2008) which have discussed issues relating to the movement of contaminants in the unsaturated soil medium. As the affected contaminant continues mobility with time some fractions will be retained as residuals in the pores due to capillary forces and differences in grain composition. The ability of the contaminant to sustain its lateral spreading may be dependent on the magnitude of deposit or spill and permeability (Charles and Skinner, 2001). The concern is that if unchecked, it may likely approach and enter the water table or/and surface water if in coastal beach-sediments which in most cases are low permeable strata (Itugha et al, 2016).

In view of the foregoing, it should be noted that the groundwater and saturated zone will be the target through the varying mechanisms of spreading which are affected by such factors as chemically characteristic contaminants, the heterogeneity of the unsaturated zone and the aquifer (Newell et al, 1995). Consequently, it is clear that humans, plants and marine aquatic lives and entire vegetation could be affected; and in some cases

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quantification techniques of the migration pattern may be difficult to produce expected outcomes. This will alienate control measures such as site characterization plans from meeting expected goals thereby affecting remedial objectives.

Since the foregoing is of practical concern to both industry and academic community, it is therefore imperative for engineers and scientists of all branch of learning to understand the variables controlling pollutants in soils through the use of detection and measurement techniques that can be applied to identify and characterize contaminated sites. Several techniques such as conventional (drilling and installment of observation wells, sampling and analysis of soil and groundwater) and alternative techniques (geophysical, direct-push, soil gas sampling and field analytical techniques) are sited in literature (Wright et al, 1973; Annable et al, 2008; Duncan and Wright, 1980).

Instructively, the conventional techniques enable actual view of pollution problems while the alternatives are incorporated because of the additional information they supply; such as soil quality, sediment and strata, surface geomorphology, etc; are widely accepted by environmental services regulators and professionals as basis for decisions affecting soil support capacity.

In this study, shear box test has been incorporated in the laboratory procedure with some sediment soil samples obtained from sites to carry out undrained and drained shear tests, and to determine their residual strength parameters. The shear strength of any soil reflects its resistance to shearing stresses which is a measure of the soil resistance to deformation by continuous displacement of its individual soil particles. Primarily, shear strength depends on the mechanics of frictional and non-frictional interactions between soil grains.

Further, the occurrence of shear failure results from these mechanical stresses between grains when they slide or roll over each other (Leonards, 1982). Consequently, cohesion and internal frictions (resistance) are associated with soil shear strength relativities. While cohesion is stress independent and is associated to cementation between sand grains and electrostatic attraction between clay particles, frictional resistance is stress dependent component related to the internal frictional angles resulting from process inclinations of soil grains on each other.

II. TEST PARAMETERS AND THEIR RELATIVE SIGNIFICANCE

The test method is simple and relatively fast, thus enabling determination of the consolidated drained strength of the soil materials. It is relatively rapid because the drainage path through the test specimen is not significantly elongated, implying that excess pore pressure is dissipated faster when compared to other methods of drained stress test. The results are usually comparable to field situations, even though in the field case natural consolidation has occurred under existing normal stresses.

However, some disadvantages are associated with this test as with any other tests within the range of this expected result. These may relate to the observed rotation of the principal stress which may or may not give a true model of the natural conditions of the field, the inability to control pore pressures which is why the tests are assumed to be drained, the horizontal plane is susceptible to failure, not necessarily because it is a weak plane, and non-uniform stress conditions can be observed within the shear box. The range in normal stress, rate of shearing, and general test conditions are approximated for the soil samples prepared for the experiments.

III. SIGNIFICANCE AND DETERMINATION OF SHEAR STRENGTH PARAMETERS

The strength of the soil determines its safety in relation to loading in any geotechnical structure. The implication is that failure in the soil would mean the eventual collapse of mechanical loads or structures founded upon it. The likelihood of this discrepancy in geotechnical support efficiency of the soil being the mechanics of the structural composition of the soil aggregate analogous to the structural complexities encountered in determination of shear stress factors in welded joints (Jumbo, et al 2012). The basis for effective analysis of shear strength is to understand soil stability problems such as lateral pressure on earth retaining structures, slope stability and soil bearing capacity. These are all important problems engineers and scientists try to understand while designing strategies towards implementing pollution control in contaminated soils, using detection and measurement techniques that can be applied to identify and characterize contaminated sites. Although vertical and horizontal stresses are principal stresses before shear, they are not principal stresses at failure.

Further, in order to determine shear strength, experimental results have been generated and process graphs developed by plotting a graph between normal stress and shear stress where normal stress is plotted at the abscissa and shear stress at the ordinate as in Fig. 3. It should be noted that the shear strength (s) is determined as:

$$s = c + \sigma \tan\theta \ldots 1$$

where, c = cohesion intercept (also known as the horizontal shear force under no vertical load)
σ = stress (frictional impact between grains, also stated as n- vertical normal load per unit area)

tan θ = angle of friction between grains or angle of shearing resistance
s= shear strength (also known as the unit shear resistance to impact force)

Further other crucial calculations for the determination of parameters that are crucial to shear stress are as follows:

To determine dry unit weight, $\gamma_d = w/v$ 2
where: w= weight of solids
v= total volume (solid + water)

To determine void ratio, $e = G_s\gamma_w - 1/\gamma_d$ 3
where: Gs= specific gravity of the solids of a soil
$\gamma_{w=}$ unit weight of water
γ_d=dry weight of soil

To determine normal stress on the soil, $\sigma = F/A$ 4
where: F=impact force (N)
A= area of impact

To determine shear stress, $\tau = V/A$ 5
where: V= volume occupied by the soil sample
A= area

IV. MATERIALS AND EXPERIMENTAL METHODS IN SUPPORT OF THEORY

As studies indicate, the shear box test is one of the oldest and simplest form of shear test arrangement designed to determine residual shear strength parameters for the analysis of pre-existing slope instability (Leonards, 1982; Ting, J.M., 1982; Ladd, C.C. et al., 1977). By design, the contemporary version of this equipment is composed of a metal shear box where the soil specimen with a circular plate can be placed. The box has two horizontally split halves separated sufficiently so that a cheese wire can cut smoothly through the specimen. Normal force is applied on the specimen from the top of the box so that the specimen is subjected to large displacements as shear builds up on the surface by continuously reversing the travel directions of the box. The shear force applied result in causing failure in the soil specimen as one half of the box moves relative to the other. For a strain-controlled test constant rate of shear displacement is applied to one half of the box. The horizontal proving ring enables the measurement of the resisting shear force of the soil. Further details can be found in Bishop et al (1971) and Ladd, C.C. et al., (1977). However, modern optimized designs are currently available in the industry including digital sequence machines that can be used for this experiment as the apparatus stated below suggest.

Apparatus and Procedure for Shear Strength Determination: Shear-Box Test

In preparation for the shear-box experiment, the following apparatus are required: shear box, shear box container, base plate with cross groves on its top, porous stones (2 Nos), plain grid plates (2Nos) perforated grid plates (2Nos), loading pad with steel ball, digital weighing machine, loading frame with loading yoke, proving ring, dial gauges (2 Nos), weights, tampering rod, spatula, rammer, sampler.

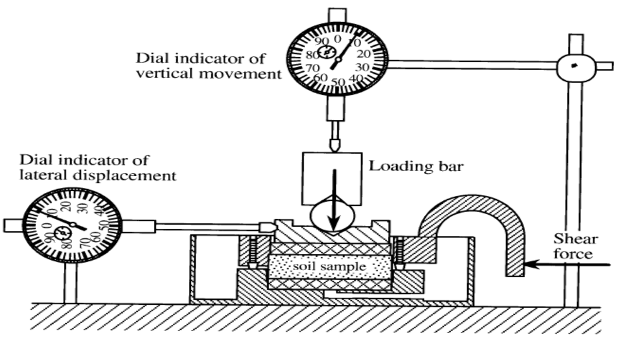

Fig 1: Schematic illustration of the shear box testing apparatus (Source: Slide 21 Geotechnical Engineering and Soil Mechanics Laboratory Manual, Texas Tech University)

The shear box testing device in (Fig 1) is a machine designed to hold soil samples securely between two porous walls in such a way that it not necessary to apply torque to the specimen. The shear provides the means of applying normal stress to the faces of the sample material. The box itself can be circular or square with divisions of horizontal plane in two halves of equal thickness, fitted together with alignment screws. Gap screws are also fitted to control the space between the top and bottom halves of the box. The testing device functions by shearing the specimen at a constant rate of displacement. As stated above crucial components in the test procedure are as follows: shear box assembly, calibrated proving ring, base frame, motorized gear box, loading screw and ball tracks, loading assembly with ball bearing and masses for the required normal loads, Vernier calipers, stopwatch timer, and other equipment for preparing the test sample from undisturbed samples in the laboratory.

V. PREPARATORY METHOD AND PROCEDURE FOR SHEAR-BOX EXPERIMENT

The technique of the test involves placing the test specimen in the shear box device (Fig 1) and applying predetermined normal stresses as follows: the shear box assembly is removed from the test machine. Remove the loading head. Insert the two vertical pins to keep the two halves of the shear box together. Fill the shear box with dry sand in small layers. The top of the compacted specimen should be 1/4 inch below the top of the shear box. Level the surface of the sand specimen. Determine the dimensions of the soil specimen. Slip the loading head down from the top of the shear box to rest on the soil specimen. Place the shear box assembly in the direct shear machine. Apply the desired normal load, N, on the specimen. This can be done by hanging dead weights to the vertical load yoke. The top crossbars will rest on the loading head of the specimen. Remove the two vertical pins.

Further, advance the three vertical screws on the side walls of the top half of the shear box. This is done to separate the two halves of the box. The space between the two halves of the box should be slightly larger than the largest grain size of the specimen. Set the loading head by tightening the two horizontal screws on the top half of the shear box. Back off the three vertical screws. After doing this, there will be no connection between the two halves of the shear box except the soil. Apply horizontal load, S, to the top half of the shear box by turning the crank. Turn the crank at the rate of 1 revolution per second. In continuation of the foregoing, record the maximum proving ring gauge reading. Repeat the above steps for at least two more times. Repeat the test with another two different normal loads, N. Normal loads 0, 8, and 16 kg.

VI. CALCULATIONS AND RESULTS

Two identical samples were tested under a different normal stresses in this report and the results used to derive sets of shear stress data. Calculations involved the area and volume, bulk unit weight, dry unit weight, void ratio, normal stress, and shear stress of the specimens. The graphs (see Figs 2 and 3) are plotted based on the gathered and calculated data deducing parameters in equations 1-5 above. The calculations and graphs were performed using Microsoft Excel following the model adopted by Smith (2006). The shear strength parameters, cohesion and angle of friction are shown in the table below.

Table 1: Computation for Laboratory Test Results

Normal load (kN)	Normal stress (kPa)	Shear force (kN)	Shear stress (kPa)
0	0.0	138	38.3
0.08	22.2	237	65.8
0.16	44.4	417	115.8
Cohesion = 35 KPa			
Angle of friction = 60°			
Correlation coefficient = 0.9862			

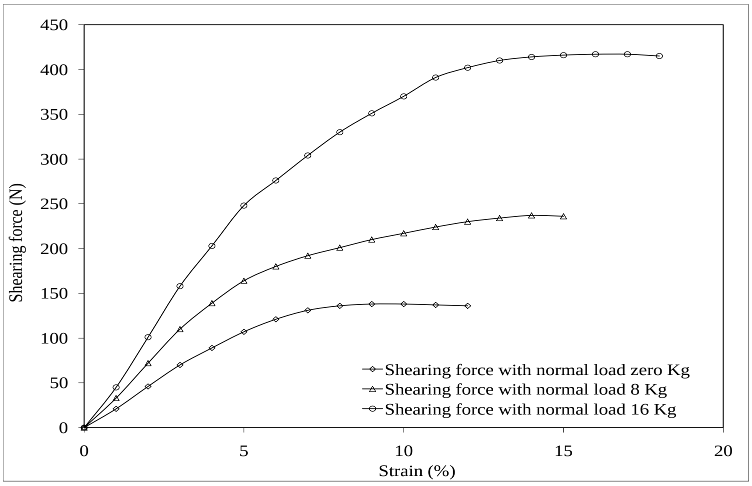

Fig 2: Stress and strain relationships

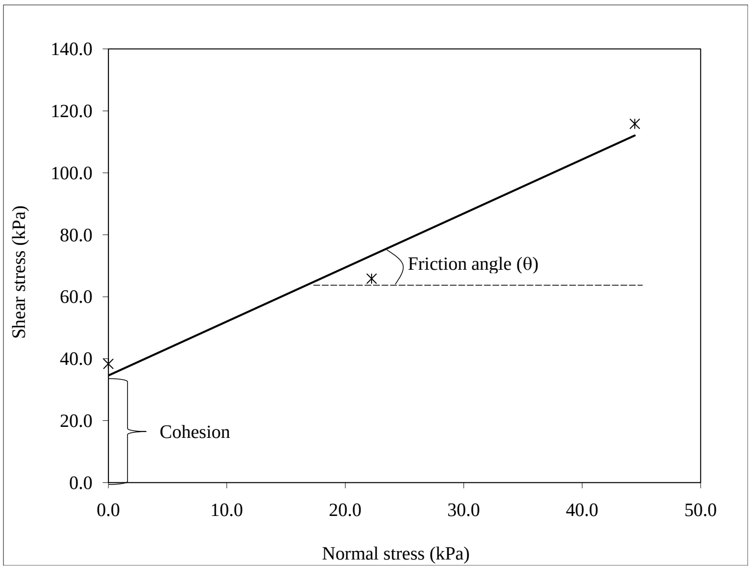

Fig 3: Shear stress and normal stress relation with correlation coefficient of 0.986

VII. DISCUSSIONS AND CONCLUSION OF REPORT

In this report, shear box test of some contaminated soil samples has been successfully completed to determine the strength of the soil and to assess safety in relation to loading of contaminant waste and implications to remediation plans. The failure in the soil is understood to mean eventual collapse of loads or structure founded upon it. This would probably imply exposure of contaminant feeds to the atmosphere of groundwater depending on the site location and proximity to populated areas.

Additionally, the sittings of building in brownfields, which are known to have different variety of fill materials, imply that the behavior of soil fills in these foundations will need considerable attention. It is necessary therefore that the materials supporting the foundations are tested for compression induced by increase in applied stress, and increase in moisture content. The shear-box test results in Figs (2 and 3) have confirmed that buildings on these soils will be vulnerable to collapse due to soil compression if the fill is structurally overwhelmed. This is the significant hazard that buildings founded on these materials will eventually face, although the problem of loose fills may exist but the more serious condition will be collapse, a function of relative compaction. Also, the materials are susceptible to contamination in the event of nearby landfill or waste site from migrating pollutant. Remedial goals will therefore target sequential ex-situ biodegradation methods that can be applied. The structural connection to this failure prone situation is directly dependent on the level and depth of structural reinforcement and the nature of the approved base foundation. Instructively, landfills from previously excavated sites that utilized non-biodegradables like polyethylene materials appear to portend more risks in the sense that their load bearing capacity may not be evenly distributed across the area.

VIII. OPTIMIZATION OF STRUCTURAL SUPPORT BY SOIL REMEDIATION

The most convenient approach to optimizing structural support conditions in this regard, rest on the remediation of this type of soil, which requires excavation of the surfaces of the soils found to be contaminated up to about 12inches or more depending on the extent of the contamination and to apply sequential ex-situ biodegradation (USEPA, 2006) to achieve target limits. On completing the remedial process, the cleaned soils can be used as excavation backfills.

In view of the foregoing, remediation of the saturated zone below the groundwater level has to be done after the excavations. This process is better done in-situ, especially because of the complexity of excavating into the groundwater in the saturated depths. The technology applied to both situations are similar except the fact that bacterial suspension and other additives are applied directly through infiltration drains into the underground body as the removal of soil is not carried out.

REFERENCES

[1]. Charles, A., Skinner, H. D. (2001). Compressibility of foundation fills. Geotechnical Engineering. 149:3, 145-157.

[2]. Newell, C.J., Acree, S.D., Ross, R.R. and Huling, S.G. (1995). “Light Nonaqueous Phase Liquids”, EPA Ground Water Issue, EPA/540/S-95/500, U.S. EPA, R.S. Kerr Environ. Res. Lab., Ada, Oklahoma, p. 28.

[3]. Bishop, A.W. (1971). "The Influence of Progressive Failure on the Choice of the Method of Stability Analysis." Geotechnique, Vol. 21, No.2, June 1971.

[4]. Wright, S.G., Kulhany, F.H., and Duncan, J M., (1973) "Accuracy of Equilibrium Slope Stability Analysis." Proc. ASCE, Vol. 99, No. SM10, October, 1973.

[5]. Ting, J.M., (1982). "Geometric Concerns in Slope Stability Analyses." Journal of Geotechnical Engineering, Vol. 109, No. 11, November 1982.

[6]. Leonards, G.A., (1982). "Investigation of Failures." Journal of the Geotechnical Engineering Division, ASCE, Vol. 108, No. GT2, Feb. 1982, pp. 185-246.

[7]. Ladd, C.C. et al., (1977). "Stress-Deformation and Strength Characteristics." Proc. 9th International Conference on Soil Mechanics and Foundation Engineering, Tokyo, 1977.

[8]. Duncan, J.M. and Wright, S.G. (1980). "The Accuracy of Equilibrium Methods of Slope Stability Analysis." Engineering Geology, Vol. 16, Elsevier Scientific Publishing Company, Amsterdam, 1980, pp. 5-17.

[9]. Annable, M. D.; Teodorescu, M.; Hlavinek, P.; Diels, L. (2008). Methods and Techniques for Cleaning-up Contaminated Sites. Springer, The Netherlands

[10]. Jumbo, E. E. et al (2012) Thermodynamic Nucleation and the Extended Effects of Microporosity and Inclusion on Tensile Strength of Welded Joints: IREJEST- International Research Journal in Engineering, Science and Technology IREJEST. Vol. 9 no. 2 June, 2012 ISSN: 1597-5258. Pg 76-85

[11]. Itugha, O.D., (2008). Solute and Particulate Transport at the Interface of Near-shore Permeable Estuarine Beach-sand: An Experimental Study of the Outer Reachesof River Mersey Estuary, N W England. Harold Cohen. THESIS 20860.ITU,Liverpool: Thesis Ph.D., 2008.

[12]. Itugha, O. D., Daoyi Chen, and YakunGuo (2016), Pollutant Advective Spreading in Beach Sand Exposed to High-energy Tides. Estuarine, Coastal and Shelf Science, Vol.181, pp. 70-82, http://dx.doi.org/10.1016/j.ecss.2016.08.011. 2016 Elsevier Ltd.

[13]. Smith, I. (2006).Smith's Elements of Soil Mechanics, 8th Edition. Published by Blackwell Publishing, ISBN: 1-4051-3370-8, May 2006

[14]. Geotechnical Engineering and Soil Mechanics Laboratory Manual, B.M. Das, C. Liu, J. Evett, Department of Civil Engineering, Texas Tech University. Document available at:

[15]. https://www.slideshare.net/hronaldo10/class-6-shear-strength-direct-shear-test-geotechnical-engineeringvisited on the 20th June, 2019

[16]. United States Environmental Protection Agency: In Situ and Ex Situ Biodegradation Technologies for Remediation of Contaminated Sites. Document available at: https://clu-in.org/download/contaminantfocus/dnapl/Treatment_Technologies/epa_2006_engin_issue_bio.pdfvisited on the 24th June, 2019

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