EFFECT OF CLIMATIC CONDITIONS ON ENGINEERING PROPERTIES OF CLAYS

by

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Synopsis

Soils showing changes in plasticity characteristics upon drying from an important group in clayey soils which exposed to several climatic condition . These changes are attributed to the grouping of particles into aggregates either due to mineralogy or presence of cementing agents or pore fluid characteristics . These changes are found to be permanent : In this paper , the effect of these changes leading to changes in index properties , compressibility and shear strength are discussed .

The compressibility and shear strength depend upon pore geometry .These micro structural aspects of liquid limit as a reference state for the analysis of engineering behavior of clayey soil is examined in detail . The general impression with clayey soil showing changes in plasticity characteristics upon drying is that the compressibility decreases , and shear strength increasing with drying . Drying causes a reduction in the overall potential represent by liquid limit leading to a reduction in void ratio for equilibrium condition is reached .

The results were estimated using linear regression analysis . Formulas related to void ratio and compressibility or shear strength were predicted . These formulas were compared to similar formulas published in ether literature . Corresponding graphs to explain all results were plotted .

1 Introduction

Engineering behavior of clays exposed to several climatic condition has in recent years increasingly attracted the attention of geotechnical engineers . These soils are essentially products of physical and chemical in-situ weathering of igneous , sedimentary , and metamorphic rocks under varying climatic conditions . Their behavior is strongly influenced by genesis , chemical and mineralogical compositions , degree of weathering and environmental conditions Vaughan, (1985) .

The geology associated with these soils and the index properties have received more attention than their engineering characteristics . In the context of geotechnical engineering in clayey soils ,little emphasis has been given to linking index properties with the engineering properties of soil.

There are differences in opinions expressed over the understanding of the engineering behavior of residual soils . Gidigasu (1988) concluded that classical soil mechanics principles have failed in answering some of the geotechnical problems in certain soils formed under subtropical and tropical environments . On the other hand , Mitchell and Sitar (1982) indicated that it is possible to use the results of simple classification tests , such as Atterberg limits , in evaluation some of the engineering characteristics like compressibility and permeability on regional basis . However , care must be taken to simulate the field conditions . Wesley (1988) stated that the conventional tests are more useful with residual soils .

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The present study aims at better understanding of the properties of clays in difficult environment as in aerial areas in Egypt, e.g. Aswan, New Valley ,and Saudi Arabia, etc.. The climatic conditions in which soils in these areas are formed, transformed, and encountered at different degrees of weathering have a role to play in influencing the engineering behavior .Clays exhibit changes in plasticity upon drying . These changes are partly due to minimal change in clay , although they have undergone various cycles of drying and wetting over the geological time scale. The present investigation is intended to examine the behavior of these soils in terms of index properties when they are subjected to different degrees of drying .The behavior of clays in terms of consolidation, permeability ,and shear strength is also examined.

2 Experimental Work and Material Testing

The tests were performed in the Soil Mechanics Laboratory, College of Technology, Abha , Saudi Arabia . The samples used in this research are dark-green clay from Abhor area ,south of Saudi Arabia. Their principal characteristics are summarized as below:

Sand	7 %
Silt	42 %
Clay	51 %
Type of soil according Unified Classification	MH
Liquid Limit	106 %
Plastic Limit	47 %
Plasticity Index	59 %
Specific Gravity	2.64

This clay is tested in five conditions obtained by drying. These conditions are natural, partially air-dried, and air-dried conditions as well as conditions obtained by drying the clay at 65^{0} C and 110^{0} C

3 Effect of Cyclic Drying and Wetting and Temperature Change on The Index Properties

3-1 Atterberge Limits

The atterberge limits are simple and have provided a basis for explaining the mechanical properties of soils in several aspects of engineering practice. The liquid limit is the most widely used parameter. The tests to determine the liquid limit of soils are analogous to shear tests. The number of blows, N, in the casagrandes method of liquid limit determination or D, the depth of penetration in mm in a liquid limit cone penetrometer device , is a measure of the shear strength of soil at the test water content. Nagaraj and Jayadeva (1981) have shown that the flow curves of different soils can be generalized using their respective liquid limit , L.L , to obtain functional relationships of the form

$$(w/L.L) = a - b \log N \qquad (1)$$

and

$$(w/L.L) = a - b \log D \qquad (2)$$

where :

a , b , a , and b = constant and w = the water content at any penetration, D, or number of blows, N.

The different initial conditions of clayey soil are characterized by their flow lines obtained from liquid limit cone penetrometer tests and are shown in Fig. (1). The flow line for natural moisture content condition with the greatest liquid limit has a greater slope and intercept compared to the other conditions examined . When the water contents at different penetrations are normalized using the respective liquid limit values , all the flow lines collapse into a narrow band that can be represented by an equation of the form:

$$(w/L.L) = 0.73 + 0.014\,D \qquad (3)$$

with a correlation coefficient of 0.969 and is shown in Fig. (2). These results are compared with the date of Wesley (1974) on volcanic soils. Comparison shows that the specific gravity decreases with drying for clayey soil as well as volcanic soils. The changes in the values of specific gravity determined in all the cases are apparent in that the aggregation that results in drying or the less of interparticale water in volcanic soils cannot be accounted for it in computations. These factors, if taken into accounted, could result in absolute values of specific gravity of solids . Nevertheless , the contrasting changes in the specific gravity values that result can be taken as a measure of the possible reasons.

3-2 Relationship Between Liquid Limit and Plasticity Index

Several attempts can be traced in the literature wherein plasticity index is linked to liquid limit mostly through correlation, e.g., Pandian and Nagaraj (1990) and Seed et al. (1964) . Apart from the Casagrandes A line, representing the boundary between inorganic and organic soils , these investigators have attempted to establish a relationship between the two parameters. It has been observed that all the soils reach their liquid and plastic limits when they are subject to suction / consolidation pressures of 0.05 kg/cm^2 and 5 kg/cm^2 respectively, Russel and Mickle (1970), and Schofield (1980) . Further , it has also been found reasonable, Wroth and Wood (1978), to assign a near-unique value of shear strength at the respective limits and redefine plastic limit as the equilibrium water content at which the strength is of the order of 100 times that at liquid limit . Nagarai and Jayadeva (1981) observation that the consistency limits are reached under a specific external effective stress field and can be associated with specified strength values irrespective of the soil type and that plasticity index is a direct function of liquid limit. This aspect is in accordance with the work of Panda and Niagara (1990) , but it needs to be established for clayey soils in which changes in plasticity characteristics upon drying are observed particularly for cases in which mineralogical factors such as the presence of halloysite, gibbsite and allophane affect the relationship. With this aim, the plasticity characteristics are further examined. The plasticity properties of clayey soil in different initial conditions are plotted with respect to the A-line and shown in Fig. (3). All these conditions follow the A-line very closely. Drying induces aggregation and the extent of aggregation is reflected by the points moving down along the line. In contrast, the deviation from this line are considerable, if the changes in plasticity characteristics upon drying were due to the presence of halloysite, gibbsite and allophane. This aspect can be understood from Mitchell and Sitar (1982).

4 Compressibility Behavior

The implication of drying on consolidation behavior, in terms of Skemtpons relationship for compression index is that the calculated compression index is less, if instead of the plasticity characteristics based on soil in the natural condition, the plasticity characteristics based on soil in an air-dried condition are used. In such cases, estimates of total and differential settlements need be treated with caution since it leads to an underprediction of settlements. In many situations in this area, soil is encountered in natural, partially air-dried and air-dried conditions because of seasonal temperature variations. In such cases, it is advantageous to know the extent of drying from the natural condition as well as the corresponding consolidation characteristics for settlement computations .Fig. (4) shows the consolidation paths of the clayey soil in different conditions. Though the soil is from the same location, depending on the extent of drying, different e-log P plots are obtained. The different plots are normalized by the void ratios at respective liquid limit values and are shown in Fig. (5). It appears from the figures that the normalized behavior of dried at elevated temperatures (65°C and 110°C) and rewetted is distinctly different, having a parallel shift respect to the others. For the three conditions that are relevant in normal practice (i.e. ,natural , partially air-dried ,and air-dried) the generalized relationship can be given by

$$e/e_l = 1.185 - 0.26 \log P \qquad (4)$$

with a correlation coefficient of 0.96.

where:

e = the equilibrium void ratio under consolidation pressure P

e_l = the void ratio at liquid limit water content.

Comparison of this equation is made with respect to the data of Wesley (1974), wherein e-log P paths obtained from slurry consolidation for three residual soils of volcanic origin are reported. These soils are prone to changes in plasticity upon drying due to the presence of halloysite, Fig. (6) shows the results.

The corresponding normalized plot can be represent by the equation

$$e/e_l = 1.392 - 0.245 \log P \qquad (5)$$

with a correlation coefficient of o.945 and in shown in Fig. (7)..

Fig. (8) shows the e-log P paths for different conditions of clayey soil upon unloading. The unloading paths have considerably flatter slopes. As before, when normalized with respect to void ratio at respective liquid limits, the rebound paths of natural air-dried and partially air-dried conditions combine in the form of a narrow band, compared to the conditions obtained by heating to 65° C and 110° C. The normalized relationship for unloading paths has a poor correlation coefficient of 0,43 and is given by

$$e/e_l = 0.522 - 0.028 \log P \qquad (6)$$

which is shown in Fig. (9). The fact that unloading resulted in very low rebound loading to only marginal changes in void ratio contributed to the poor correlation between the two variables. Fig. (10) shows the void ratio - pressure relationship pertaining to rebound paths for the data of Wesley (1974). Fig. (11) shows the corresponding normalized plot. The convergence in this case, upon normalization, is not good and resulted in a poor correlation coefficient of o.18. However, the relationship can be represented by the equation:

$$e/e_l = 0.61 - 0.02 \log P \qquad (7)$$

Comparison of (4) and (6) based on Wesleys data with (3) and (5) obtained in the present investigation shows that the intercepts for normally consolidated and over consolidated paths are rather high. The higher intercepts may be attributed to the nature of aggregates in these soils Wallace, (1973). However, it is interesting to note that the slopes compare reasonably well, though they are clayey soils of different origins. Thus, Weselys data can be taken to lend support, in principle, to the validity of the approach suggested in the present investigation.

5 Undrained Shear Strength Behavior

In this section, the effect of drying on strength behavior is examined for clayey soil in such conditions as natural and partially air-dried. They are included in the study to obtain the possible range of variation commensurate with the temperature level used for drying soils in liquid limit determination. Fig.(12) can be seen that, the coefficient, (the slope and intercept) is in the same range lending support, in principle, to generalization. Fig. (13) shows the variation of shear strength with void ratio for clayey soil .From the figure it appears that at the same void ratio, soil with higher liquid limit exhibits a higher strength, contrary to the typical observations that soils with higher liquid limit exhibit lower strength .This aspect can be examined with reference to Figs. (8) and (12). From these figures, it is clear that obtain the same void ratio, in the case of soils of higher strength .Fig. (14) shows the corresponding normalized relationship and given by

$$e/e_l = 0.92 - 0.196\,((\sigma_1 - \sigma_3)/2) \qquad (8)$$

with a correlation coefficient of 0.942. This equation suggest that the belief that drying of soil, even though subsequently rewetted and fully saturated, increases the shear strength ,is not well founded . This is because drying reduces the operating surface area permanently, which is discernible from the reduced liquid limit. Under a given external load there is also a reduction in the void ratio commensurate with the reduction in the liquid limit such that a particular strength value is associated with a particular value of (e/e_l).

6 Shear Strength Parameter

Fig. (12) shows the modified Mohr-Coulomb envelope for clayey soil . From a statistical analysis, for natural, partially air-dried, and air-dried conditions considered , constant value of friction angle 28^o is obtained with a cohesion intercept of 0.,11 kg/cm^2 . Since the soils dried to different extents were rewetted and remolded thoroughly , the small value of cohesion, which is negligible, can be considered as apparent This implies that there is no change in the available strength unless there is a change in the material states , that is, change eighteen in void ratio or liquid limit or both . The slope of the envelope, representing the friction angle, accounts for the rate of change of shear strength with respect to variation in equilibrium states . Fig. (15) shows the modified Mohr-Coulomb envelope for rebound states of clayey soil both in natural and air-dried conditions indicating a friction angle of 25^o with a cohesion intercept of 0.24 kg/cm^2 . This aspect shows that these clays are good angle , particularly in the construction of embankments and other structures . .

7 Conclusion

In this paper, index properties, compressibility and shear strength properties of clayey soils present in different climatic conditions are studied . It is concluded that :

1- Drying results in considerable changes in index properties arising mineralogy or aggregation . They are in turn characterized by contrasting trends in terms of their position in plasticity chart, and changes in apparent specific gravity.

2- Parameters such as void ratio and liquid limit are very simple to determine and formal part of any inferential testing program.

3- The relationship between generalized state parameter and engineering properties reflected in consolidation pressure and shear strength show that the parameters involved are not just inferential, but have enough potential to approximate inputs to design consideration.

4- The usual observation that compressibility decreases and shear strength increase, needs be treated with caution in these soils . Due consideration is necessary to examine the changes in soil states with respect to void ratio or water content in relation to liquid limit.

5- The study shows that changes in plasticity characteristics occur due to drying.

8 References

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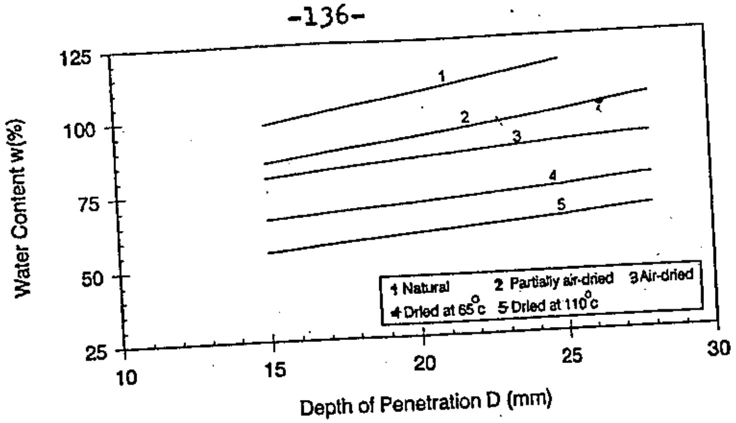

Figure (1) Relationship Between Water Content and Depth of Penetration for Different Conditions

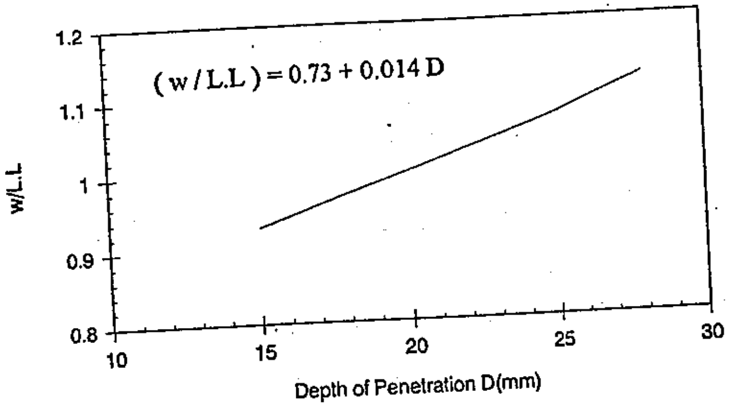

Figure (2) Correlation Between (W/L.L) and Depth of Penetration for Different Conditions

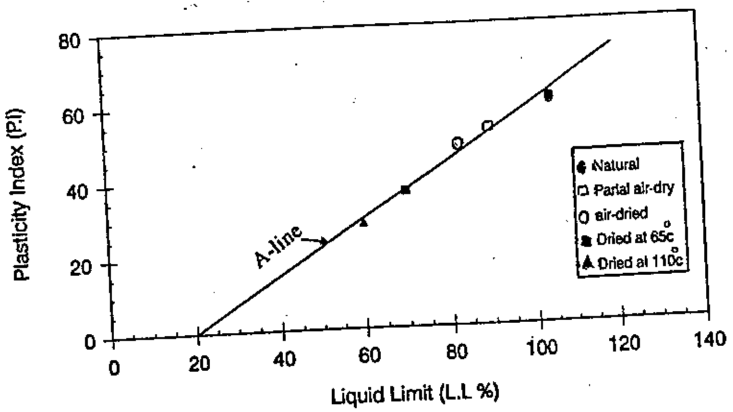

Figure (3) Plasticity Properties of Clayey Soil for Different Conditions

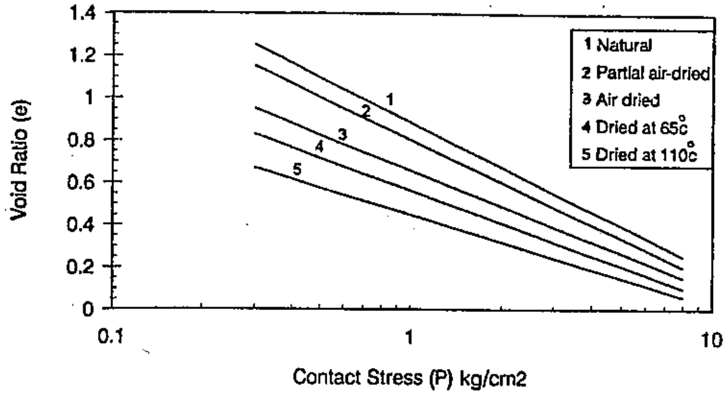

Figure (4) Relationship Between Void Ratio and Contact Stress for Different Conditions

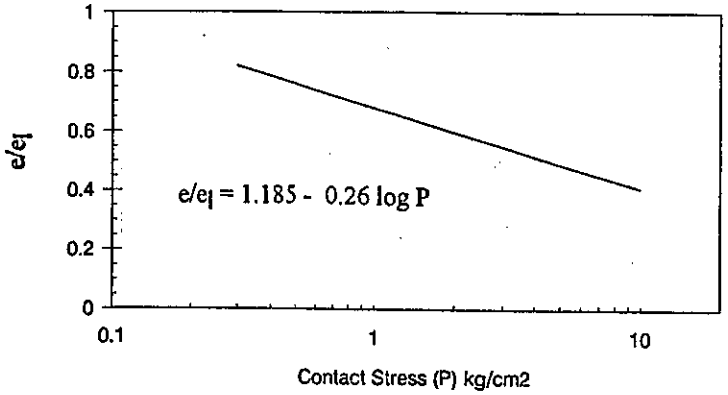

Figure (5) Correlation Between (e/e_l) and Contact Stress for Different Conditions

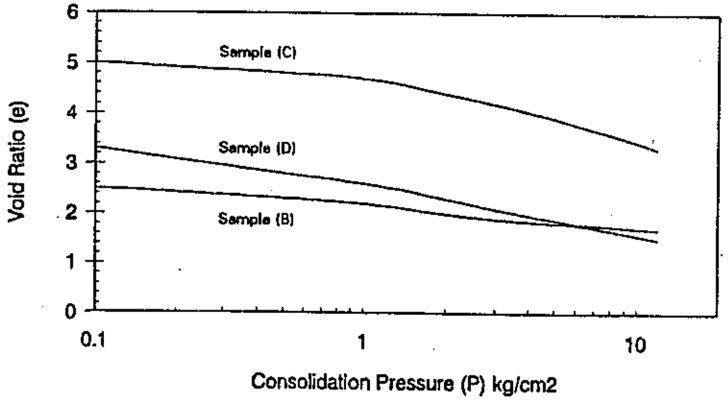

Figure (6) Void Ratio-Consolidation Pressure Relationship for Clays of Volcanic Origin (After Wesley 1974)

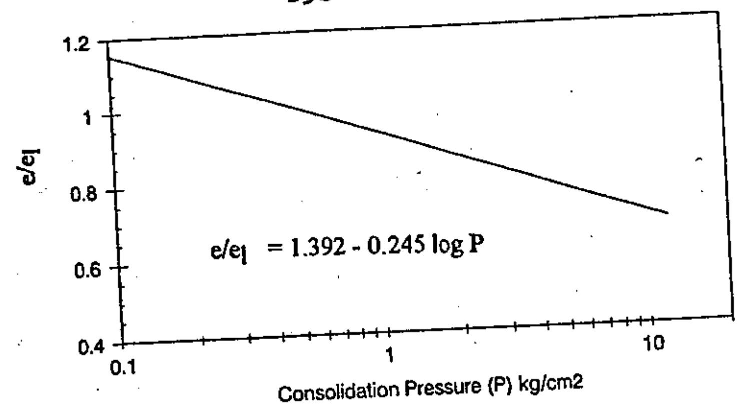

Figure (7) Correlation Between (e/e_l) and Consolidation Pressure (After wesley 1974)

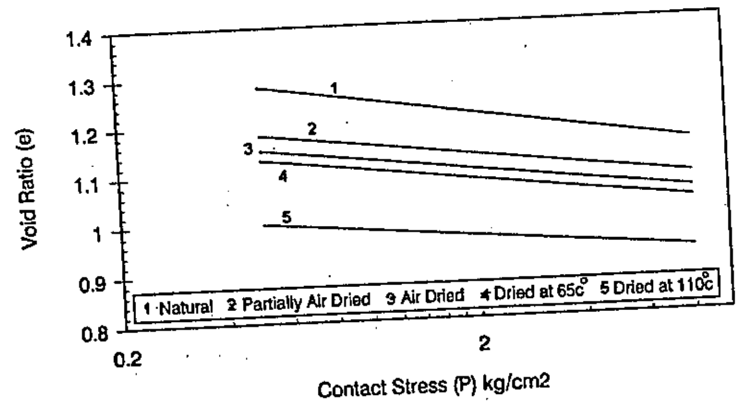

Figure (8) Relationship Between Void Ratio and Contact Stress (Unloading) for Different Conditions

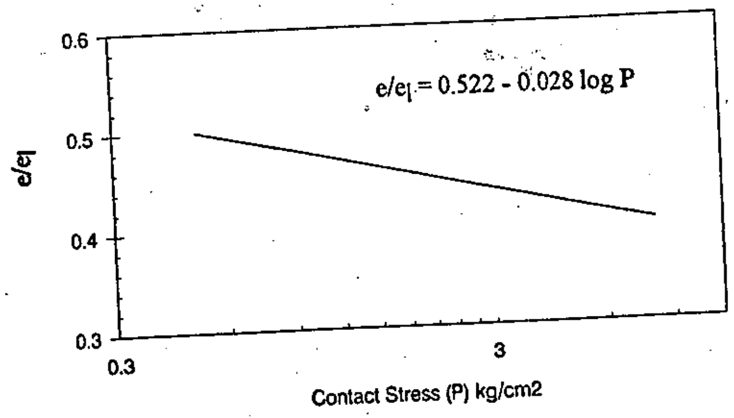

Figure (9) Correlation Between (e/e_l) and Conatct Stress (Unloading) for Different Conditions

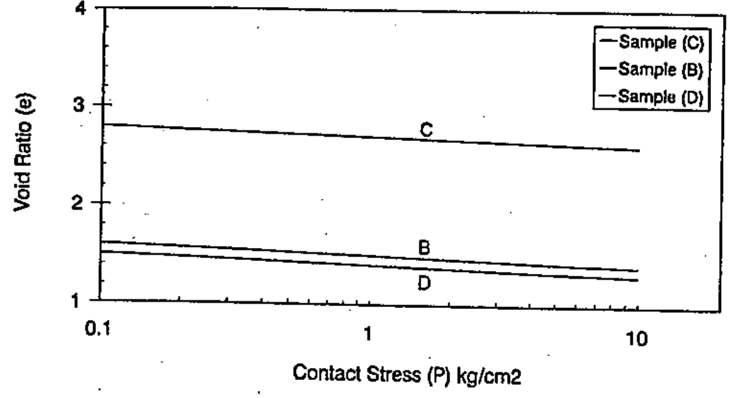

Figure (10) Relationship Between Void Ratio and Contact Stress (Unloading) for Clay Soils of Volcanic Origin (After Wesley 1974)

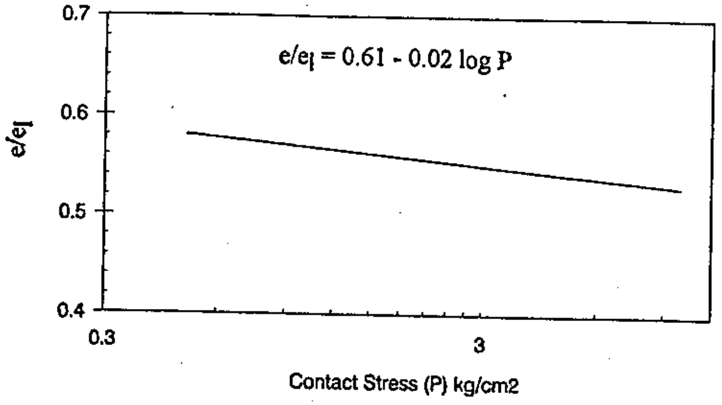

Figure (11) Correlation Between (e/e_l) and Contact Stress (Unloading) for Clayey Soils (After Wesley 1974)

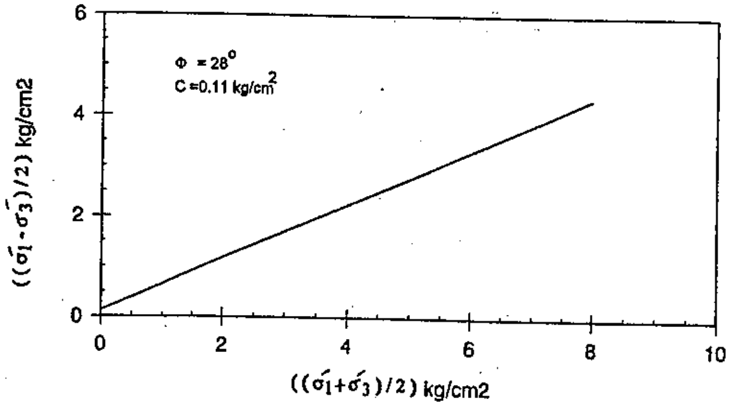

Figure (12) Modified Mohr-Coulomb Envelope for Different Conditions of Clayey Soil

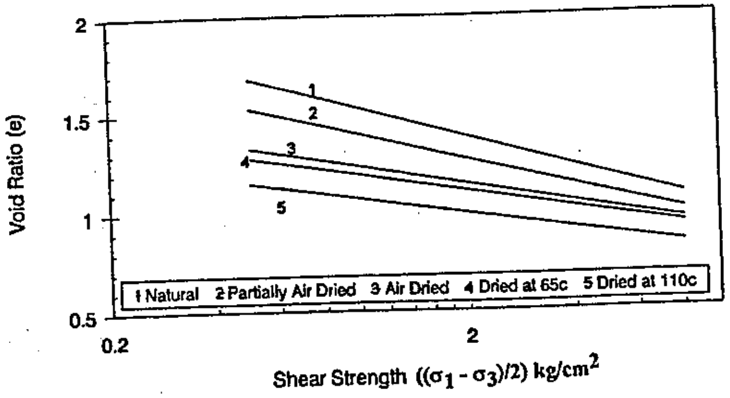

Figure (13) Relationship Between Void Ratio and Shear Strength for Different Conditions

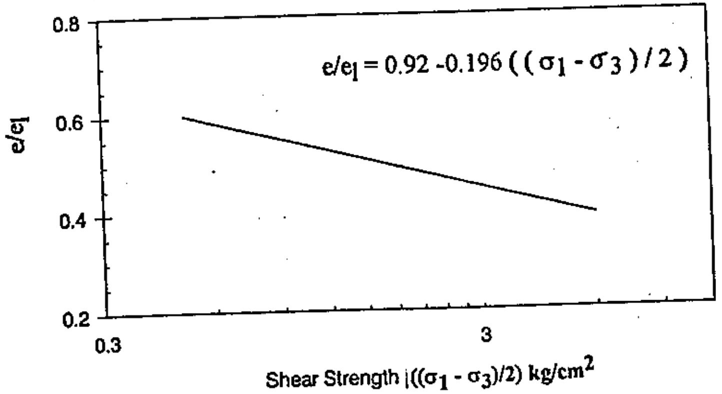

Figure (14) Correlation Between (e/el) and Shear Strength for Different Conditions

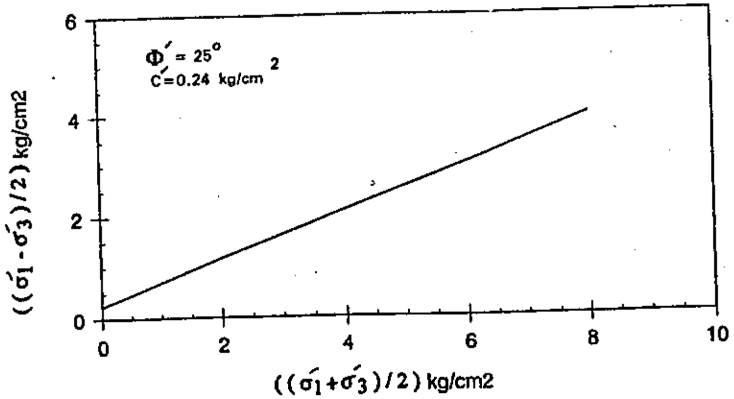

Figure (15) Modified Mohr-Coulomb Envelope (Unloading)for Different Conditions of Clayey Soil