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Undrained Behavior of Lime Treated Soft Clays

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ABSTRACT

Unconfined compression tests are normally carried out on lime treated soft clays with variation of the additive content and curing time. These studies were valuable in having a good understanding on the strength of the treated clays. In this paper, some works carried out under triaxial undrained consolidation conditions are presented and discussed within the frame work of state boundary surface and associated stress-strain behavior. The results clearly illustrate the effect of additive content and the curing time in the development of pore pressure and shear strain under undrained condition.

KEY WORDS: Soft clay, triaxial tests, lime, state boundary surface.

INTRODUCTION

Chemical stabilization method has been used successfully for more than three decades to reduce settlements and to increase the stability of embankments and excavations (Broms and Boman, 1976; Holm and Ruin, 1999; Bergado e*t al* 1999). Most of the fundamental studies related to the behavior of these columns were based on unconfined compression tests of additives treated soft clays.

The critical state concept (Roscoe et al., 1963; Roscoe and Poorooshasb, 1963; Roscoe and Burland, 1968), originally proposed by the Cambridge group assumes that the behavior of normally consolidated clay is frictional in nature. With the use of lime additives, cementation bonds are developed depending on the additive content and the curing time. These bonds give a porous structure to the soft clay whereby, the voids ratio of the treated samples is found to be much looser than the states corresponding to the virgin condition of the untreated samples. In the earlier studies conducted, little attention was paid to the compressibility characteristics of the treated clays as studied in the Oedometer and triaxial conditions. wherein the (e, log p) relations can be studied with a view to explain the treated behavior in terms of the apparent pre-consolidation pressure of the untreated samples and the quasi-pre-consolidation pressure as developed with lime and cement treatment. In this paper and in others the authors were trying to interpret the behavior of lime and cement treated soft clays somewhat similar to those of the heavily over-consolidated clays with very high quasi-pre-consolidation pressure thought to have developed as a result of the cementation bonds formed by the treatment. It is therefore easy to present this idea by appealing to the (e, log p) relationship.

The data presented in terms of the stress strain behavior (under undrained condition) is to illustrate the effect of the cementation bonds in demonstrating the progressive growth of the yield loci with increasing contents of the additive and thereby developing a rigid structure of the treated soil which is highly incompressible and shear resistant.

The second aspect emphasized in this paper is the dilatancy characteristic as represented by the quantity $d\varepsilon_v / d\varepsilon_s$ as obtained from isotropic and anisotropic consolidation paths, which are radial in nature in the (q, p) plot. No attempt is made to estimate the plastic version of the dilatancy as defined by $d\varepsilon_v^p / d\varepsilon_s^p$, since this later quantity is of the same order as the dilatancy defined with respect to total strains, since the elastic volumetric strains are small and the elastic shear strains are neglected. For the purpose of the intended communication here, it was thought that such an approach is adequate.

Also, the third aim of the paper is to study the pattern of strength increase with additive content and curing period as well as the strength degradation of the treated soil with shear strains larger than those corresponding to the peak deviator stress. This latter aspect is an important issue to be aware of in the design of lime piles as well as in jet grouting that there is substantial strength reduction with progressive shear strains beyond the peak value and the treated strength values can reduce to as low as the original untreated value corresponding to the critical state condition.

TRIAXIAL CONSOLIDATION BEHAVIOUR

Soft clay when tested under triaxial consolidation at increasing stress ratio from 0 to 0.8 (close to the critical state), illustrate a zone with voids ratio-log mean normal stress as shown in Fig. 1. At any value of mean normal stress the incremental voids ratio between the isotropic consolidation and the critical state is about 0.6. With lime and cement treatment all these voids ratio-mean normal stress relations cluster together as a band and are curved, so that the lime treated samples undergo very little voids ratio change as they are sheared from the isotropic state to failure. Also, the $\eta_{\max}$ value at peak condition is much higher than the critical state, M value.

Another important point to note is how the (e, log p) relations are very similar to heavily over-consolidated clay and the slope changes from a