Project Summary

Texas Department of Transportation

0-5530: Predictions of Embankment Settlement Over Soft Soils

Background

Overestimation of settlement on overconsolidated soft clays (determined by the undrained shear strength and/or Texas Cone Penetrometer blow count) may require ground improvement before construction with added delay and cost to a project. Since soft soil shear strength is low, structures on soft soils are generally designed so that the increase in the stress is relatively small and the total stress in the ground will be close to the preconsolidation pressure. Hence, there is a need to investigate methods to better predict the total and rate of settlement of embankments on soft soils. Hence, a research study was initiated at The University of Houston to review the current design methods used by TxDOT to predict the total and rate of settlement and proposed methods to further improve the predictions by performing a series of laboratory tests and field monitoring of highway embankments.

What the Researchers Did

Several TxDOT designs of embankments on soft soils were reviewed. The review included the method used to determine the increase in in-situ stress due to embankment load, determination of the preconsolidation pressure, and estimating the rate of settlement. In order to verify the prediction methods, two highway embankments on soft clay with settlement problems were selected for detailed field investigation. Soil samples were collected from nine boreholes for laboratory testing. The embankments were instrumented with extensometers, inclinometer, pore pressure transducers, and tensiometers and monitored up to 20 months to measure the vertical settlement, lateral movement, changes in the pore water pressure in the soft clay layer, and suction pressure in the active zone. Over 30 consolidation tests were performed to investigate the important parameters, including the stress level that could influence the consolidation parameters of the soft soils. Several Constant Rate of Strain (CRS) tests were performed, and the results were compared to the more popular incremental load (IL) method that is currently used by TxDOT. Also, correlation between compression index, moisture content, and soil unit weight was investigated.

What They Found

The method currently used by TxDOT to determine the increase in in-situ stress is comparable to the Osterberg method and is acceptable. The approach used by TxDOT to determine the preconsolidation pressure is acceptable (Casagrande Method). The procedure used by TxDOT to determine the rate of settlement is not acceptable. In determining the rate of settlement, the thickness of the entire soil mass must be used with the average soil properties and not the layering method. The layered approach will not satisfy the drainage conditions needed in the time factor formula and determine the appropriate coefficient of consolidation.

Research Performed by:

The University of Houston (UH)

Research Supervisor:
Cumaraswamy Vipulanandan, UH

Researchers:
Omer Bilgin, UH
Mustafa Bahadir Erten, UH
Y Jeannot Ahossin Guezo, UH
Kalaiarasi Vembu, UH

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Based on this study, it was determined that the increase in in-situ stresses due to the embankment was relatively small (generally less that preconsolidation pressure), and hence, using the proper recompression index was important to estimate the settlement. Since there is a hysteresis loop during the unloading and reloading of the soft CH clays during the consolidation test, three recompression indices (C_{r1}, C_{r2}, C_{r3}) have been identified, and recompression index C_{r1} (based on stress level) was recommended to use to determine the settlement up to the preconsolidation pressure. Based on the laboratory tests and analyses, the results showed that the consolidation parameters such as compression index (C_c), recompression indices (C_r) and coefficient of consolidation (C_v) for soft soils were all stress dependent. Hence, when selecting representative parameters for determining the total and rate of settlement, expected stress increases in the ground should be considered. Linear and nonlinear relationships between compression indices of soft soils and moisture content and unit weight of soils have been developed. Also, the 1-D consolidation theory predicted continuous consolidation settlement in both the embankments investigated. The predicted consolidation settlements were comparable to the consolidation settlement measured in the field. The pore pressure measurements in some cases didn't indicate consolidation because they may have been located close to the bottom drainage. In one case it indicated excess pore water pressure indicating consolidation was in progress. The active zone influenced the movements in the edge of the embankments. Movements in the active zone influenced the crack movements in the retaining wall panels. There was no extreme effect in the active zone (suction pressure and swelling) due to Hurricane Ike with 8-inches of rain in a day. The Constant Rate of Strain (CRS) test can be used to determine the consolidation properties of soft clay soils. The rate used in the test influenced the coefficient of consolidation.

What This Means

Based on limited field tests, conventional consolidation theory can be used to predict the total and rate of settlement of embankments on soft soils using recommended soil parameters developed during this study. Instruments used for the field monitoring worked very well and can be adopted for future studies. TxDOT's currently used approach to determine the rate of settlement must be modified. The CRS test can be used to determine the consolidation parameters of soft soils. Active zone effects must be considered when designing the edges of the embankment, including retaining walls.

For More Information:
0-5530-1 Prediction of Embankment Settlement Over Soft Soils

Research Engineer - German Claros, TxDOT, 512-465-7403
Project Director - Stanley Yin, TxDOT, 713-802-5211
Research Supervisor - Cumaraswamy Vipulanandan, UH, 713-743-4278

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keyword: research

Texas Department of Transportation
Research and Technology Implementation Office
P.O. Box 5080
Austin, Texas 78763-5080
512-465-7403