

JOINT TRANSPORTATION RESEARCH PROGRAM

Principal Investigator: Professor Maria Caterina Santagata, Purdue University, mks@purdue.edu, 765.494.0697

Program Office: jtrp@purdue.edu, 765.494.6508, www.purdue.edu/jtrp

Sponsor: Indiana Department of Transportation, 765.463.1521

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Identification and Behavior of Collapsible Soils

Introduction

Collapsible soils are susceptible to large volumetric strains when they become saturated. Numerous soil types fall in the general category of collapsible soils, including loess, a well-known aeolian deposit, present throughout most of Indiana. Loess is characterized by relatively low density and cohesion, appreciable strength and stiffness in the dry state, but is susceptible to significant deformations as a result of wetting.

Cases of wetting induced collapse in loess type soils have been documented in natural deposits and in man-made fills. In the latter case they can often cause large differential settlements that reduce the serviceability of the structure, and raise the frequency and cost of rehabilitation. These issues are especially of concern to the Indiana DOT due to the growth of the infrastructure in regions with significant loess deposits. This was the motivation for the research presented in this report.

The research reviewed the existing literature on: loess, on criteria used for quantifying the degree of collapsibility, on methods for measuring collapse potential in the laboratory and in the field, and on the collapsibility of compacted soils. Additionally, available documentation on loess deposits in Indiana was summarized.

This research also included experimental work conducted on two natural loess samples: one (Soil A) obtained in Daviess county, an area of Indiana overlain by medium to thick natural loess deposits, and one (Soil B) from Tippecanoe county. The two soils have similar characteristics, with close to 70% silt content and plasticity characteristics that classify both of them as CL (USCS) and A-6 (AASHTO).

Experiments performed on the two soils included index tests (particle size analysis, Atterberg limits and specific gravity determination), standard Proctor compaction tests, and an extensive program of double oedometer tests to measure the wetting induced collapse strains as a

function of stress level (12.5 kPa to 2760 kPa).

Specimens of soils A and B were compacted over a wide range of values of relative compaction (from 75% to close to 100% R.C.) and of water contents (from 5-6% points dry of optimum to optimum). The collapse potential was quantified using the criterion in ASTM D5533, which uses the collapse index I_e , the collapse strain measured under a stress of 200 kPa. This criterion allows to distinguish between severe, moderately severe, moderate, slight and no degree of collapsibility.

Findings

Loess deposits are common throughout Indiana and, based on the existing literature, concerns on the use of these materials in compacted fills and embankments are legitimate given the lack of data prior to this study on the wetting induced collapse of compacted loess.

The experimental work conducted as part of this research has demonstrated that if relative compaction and compaction water content are not appropriately controlled, subsequent wetting can cause significant collapse strains. For the soils and compaction conditions tested in this research the degree of collapsibility was found in all but one of the specimens to vary from slight ($I_e < 1\%$) to severe ($I_e > 11\%$). The collapse was found to increase with decreasing relative compaction, compaction water content and degree of saturation. Significant wetting induced strains were observed even for specimens compacted around 90% RC, in the case of water contents significantly on the dry side of optimum. While the collapse strains were typically observed to decrease with stress level, in some cases significant collapse strains were observed at relatively low stresses (25-100 kPa), indicating that wetting induced collapse may require consideration even for small fill thicknesses. For the soils examined in this research elimination of wetting induced collapse required compaction to over 100% RC.

Compaction on the wet side of optimum eliminates the

issue of wetting induced collapse. However, the collapsibility of the soil is very sensitive to small reductions in compaction water content, especially as the relative compaction decreases.

While the behavioral trends observed in this study are generally consistent with the data presented in the literature, the measured values of the collapse strains exceed previous data for Indiana loess.

Existing criteria for estimating collapse potential do not completely capture the collapse behavior of the soils examined in this research. They may be used to gain an initial assessment of the degree of collapsibility of a soil but cannot be considered a substitute for laboratory determination of the collapse potential. For this purpose the double oedometer test has been found to be an effective method for measuring the collapse potential of compacted soils.

Implementation Recommendations

The research performed has: reviewed the literature on loess soils; examined existing criteria for estimating the degree of collapsibility, and methods used for measuring the collapse potential in the laboratory; highlighted the significance of loess deposits in Indiana; developed a data base on the collapse properties of two soils representative of Indiana loess deposits, that may be used as a starting point when evaluating a similar soil as a candidate material for a fill or embankment; drawn conclusions on compaction conditions that reduce or eliminate problems of wetting induced collapse; provided suggestions for compaction specification to be used for these soils and for laboratory methods to be use in evaluating the collapse potential of a given soil.

The following recommendations can find immediate implementation in INDOT practice and specifications: a) when a loess soil is being considered for use in a fill or embankment a series of double oedometer tests should be performed on specimens compacted at conditions representative of those expected in the field to establish the soil-specific risk for wetting induced collapse and define soil-specific compaction specifications; b) where soil-specific data cannot be obtained, the required field relative compaction for these soils should always exceed 105-110% of the optimum value derived from standard Proctor tests, and the compaction water content should exceed $w_{opt} - 1.5\%$, where w_{opt} is the optimum water content derived from standard Proctor tests; c) project specifications should include provisions for avoiding or minimizing subsurface wetting; d) given the many uncertainties involved in the problem of wetting induced

collapse, a risk-based approach should be taken. In terms of future research, further evaluation on a broader range of soils is recommended, as well as assessment of the performance of compacted loess on the wet side of optimum, to better define an upper bound for the field compaction water content.

References

Howayek, A. E., P. T. Huang, R. Bisnett, and M. C. Santagata. *Identification and Behavior of Collapsible Soils*. Publication FHWA/IN/JTRP-2011/12. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2011. doi: 10.5703/1288284314625

