Alaska Department of Transportation & Public Facilities
Alaska University Transportation Center

Frozen Soil Lateral Resistance for the Seismic Design of Highway Bridge Foundations

Final Report


Prepared By:

Zhaohui "Joey" Yang
Xiaoxuan Ge
Benjamin Still
Anthony Paris
University of Alaska Anchorage, School of Engineering

December 2012

Prepared By:

Alaska University Transportation Center
Duckering Building Room 245
P.O. Box 755900
Fairbanks, AK 99775-5900

Alaska Department of Transportation
Research, Development, and Technology Transfer
2301 Peger Road
Fairbanks, AK 99709-5399

INE/AUTC 12.34

FHWA-AK-RD-12-23

REPORT DOCUMENTATION PAGE			Form approved OMB No.
Public reporting for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestion for reducing this burden to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-1833), Washington, DC 20503			
1. AGENCY USE ONLY (LEAVE BLANK) FHWA-AK-RD-12-23	2. REPORT DATE December 2012	3. REPORT TYPE AND DATES COVERED Final Report (08/01/2011-12/31/2012)	
4. TITLE AND SUBTITLE Frozen Soil Lateral Resistance for the Seismic Design of Highway Bridge Foundations			5. FUNDING NUMBERS AUTC#510021 DTRT06-G-0011 T2-11-04
6. AUTHOR(S) Zhaohui "Joey" Yang, Xiaoxuan Ge, Benjamin Still, Anthony Paris			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Alaska University Transportation Center P.O. Box 755900 Fairbanks, AK 99775-5900			8. PERFORMING ORGANIZATION REPORT NUMBER INE/AUTC 12.34
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Alaska Department of Transportation Research, Development, and Technology Transfer 2301 Peger Road Fairbanks, AK 99709-5399			10. SPONSORING/MONITORING AGENCY REPORT NUMBER FHWA-AK-RD-12-23
11. SUPPLENMENTARY NOTES			
12a. DISTRIBUTION / AVAILABILITY STATEMENT No restrictions			12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

With recent seismic activity and earthquakes in Alaska and throughout the Pacific Rim, seismic design is becoming an increasingly important public safety concern for highway bridge designers. Hoping to generate knowledge that can improve the seismic design of highway bridges in Alaska, researchers from the University of Alaska plan to test a fixity depth approach and a lateral resistance (p-y) approach in seismic bridge design.

Currently, the Alaska Department of Transportation and Public Facilities (ADOT&PF) utilizes soil lateral resistance in the seismic design of bridge pile foundations. Knowledge about lateral resistance of frozen soils, particularly seasonally frozen soils at shallow depths, will help improve pile foundation design in cold regions such as Alaska. Researchers Zhaohui Yang and Anthony Paris are conducting laboratory experiments to examine key mechanical parameters for the frozen soils used to construct the p-y curve for modeling frozen soils.

Although there have been studies on the mechanical properties of frozen soils, existing studies were based on remolded, artificially frozen soil samples, which do not necessarily represent the soil in the field. How much impact these disturbances have on the frozen soil strength and stress-strain behavior is not clear. Additionally there is a lack of studies of the stress-strain behavior at small strains based on naturally frozen samples. Yang and Paris hope to fill this knowledge gap by providing key frozen soil parameters for typical Alaska soils. These key soil parameters, Yang and Paris claim, are needed for predicting the formation and location of plastic hinges, and internal loads in bridge pilings embedded in frozen soils during seismic loading. The team will use this developing knowledge to conduct a bridge design engineers workshop to discuss their findings and how to apply them in the seismic design of bridges.

14- KEYWORDS: Earthquake resistant design (Esdc), Bridge design (Esusb), Frozen soils (Rbespfh)			15. NUMBER OF PAGES 91 16. PRICE CODE N/A
17. SECURITY CLASSIFICATION OF REPORT Unclassified	18. SECURITY CLASSIFICATION OF THIS PAGE Unclassified	19. SECURITY CLASSIFICATION OF ABSTRACT Unclassified	20. LIMITATION OF ABSTRACT N/A

NSN 7540-01-280-5500

STANDARD FORM 298 (Rev. 2-98)
Prescribed by ANSI Std. 239-18 298-1

ABSTRACT

Frozen soils, especially seasonally frozen soils, have a significant effect on the seismic performance of bridge pile foundations. To account for this effect, it is necessary to evaluate frozen soils' mechanical properties. This report focuses on obtaining the mechanical properties of naturally frozen silty soils in Alaska. High-quality specimens of both permafrost and seasonally frozen soil were prepared by block sampling and machining following a procedure designed to minimize mechanical and thermal disturbances. Both horizontal and vertical specimens were prepared to investigate the effect of specimen orientation. Unconfined compression tests were performed at temperatures ranging from -0.7° to -11.6°C at a constant deformation rate that corresponds to a strain rate of about 0.1%/s. This strain rate is equivalent to that expected in the frozen soil during a design earthquake in Interior Alaska. Test results including soil characteristics and mechanical properties (stress-strain curves, compressive strength, yield strength, and modulus of elasticity) are presented and compared with data in the literature. The impact of temperature, dry density, water content, and specimen orientation on mechanical properties is discussed. These mechanical properties can be directly used to evaluate frozen soil lateral resistance in the analyses of laterally loaded pile foundations during seismic or other events in cold regions.

EXECUTIVE SUMMARY

This report describes the sampling, machining, conditioning, and unconfined compression testing procedures used to determine the mechanical properties of naturally frozen soils in Alaska—both seasonally frozen soil and permafrost—and presents the testing data and analyses that resulted from that work. The main findings from this project are summarized below:

1. The ultimate compressive strength decreases with increasing temperature; it decreases with increasing dry density, or increases with increasing water content. This trend for the latter is clearer at lower temperatures. In addition, there is a correlation between yield strength and ultimate compressive strength.
2. The Young's modulus decreases with increasing temperature. The horizontal specimens tend to have higher Young's modulus, especially for permafrost. Similarly, the shear wave velocity of frozen soils decreases with increasing temperature.
3. For permafrost, the ultimate strength of horizontal specimens is substantially higher than that of vertical specimens at the same testing temperature. This strength anisotropy is likely due to ice wedge formation commonly observed in permafrost.
4. The ultimate strength of naturally frozen soils is lower than that obtained from remolded frozen soils.
5. Factors that affect the mechanical properties of frozen soils include temperature, water content or dry density, specimen orientation, and soil type.