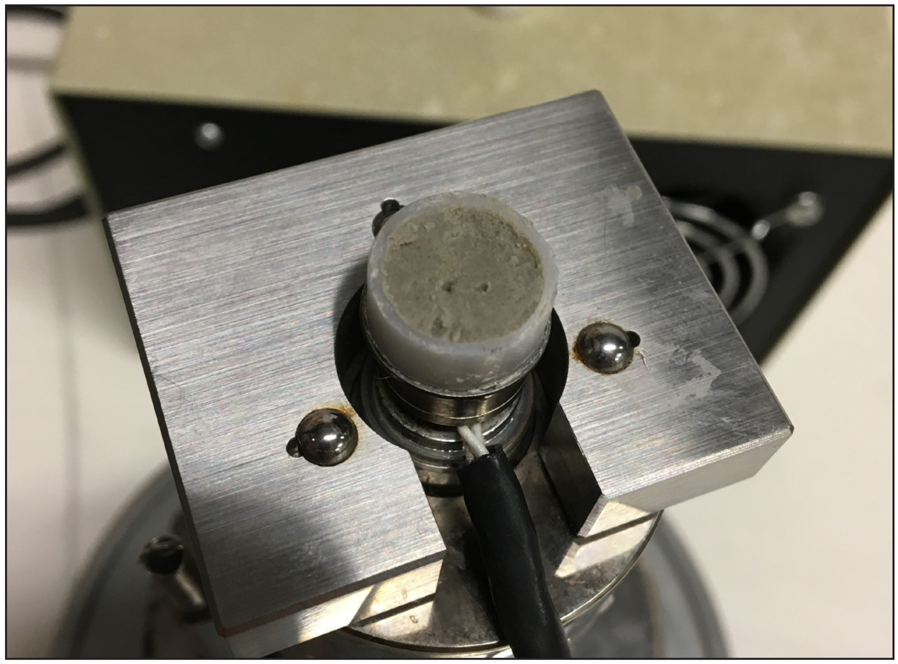
MOUNTAIN-PLAINS CONSORTIUM

RESEARCH BRIEF | MPC 19-406A (project 506) | December 2019

Development of Models for the Prediction of Shear Strength of Swelling Clays

INTERIM REPORT



the ISSUE

Accurate prediction of the shear strength of swelling clays is critical for the design of transportation infrastructure. Damage caused to U.S. infrastructure by swelling clays is estimated to be about $13 billion per year. Overestimation of strength can lead to failures, and underestimation can lead to an increase in project cost. Due to the small size of the clay particles and the nature of clay minerals, molecular interactions between the clay and fluids strongly influence engineering properties.

the RESEARCH

Modeling and experimental tasks of the project are in progress. Specifically, molecular-scale modeling of clay with fluids with a wide range of polarities is in progress. Molecular dynamics (MD) simulations to evaluate clay swelling and relate swelling to the molecular interactions between clay constituents and the fluids are completed. The results from the molecular dynamics simulations have been correlated to the results from the Fourier transform infrared spectroscopy (FTIR) experiments and show good agreement. FTIR can thus be used as an experimental technique to evaluate molecular interactions in the clay fluid systems. MD simulations are conducted to evaluate the compressibility of the clay interlayer containing fluids with a wide range of polarities. The simulations indicate that the compressibility of the clay interlayer is affected by the fluid in the interlayer and fluid content. We have made similar observations in macroscale experiments with the same clay. Shear strength experiments on samples swollen by different magnitudes are in progress. We have also conducted nanoindentation experiments on wet undisturbed clay samples to correlate nanoindentation results to macroscale shear properties. Other modeling tasks in progress include molecular modeling of tactoids and aggregates of clay and the development of a coarse-grained model for clays. In addition, three representative feature extraction techniques were explored to provide effective data fusion and information processing for in-depth/special/damage inspections. Results confirmed that these data-driven techniques exhibited

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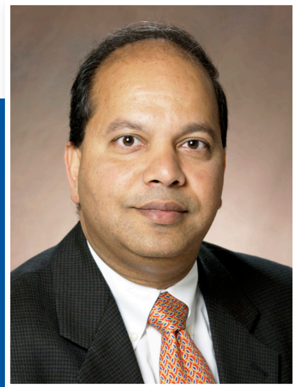
University of Denver
University of Utah
Utah State University
University of Wyoming



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Project Title

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the RESEARCH continued

high accuracy for distinguishing between undamaged and damaged elements, even when there was noise interference and under various operational conditions. Moreover, the data-driven classification methods in this study could effectively address the major factors of interest, including damage level, damage location, sensor location, and moving load.

the FINDINGS

- Molecular interactions between the clay constituents and fluids strongly influence the swelling of clay interlayer. Higher the fluid polarity or dielectric constant, the higher the swelling.
- Clay interlayer compressibility is influenced by the interlayer fluid. Higher fluid polarity results in decrease in the compressibility of the clay interlayer.
- Fourier Transform Infrared Spectroscopy is an excellent experimental technique to evaluate molecular interactions in clay-fluid systems.

the IMPACT

This research will explain the key mechanisms that influence the shear strength of expansive clays, which are responsible for significant damage to transportation infrastructure. The understanding of the mechanisms will improve prediction of the strength of swelling clays and lead to reliable design of transportation infrastructure in these areas.

The major outcome of this basic research will be a multiscale computational framework for swelling clays to evaluate the mechanical response of swelling clay to external loading. The models incorporate the molecular scale clay-fluid interactions and the evolution of microstructure during swelling, the two critical factors that influence the mechanical properties of swelling clays. These simulation testbeds will provide insight into the mechanisms that affect the mechanics of swelling clays. The innovative experiments developed in this research would not only serve as model development and verification tools but could lead to the introduction of new experimental techniques for swelling clays.

For more information on this project, download the entire report at https://www.ugpti.org/resources/reports/details.php?id=987

For more information or additional copies, visit the Web site at www.mountain-plains.org, call (701) 231-7767 or write to Mountain-Plains Consortium, Upper Great Plains Transportation Institute, North Dakota State University, Dept. 2880, PO Box 6050, Fargo, ND 58108-6050.