UTC Project Information	
Project Title	MPC-506 – Reliable Prediction of Shear Strength of Swelling Clays
University	North Dakota State University
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Agency ID or Contract Number	DTRT13-G-UTC38
Project Cost	$100,000 /year for 3 years
Start and End Dates	September 30, 2013 to September 30, 2018
Project Duration	September 30, 2013 to September 30, 2018
Brief Description of Research Project	Accurate prediction of the shear strength of swelling clays is extremely important for the design of roads, railway infrastructure, foundations, embankments, slopes, canals, erosion control, retaining walls, etc. The damage caused by swelling clays to the U.S. infrastructure is estimated to be of the order of about $13 billion per year (2009) [1]. Swelling clays are found in various parts of the United States **(Fig. 1)**[2] and the world. In **Fig. 1**, the red and blue colored regions contain soils with high swelling potential and orange, and green colored regions contain soils with moderate to low swelling potential. Portions of North and South Dakota contain soils that have high swelling potential. Overestimation of strength parameters can lead to failures and underestimation can lead to significant increase in the cost of the project. Shear strength of soils with high swelling clay content, can vary from high values when swelling is restrained to significant degradation in strength or even complete loss of strength due to swelling. The change in shear strength can also be seasonal. Fundamental strength parameters that define strength properties of soils are related to a variety of factors that include soil type, microstructural characteristics, fluid properties, mineralogy, saturation, etc. Reliable predictive tools that can accurately predict the shear strength of swelling clays are lacking. Our prior work on clays

	demonstrates the key role of molecular interactions on the evolution of microstructure and the macroscopic properties such as permeability, consolidation, and swelling pressure[4]. **Research Objectives:** Bridging the molecular interactions to the evolution of microstructure and bridging both molecular interactions and microstructure to the mechanics of the swelling clays will provide powerful predictive capabilities and develop a clear understanding of underlying mechanisms that lead to shear strength properties in swelling clays. **Specific objectives are,** 1) Construction of multiscale computational simulations test-beds for swelling clays to evaluate the role of molecular interactions and microstructure to macroscale shear strength properties of swelling clays. 2) Development of experimental techniques to evaluate the swelling clay-fluid interactions and mechanical properties at various length scales: molecular scale to macroscale.
Describe Implementation of Research Outcomes (or why not implemented) Place Any Photos Here	The research results are published and presented at conferences. The implementation will occur upon completion of the research project.
Impacts/Benefits of Implementation (actual, not anticipated)	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.
Web Links • Reports • Project Website	https://www.ugpti.org/resources/reports/details.php?id=987