MPC-538
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Project Title:
Representative Testing of Expansive Soil Treatment Technologies for Transportation Earthworks

University:
Colorado State University

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Research Needs:
The shrink-swell behavior of expansive soils reduces transportation infrastructure longevity in much of the Mountain Plains region (Colorado, North Dakota, South Dakota, Utah, and Wyoming). Roadways are particularly susceptible to the effects of expansive soils due the combination of low ground pressures and large surface areas. The pervasiveness of expansive soils in the continental U.S. is shown in Fig. 1. Current estimates for the annual cost of damage to transportation infrastructure from expansive soils are not readily available, but were estimated by U.S. Housing and Urban Development (HUD) to be approximately $1.1 billion in 1973 (Jones & Holtz 1973) and $4.3 billion in 1981 (Jones 1981; $12 billion in 2017 dollars adjusting for inflation). Given the prevalence of expansive soils in the Mountain Plains region, economical solutions to mitigate damage to transportation infrastructure is necessary to enhance transportation system longevity throughout the Mountain Plains region.

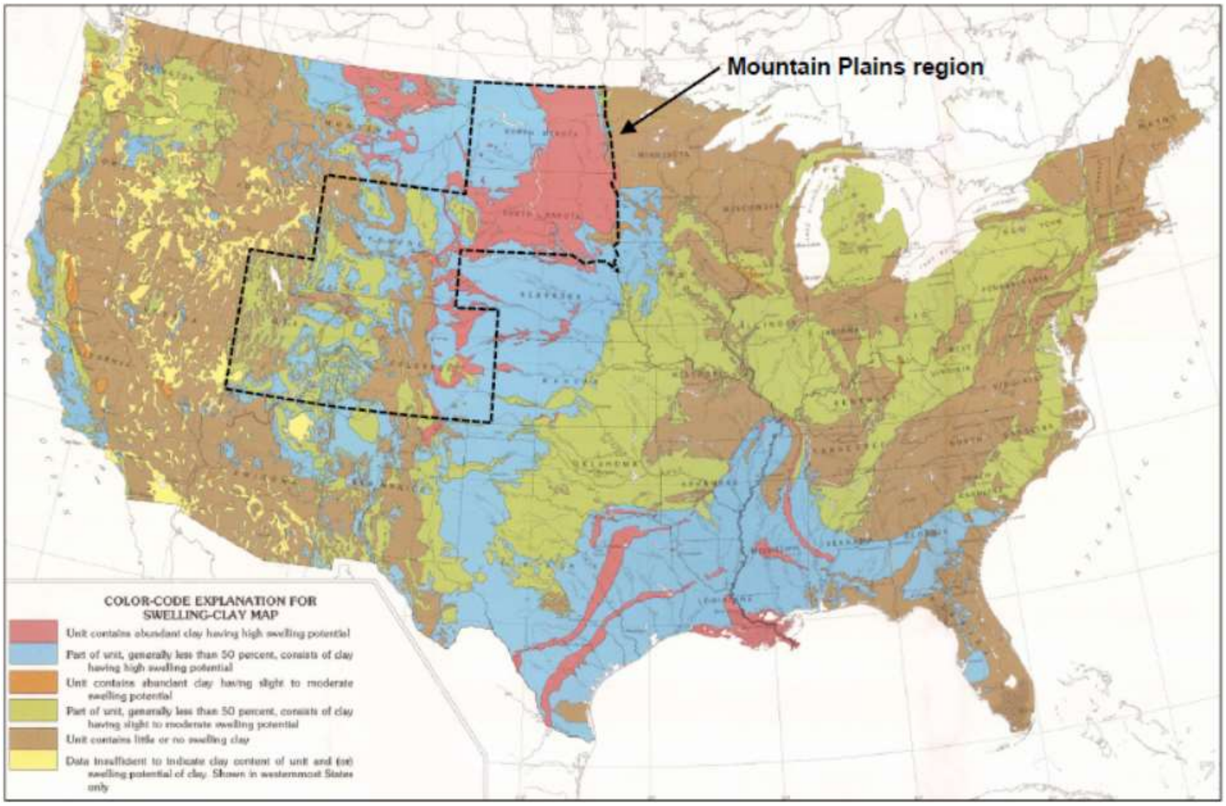

Figure 1. Map of expansive soils in the continental United States (adapted from Olive et al. 1989). Areas in red, blue, orange, and green have > slight to moderate swelling potential, and thus the potential for damage transportation infrastructure.

The current Mountain-Plains Consortium (MPC) project MPC-509 is aimed at evaluating expansive soil mitigation for transportation earthworks by polymer amendment. The goal of MPC-509 is to provide un-biased information on the effectiveness of commercially available polymer stabilizers. Testing to date has involved four commercially available polymer treatment technologies applied at different dosage rates to a highly expansive soil. Testing on the highly expansive soil has also been performed with varying dosages of Class-C fly ash, lime, and on untreated soil. Testing to date has included standard soil characterization, and tests of hydraulic conductivity (ASTM D5084), swelling potential (ASTM D4546), expansion index (ASTM D4829), and unconfined compressive strength (ASTM D5102). Results to date have shown that traditional stabilizers (lime and Class-C fly ash) are more effective at reducing swelling potential and expansion index than polymeric amendments. However, traditional stabilizers result in an order-of-magnitude increase in permeability, while polymer amendments result in reductions in permeability. Shrink-swell potential is mechanistically based on the addition of water, and the rate of ingress of water into soil is governed by the soil permeability. Thus, existing standard methods fail to provide a representative comparison of traditional and polymeric stabilizers (due to the ways these treatments modify the soils). An alternative method is needed to accurately compare traditional and polymeric stabilization of expansive soils, as well as other innovative materials proposed for use in treating expansive soils.

Research Objectives:

1. Develop and fabricate a lab-scale apparatus for comparative testing of traditional and polymeric expansive soil treatment technologies
2. Use the apparatus to compare traditional (lime and fly ash) and commercially-available polymer treatment technologies to natural (un-amended) expansive soils
3. Develop a standard methodology for testing of innovative expansive soil treatment technologies (e.g., use of different recycled materials)

The proposed study will develop and fabricate a lab-scale apparatus for comparative testing of traditional and polymeric expansive soil treatment technologies. The proposed apparatus will then be used to compare traditional (lime and fly ash) and commercially-available polymer treatment technologies to natural (un-amended) expansive soils. The proposed apparatus is necessary to effectively carrying out this comparative evaluation due the different mechanisms by which traditional stabilizers and polymeric stabilizers mitigate soil shrink-swell behavior. Finally, the procedures developed during the proposed study will be codified into a standard methodology for testing of innovative expansive soil treatment technologies (e.g., use of different recycled materials).

Research Methods:

Research efforts needed to complete the proposed study will include (1) refinement of the apparatus design, (2) fabrication of three apparatuses, (3) laboratory testing, (4) and data analysis.

(1) Apparatus design refinement: MPC-509 included a literature review of conventional expansive soil mitigation technologies used in the Mountain Plains region, and a review the mechanisms underlying the behavior of polymer stabilization of expansive soils. Sources identified during this review will be used to refine the conceptual design shown in Fig. 2.

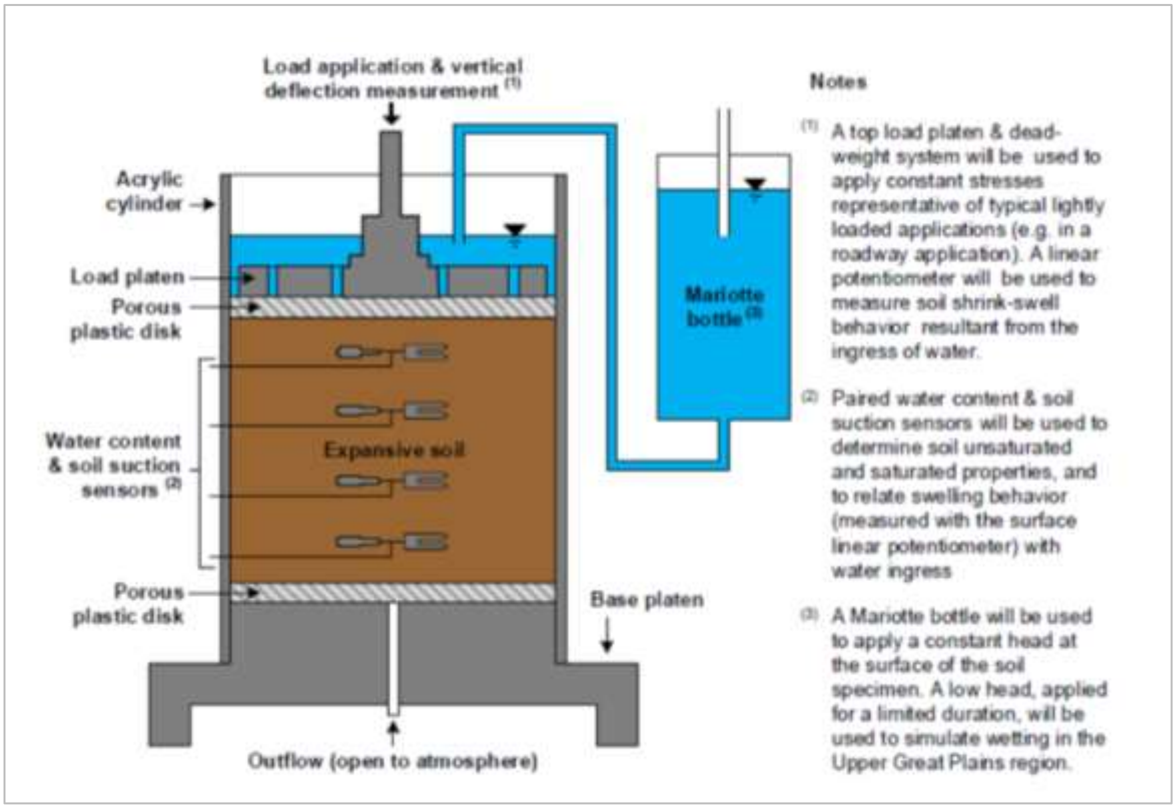

Figure 2. Preliminary conceptual diagram of proposed testing apparatus. A 12-in diameter specimen is proposed to minimize boundary effects.

(2) Apparatus fabrication: Three apparatuses will be fabricated to facilitate testing, within the proposed project duration.

(3) Laboratory testing: materials have been identified and procured as part of MPC-509. These materials will be used for this study. This will minimize costs associated with procuring and characterizing new materials, and will also allow for comparison of the results from this study with standard methods used to test expansive soils (i.e., expansion index and swelling potential).

(4) Data analysis: analysis of results from laboratory testing, including comparison of potentially significant reductions (or increases) in swelling of traditionally-treated and polymer-treated expansive soils will be compared to untreated soils.

A final report will be prepared comparing commercially-available polymeric stabilizers for mitigation of expansive soils in transportation earthworks to traditional technologies. The report will include design drawing for the apparatus as well as a standardized testing procedure, which will allow future researchers to test innovative treatment technologies more effectively.

Expected Outcomes:
The primary deliverable from the proposed project will be an assessment of expansive soil mitigation for transportation earthworks by polymer amendment. Emphasis will be placed on comparing polymer-based stabilization of expansive soils to conventional stabilization strategies. These findings will inform practitioners working on expansive soil problems in transportation

earthwork applications as to the validity of claims made by polymer-amendment manufacturers. If true, state-of-the-art polymer amendments for expansive soil mitigation may allow for more sustainable transportation infrastructure in much of the Mountain Plains region. This assessment also will have broader implications for expansive soils throughout the United States.

The Principal Investigators (PIs) also anticipate that the project will lead to opportunities for technology transfer of state-of-the-art soil amendment with polymers. Potential technology transfer will include subgrade stabilization (in non-expansive application) and dust suppression in transportation applications.

Relevance to Strategic Goals:

- State of Good Repair
- Environmental Sustainability

Polymer-based mitigation of expansive soils has the potential to improve the longevity of transportation infrastructure while simultaneously increasing economic competitiveness and enhancing environmental sustainability relative to conventional mitigation techniques. However, for these potential benefits to be realized, the viability of polymer-based stabilization technologies to mitigate expansive soils, particularly expansive soils in the Mountain Plains region, must first be demonstrated. The proposed project will allow for an effective comparison that captures the varying mechanisms of traditionally and polymer-based stabilization technologies. If polymer-based stabilization technologies do not exhibit mitigation of expansive soils greater than or equal to current stabilization technologies, the proposed project will help practitioners avoid the costly mistake of attempting use of these materials. However, this comparison can only be made if all mechanisms are considered (an objective of this proposal).

Educational Benefits:

The proposed project will provide the necessary resources for one semester of student support for a graduate student at CSU to continue pursuit of a Doctoral (PhD) degree in Civil and Environmental Engineering. This graduate student will lead the proposed research. The graduate student will gain invaluable knowledge and experience for a future career as a Geotechnical Engineer. As part of this project, the graduate student will gain a deeper understanding of expansive soils, current and future expansive soil mitigation techniques and technologies, clay-polymer interaction, and geotechnical laboratory testing. Thus, the graduate student will be well-equipped to transition into an engineering career with state-of-the-art knowledge and skills.

The proposed project will provide an opportunity for the PIs to expand and enhance their understanding of expansive soil mitigation in transportation earthwork applications. This knowledge will be used in both undergraduate and graduate courses to provide students tangible connections to relevant civil engineering problems relevant to students in the Mountain Plains region, as well as future research in this area by Drs. Bareither and Scalia.

Tech Transfer:

Findings from this study, as well as methods developed, will be disseminated directly back to geotechnical engineers at departments of transportation (DOTs) within the Mountain Plains Region. Relevant geotechnical engineers at each Mountain Plains Region DOT were identified during MPC-509. In addition, research findings will be presented at the biennial 2018 Rocky Mountain Geo-Conference in Denver, CO, and published in peer-reviewed technical journals. The CSU Geoengineering website (www.csugeoeng.com) will also be used to post research updates; these posts will be shared via online professional networks (e.g., Linkedin).

Work Plan:

1. Apparatus design refinement
2. Apparatus fabrication
3. Laboratory testing
4. Data analysis

A timeline for the proposed project is included in Fig. 3. The proposed project will require 18 months for completion. Duration of specific tasks (Tasks 1, 2, 3, and 4) are identified in Fig. 3 and correspond to each of the research objectives discussed previously. Project updates for the MPC will be developed at 6, and 12 months, with a final report prepared at the completion of the project (18 months).

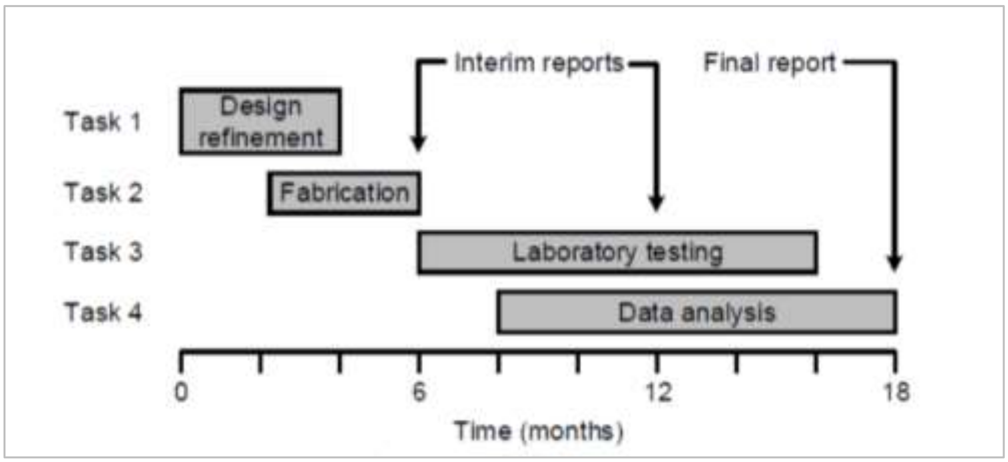

Figure 3. Estimated timeline of primary tasks for completing the proposed project.

Project Cost:

Total Project Costs: $35,870
MPC Funds Requested: $17,935
Matching Funds: $17,935
Source of Matching Funds: Two weeks of salary for Drs. Scalia and Bareither during the project, with the balance accounted for by Dr. Scalia's start-up funds at CSU used towards development of laboratory apparatus.

References:

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