MPC-477

June 9, 2015

**Project Title:** Characterizing the ductility of Portland cement stabilized soil

**University:** Utah State University

**Principal Investigators:** James A. Bay (Utah State University)

 Associate Professor

 jim.bay@usu.edu

 Department of Civil and Environmental Engineering

 Utah State University

 4110 Old Main Hill

 Logan, Utah 84322

 (435) 797-2947

 John D. Rice

 Assistant Professor

 john.rice@usu.edu

 Department of Civil and Environmental Engineering

 Utah State University

 4110 Old Main Hill

 Logan, Utah 84322

 (435) 797-8611

**Research Needs:**

Portland cement, lime, and fly-ash stabilized soils are often used as base materials in pavement. The ductility of these materials has a large impact on the performance and life of the pavement. Increasing the ductility of these materials, without decreasing the stiffness will result in materials that will experience less degradation over time, resulting in better performance and longer life. However, unlike bitumen cemented materials (D113-07), there is not currently any method to characterize the ductility of Portland cement, lime, or fly-ash cemented materials (Portland Cement Association, 1992), (NCHRP, 1976). Cementitious materials such as soil-cement and plastic concrete are also used for groundwater cutoffs and excavation support in many transportation applications as well as dam and levee mitigation. Material ductility is also important in many of these applications to deal with post-construction deformation of these structures (Kahl et. al, 1991), (Rice and Duncan, 2010).

The first step to evaluating the effect of ductility in cemented base is to have a measure of ductility. Ductility and brittleness in cementitious materials is controlled by the presence or absence of cracks or fissures during straining. Cracks, micro-cracks and fissures also have a large effect on other easy to measure engineering properties. Two of these properties are damping and permeability. A ductility index can be developed by measuring changes in damping or permeability with strain. With an easy to measure and replicate ductility index, comparisons can be made between the ductility of different materials, and the effect of ductility on long-term behavior can be studied.

**Research Objectives:**

The objective of this research is to develop one or more testing method to give indices of ductility for Portland cement, lime, or fly-ash stabilized soils. These indices will provide a relative characterization of the ductility of different materials, and that can be used to compare the ductility of different materials. This index will provide a tool that can be used in subsequent research to quantify effects of ductility on long-term performance, and to compare ductility of different materials or mix designs.

**Research Methods:**

Two methods for characterizing ductility will be investigated:

1) The researchers have observed that the damping behavior of cemented soils is strongly affected by micro-cracking and small amounts of distress. Damping can easily be measured in free-free resonance testing. To characterize the ductility of a material, a combination of free-free resonance testing and axial compression testing will be employed. The damping will be measured in unstrained specimens, and then the material will be loaded axially to increasing strains, while the damping measurements are repeated. Less ductile material will experience more micro-cracking and distress with increasing strain. A ductility index relating increase in damping to strain will be developed. Both stiffness and damping will be measured in free-free resonance testing.

2) Currently the researchers are characterizing ductility of cemented materials by evaluating increases in permeability relative to axial strain for materials used in cut-off walls in dams and levees. This testing involves loading the soils in axial compression while measuring the permeability of the material. Permeability, like damping, is strongly affected by micro-cracking and distress. Another ductility index will be developed relating increase in permeability to strain.

We hypothesize that both approaches will characterize ductility. Both approaches will be employed to characterize the ductility of typical Portland cement stabilized base materials. The approaches will be compared based upon; 1) ease of testing, and 2) quality of ductility characterization.

To simplify this investigation, only Portland cement stabilized soils will be used in this investigation. Subsequent studies may be performed to assess the effectiveness of the test methods with different cementitious additives.

**Expected Outcomes:**

The outcome of this work will be testing methods to determine ductility of cemented pavement soils and shoring and cutoff materials. This will give pavement designers tools that are currently not available to increase the ductility of pavements using cemented base materials. It will also be useful for design of cutoff or retaining structures in construction applications as well as dam and levee applications. This work will be submitted to the Transportation Research Board for presentation and publication.

**Relevance to Strategic Goals:**

This work will increase the design life, state of good repair, economics, and environmental sustainability of pavements, retaining structures, and groundwater cutoffs.

**Educational Benefits:**

This research will support one graduate student and will be used to generate a Plan B report. These testing approaches will be incorporated into the graduate course, Laboratory and Field Methods in Geotechnical Engineering.

**Work Plan:**

|  |  |  |
| --- | --- | --- |
| Task | Responsible Person(s) | Period |
| Select test materials | Bay & Rice | June 2015 |
| Create test specimens | Bay & Rice | June– Aug 2015 |
| Perform damping/ductility tests | Bay | Aug-Oct 2015 |
| Perform permeability/ductility tests | Rice | Aug-Oct 2015 |
| Develop ductility indices, compare test methods | Bay & Rice | Nov 15 – Jan 2016 |
| Draft TRB article | Bay & Rice | Feb-May 2016 |

**Project Cost: $50,968**

Total Project Costs: $ 101,936

MPC Funds Requested: $50,968

Matching Funds: $ 50,968 Source of Matching Funds: $50,968

**TRB Keywords:**

Base course, ductility, ductility tests, Portland cement, Soil stabilization.

**References:**

ASTM International D113-07, (2007). *Standard Test Method for Ductility of Bituminous Materials*, West Conshohocken, PA: ASTM International.

Kahl, T. W., Kauschinger, J.L., and Perry, E.B. (1991). *Plastic Concrete Cutoff Walls for Earth Dams*, United States Army Corps of Engineers, Technical Report REMR-GT-15, Waterways Experimentation Station, Vicksburg, MS.

NCHRP (1976), Lime-Fly Ash-Stabilized Bases and Subbases. In National Cooperative Highway Research Program Synthesis of Highway Practice, No. 37, TRB, National Research Council, Washington, DC.

Portland Cement Association, (1992) *Soil-Cement Laboratory Handbook*. Publication EB052.07S. Skokie, IL.

Rice, J.D.; and Duncan, J.M. (2010). *Deformation and Cracking of Seepage Barriers in Dams due to Changes in the Pore Pressure Regime*. ASCE Journal of Geotechnical and Geoenvironmental Engineering, Vol. 136, No. 1, pp 16-25.