SURVEY OF MICROPILE USE IN NEIGHBORING WESTERN STATES

MPART Research Proposal

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1 Problem Statement

Micropiles are small diameter piles that are constructed by drilling and grouting techniques. Micropiles are a foundation alternative that are cost-effective in a variety of conditions encountered in Montana Department of Transportation (MDT) projects. While the technology was first introduced in the US in 1973, MDT's experience with micropiles is limited. A limited experience base has led to underutilization of a potentially beneficial foundation alternative.

MDT is interested in exploring a greater use of micropiles and would like to begin by gathering information from neighboring western states on their use of micropiles in transportation-related projects.

2 Background Summary

A micropile is constructed by drilling a borehole, placing steel reinforcement, and grouting the hole as illustrated in Figure 1. The small diameter of micropiles allows them to be constructed with standard geotechnical drilling equipment. Micropiles can withstand relatively significant axial loads and moderate lateral loads, and may be considered a substitute for conventional driven piles or drilled shafts. Micropiles are installed by methods that cause minimal disturbance to adjacent structures, soil, and the environment. Construction can take place in areas having difficult ground conditions, limited access, and environmentally sensitive areas where conventional foundation alternatives may be inappropriate.

Micropiles are classified according to a design application as either CASE 1 or CASE 2 micropiles. CASE 1 micropiles are comparable to conventional piles in that they are used to transfer structural loads to a deeper, more competent or stable stratum. The load is primarily resisted structurally by the steel reinforcement and geotechnically by side resistance developed over a "bond zone" of the individual micropiles. At least 90 percent of all international applications as of 2005, and virtually all of the projects in North America have involved CASE 1 micropiles. Such micropiles are designed to act individually, although, they may be installed in groups.

Micropiles can be constructed using different types of grout placement techniques and leads to Type A, B, C or D classifications. Type A involves the simplest type of grout placement where the grout is placed under gravity head only. Type B, C or D involve different techniques where grout placement occurs under pressure.

The use of micropiles has grown significantly since their conception in the 1950's in Italy, and in particular in the USA since the mid-1980's. The first state-of-the-practice document produced by FHWA was published in 1996. The latest FHWA document was published in 2005 (Sabatini et al. 2005).

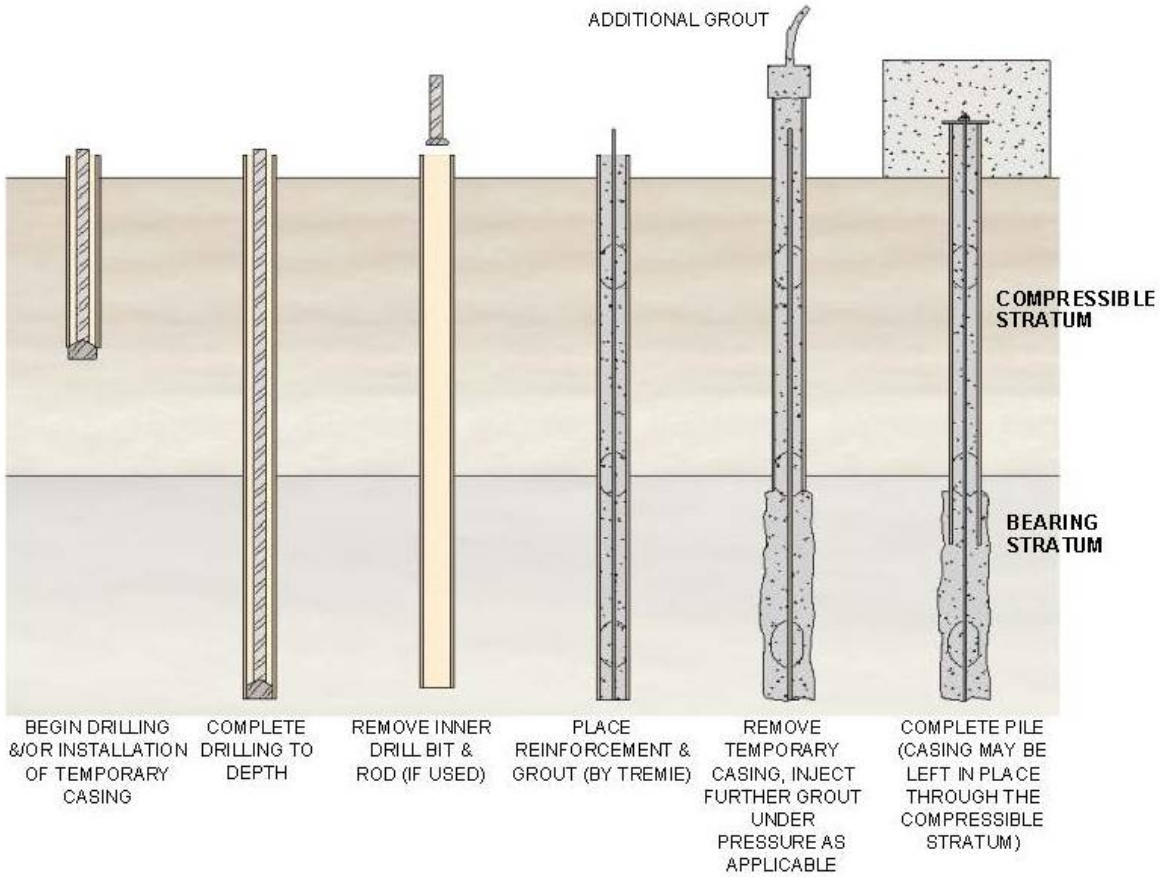

Figure 1: Micropile construction sequence (Sabatini et al. 2005)

3 Benefits and Business Case

Micropiles offer a cost effective solution for the retrofitting of deteriorating bridge foundations, new foundation installations, and mitigation of slope instability. The technology can be particularly effective in difficult ground conditions (i.e. presence of cobbles and boulders, intermediate geomaterials), restricted work areas having limited space and/or remote access, for urban, noise and vibration sensitive sites, and for scour protection of shallow foundations. Micropile construction is generally less intrusive in sensitive environments as compared to more traditional foundation alternatives. MDT has a significant catalog of existing bridges founded on timber piles whose design life has been exceeded. Retrofitting these bridges to correct design deficiencies and extend design life is an urgent need. Micropiles offer an effective means of carrying this out. The expected outcome of this research is to allow MDT to formulate a path forward for the use of micropiles in bridge retrofitting projects and potential other applications. Use of micropiles in MDT projects is expected to result in cost savings, improved service and increased safety of deteriorating structures and increased design efficiency.

4 Objective

The objective of the proposed project is to gain knowledge of the state-of-practice in neighboring western state departments of transportation regarding the use of micropiles for foundation support and earthen slope repair. This objective will be met by developing, conducting and compiling the results of a survey given to neighboring western state departments of transportation on the use of engineered micropiles.

5 Research Plan

This research is considered to be the first of possibly several phases designed to place MDT in a better position to utilize micropiles as a foundation alternative. The work in the present proposal will involve developing a series of survey questions designed to assess the use of micropiles within neighboring state departments of transportation. These states include Idaho, North and South Dakota, Oregon, Utah, Washington and Wyoming. The survey will focus on the level of use, types of projects where use has occurred, subsurface conditions when used, site surface conditions, design methods used, typical costs, cost comparison to other alternatives, availability of contractors, construction methods, construction success, load testing methods, assessment of performance, and lessons learned.

For each of the state DOT's, a key person will be identified as the point of contact and as responsible for completing the survey on behalf of the DOT. Communication and agreement will be made with each key person prior to sending the survey. The survey will be written within a word processing document with responses being added to the document. This form will allow responders the freedom to expand upon items that might not have otherwise been anticipated. Once responses are received, a second round of questions may be developed and/or specific follow-on questions may be asked of particular responders. The results of the survey will shared and discussed with the MDT technical panel and compiled in a project final report.

Task 0 – Project Management

The Principal Investigator for this project will manage the project in terms of contractual compliance, budget and schedule, administrative tasks, and communications with the Technical Panel. Dr. Steve Perkins of Montana State University will serve as the Principal Investigator for the project. He will be the primary contact and assume the majority of the project management responsibilities.

Project management is important to ensure that the work proposed herein is completed on time, on budget and high quality. Management will generally be achieved through regular communication between the Principal Investigator and the MDT project manager. Given the relatively short duration of the project, the PI will submit a single quarterly progress report to describe accomplishments, status of the project and future plans. Major deliverables will follow

MDT reporting requirements and formats and will first be sent to the Technical Panel for review and comment.

Task 1 – Identification of State DOT Contacts

The PI will work in conjunction with the Technical Panel to identify a key individual within each state DOT to assume responsibility for completing the survey. The PI will contact each person to discuss the survey and to obtain their agreement to be the person of charge.

Task 2 – Development of Survey

The PI will develop the survey document. The document will be sent to the Technical Panel for review and approval. The PI will deliver the document to the people identified in Task 1 and be responsible for collecting the completed survey.

Task 3 – Survey Review and Follow-Up

The PI will review the survey responses and develop a follow-up questionnaire as appropriate. All documents will be forwarded to the Technical Panel for review and comment. The PI will be responsible for any follow-up actions.

Task 4 – Survey Compilation and Reporting

The PI will compile the responses of the survey and prepare a comprehensive final report that includes all responses and a summary of the knowledge gained. The report will be written in conformance with MDT's standard research report format to thoroughly document the findings of this project. A draft report will be sent to MDT to be distributed to the Technical Panel for review and comment. A four-page "Project Summary Report" will be written and submitted to MDT near the end of the project to summarize the background, methodology, results and recommendations of this research. This summary report will be edited, published and distributed by MDT to be distributed to the Technical Panel for review and comment. Additionally, an "Implementation Report" will be written to summarize how the results from this research project were implemented, and a "Performance Measures" report will be written to summarize the benefit of this research in terms of cost savings to the department.

A single combined task report and quarterly progress report will be submitted mid-way through the project to provide updates on the administrative aspects of the project, such as progress regarding the deliverables, schedule and budget.

6 MDT Involvement

MDT's involvement consists of the review items contained in the research tasks described above and performed by the MDT technical panel.

7 Products

The products to be delivered during this project include the following items.

- One combined task report and quarterly progress report.
- A draft final report and executive summary describing the research methodology, findings, conclusions, and recommendations, followed by a final report addressing comments and suggestions from the Technical Panel.
- A project summary report.
- An implementation report.
- A performance measures report.

8 Implementation

The results of this research will be used to develop plans and methods for the use of micropiles in bridge retrofitting projects, but will also be applicable to other applications. It is anticipated that the results this project will be used to develop a phase II project focused on the development of a simplified design manual for these types of projects. This manual will then be implemented on specific projects, which may contain research elements in order to optimize the design and construction process.

9 Schedule

The estimated project schedule is shown in Table 1. The total proposed duration of the project is 7 months, with an estimated start date of April 2, 2015, and an estimated completion date of October 30, 2015. A draft final report will be sent to the Technical Panel 2 months prior to the end date (by August 31, 2015) to provide sufficient time for review and revision. A combined task and quarterly report will be delivered by July 30, 2015 and will contain a summary of the responses received to date. Finally, an Implementation report and Performance Measures report will be submitted together with the final report. Effort will be made to accelerate the schedule provided in Table 1 to complete the project ahead of schedule.

Table 1: Project Schedule

Work Tasks	Milestone Dates	2015						
		Apr	May	June	Jul	Aug	Sep	Oct
Project Commencement	April 2, 2015	★						
1 - ID State Contacts								
2 - Survey Development								
3 - Survey Review and Follow-Up								
4 - Survey Compilation and Reporting					★			
4a - Draft Final Report	August 31, 2015							
4b - Review & Address Comments								
4c - Submit Final Report	October 30, 2015							
4d - Impl. & Perf. Meas. Reports	October 30, 2015							
Project Conclusion	October 30, 2015							★

★ = Quarterly Report and Task Report

★ = Meetings with MDT Technical Panel

10 Budget

The requested project budget is $20,631. Schedule, budget, and staffing plans are based on state and federal fiscal year proportioning, as shown in Table 2. Indirect costs are calculated based on a negotiated rate of 25 percent. The travel budget is itemized in Table 3. Itemization of deliverables (products) is shown in Table 4. Salary and benefit rates for individual staff members are listed in Table 5.

Table 2: Detailed Budget by State and Federal Fiscal Year

Budget Category	State Fiscal Year		Federal Fiscal Year		Total
	2015	2016	2015	2016	
Salaries	$6,815.36	$6,495.84	$13,311.20	$0.00	$13,311.20
Benefits	$1,534.53	$1,429.08	$2,963.61	$0.00	$2,963.61
Travel	$115.00	$115.00	$115.00	$115.00	$230.00
Direct Costs	$8,464.89	$8,039.92	$16,389.81	$115.00	$16,504.81
Indirect Costs	$2,116.22	$2,009.98	$4,097.45	$28.75	$4,126.20
Total	$10,581.11	$10,049.91	$20,487.26	$143.75	$20,631.01

Table 3: Itemized Travel Budget

Trip 1: Kick-Off Meeting	
Vehicle Rental	$50.00
Per diem	$11.00
Fuel	$54.00
Trip 2: Implementation Meeting	
Vehicle Rental	$50.00
Per diem	$11.00
Fuel	$54.00
Total	$230.00

Table 4: Itemized Product Budget

Final Report	$4,286.32
Project Summary Report	$476.26
Implementation Report	$476.26
Performance Measures Report	$476.26
Implementation Meeting	$476.26

Table 5: Staff Salary and Benefit Rates

Staff Person	Hourly Rate	Benefit Rate	Total Hours	Total Cost
Steve Perkins	$62.46	22%	208	$15,850
Buisness Manager	$39.94	33%	8	$425

11 Staffing

Dr. Steve Perkins will be the Principal Investigator and will be the manager and sole point of contact with the MDT project manager. The Principal Investigator will be responsible for ensuring that the objectives of the study are accomplished, executing the project tasks, and preparing the written reports.

Dr. Perkins is well qualified, experienced and available to conduct this research, and, to the best of his ability, will deliver a quality finished product in a timely and efficient manner. The level of effort proposed above will not be changed without prior consent of the Technical Panel. The following subsection describes some of the qualifications and experience of the PI.

Dr. Steve Perkins, Ph.D., P.E.—Principal Investigator

Dr. Steve Perkins is a Professor in the Department of Civil Engineering at Montana State University and is a licensed professional engineer in the state of Montana. Dr. Perkins has 23 years of experience as a University Professor, researcher and consultant involving transportation infrastructure including topics in foundation analysis and design, slope stability and repair, advanced soils testing, analysis and design of geosynthetic reinforced structures, pavement design, subgrade stabilization and numerical modeling.

Example projects within the topic areas listed above include:

- Load Testing of Case 1, Type A Micropiles—this was a pilot project performed in conjunction with a consultant from Great Falls where four micropiles of different diameters and lengths were installed in an overconsolidated clay in the Great Falls area and load tested in tension. Results are currently being analyzed to draw preliminary conclusions on the capacity of micropiles as a function of pile size.
- Bearing Capacity of Shallow Foundations on Dense Sand—the objective of this project was to provide new design equations for shallow foundations on dense high-friction angle sands taking into account the effects of mean stress dependency and progressive failure by performing centrifuge model experiments.
- Evaluation of the Deep Patch Slope Repair Method for Forest Roads (Phases I, II and III)—the objective of these projects was to use numerical methods and centrifuge model experiments to evaluate and develop design recommendations for the deep patch slope repair method for failed slopes along US Forest Service roads.
- Field Investigation of Geosynthetics Used for Subgrade Stabilization (Phases I and II)—the objective of these projects was to construct test sections in the field to investigate the

relative benefit of various geosynthetics available on the market to an unpaved road built on a very weak subgrade, and to relate their performance to specific material properties.

- Influence of Cold Temperatures on the Shear Strength and Consolidation Properties of Soft Clays—this project involved performing advanced triaxial and consolidation tests at temperatures just above freezing on soft marine clays to examine the shear strength and consolidation properties for this environment.

As the Principal Investigator, Dr. Perkins will conduct all components of this research project. He will coordinate with the Technical Panel as needed throughout the project and will write and review the technical memoranda and final report.

PI Hours and Availability

It is anticipated that the proposed work associated with this research project will take 208 person hours. The PI is available throughout the duration of this project to provide this level of work. In the event that the level of effort proposed for the principal investigator requires significant modification, written consent will be sought from the Technical Panel to justify and approve this change.

12 Facilities

The scope of work for this project involves minimal use of facilities available to the PI at MSU. Nevertheless, these facilities are described below for sake of completeness.

The PI is a member of the Civil Engineering faculty at MSU and has access to all facilities associated with this department. The PI has historically worked closely with researchers at the Western Transportation Institute (WTI) and maintains a cooperative relationship with the institute for use of their facilities and personnel. This project will be administered with the help of WTI staff.

The Western Transportation Institute (WTI) is the nation's largest transportation institute focusing on rural transportation issues. The Institute was established in 1994 by the Montana and California departments of transportation, in cooperation with Montana State University–Bozeman. WTI is part of the College of Engineering at MSU and has a multidisciplinary research staff of professionals, students, and associated faculty from the fields of engineering (civil/mechanical/industrial/electrical), computer science, psychology, fish and wildlife, business, biology and economics.

WTI integrates expertise from eight research areas: Infrastructure Maintenance and Materials, Road Ecology, Safety and Operations, Winter Maintenance and Effects, Systems Engineering Development and Integration, Logistics and Freight Management, Mobility and Public Transportation, and Transportation Planning and Economics. This research will be conducted within the Infrastructure Maintenance and Materials program area of which Eli Cuelho (the Principal Investigator for this project) is the program manager. The Infrastructure Maintenance and Materials program area at WTI conducts basic and applied research to address the immediate

and long-term construction and maintenance needs of rural highway departments in the following areas:

- Materials—conduct research using new materials, such as geosynthetics or high performance concrete, to evaluate their benefit in new and rehabilitated highway structures.
- Maintenance—develop best management practices using cost–benefit analyses to help state highway departments select the most appropriate and cost-effective maintenance methods to extend the life of their facilities.
- Monitoring—test and evaluate instrumentation and remote sensing technologies to better monitor the condition of transportation infrastructure.

Additional information on WTI can be obtained from our web site at www.WesternTransportationInstitute.org.

Laboratories

WTI and the Civil Engineering Department at MSU have extensive laboratory facilities including Geotechnical, Aggregate Materials, Asphalt, Concrete, Geosynthetics, Environmental, Structural, and Subzero Research testing labs, as well as a large-scale outdoor research and testing facility (TRANSCEND – www.transcendlab.org). These laboratory facilities are used for both teaching and research purposes. The geotechnical and materials laboratories are fully equipped to conduct a wide range of tests on soils and aggregates using AASHTO and ASTM standard methodologies. The laboratories contain fully functional and up-to-date equipment to conduct a wide variety of tests, including:

- soil index testing (e.g., gradation, Atterberg limits, AASHTO and ASTM material classifications, etc.),
- specific gravity tests,
- L.A. abrasion tests,
- gyratory compaction of asphalt and soil,
- small- and large-scale (12 in x 12 in) automated direct shear tests,
- computer-controlled consolidation testing,
- advanced triaxial testing,
- cyclic modulus testing of geosynthetics,
- x-ray computed tomographic (CT) scanning,
- environmentally controlled tests (accurate temperature control over a wide range, humidity control, UV radiation, etc.), and
- asphalt and concrete tests.

Information Services

The research team regularly conducts literature and information gathering through the Carnegie Research Level 1 Library (Renne Library) on the MSU campus. In addition to an extensive collection of printed material, the library subscribes to dozens of databases and hundreds of

refereed journals in print and electronic format. Specific items not accessible through these sources can be located and retrieved by the Interlibrary Loan service, which is affiliated with other research libraries across the United States. Typical sources used to aid literature searches include: TRID (Transport Research International Documentation), E-Science Server, Transportation Research Board Research Records and Annual Meeting CD-ROMs, Google Scholar, Google, and Montana Local Technical Assistance Program library.

Administrative Services

The PI is assisted by a highly qualified group of experienced support staff. Administrative staff members assist with budgeting, procurement, contracts, and accounting. Communications staff provide technical editing, layout, graphic design, and web page support. Information Technology staff maintains network servers and individual computers, software and hardware.

13 References

Sabatini, P.J., Tanyu, B., Armour, T., Groneck, P., Keeley, J. (2005) "Micropile Design and Construction", U.S. Department of Transportation, Federal Highway Administration, Washington, DC, Report No. FHWA-NHI-05-039, 436 p.