SURVEY OF MICROPILE USE IN NEIGHBORING WESTERN STATES

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RESEARCH PROGRAMS

SURVEY OF MICROPILE USE IN NEIGHBORING WESTERN STATES

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16. Abstract

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, however a limited experience base has led to underutilization of a potentially beneficial foundation alternative. To explore a greater use of micropiles, a survey of nine neighboring western state transportation agencies on the use of engineered micropiles has been developed and conducted with the results compiled and presented in this report.

Response to this survey indicated use of micropiles in situations for which they were intended. The use of micropiles was tied to the availability of qualified contractors. With the Pacific Northwest containing such contractors, use in this area has become common practice and satisfaction is high. In states where population density is lower and local micropile contractors are not available, micropiles have been used less frequently. Responses emphasized the importance of a well-qualified contractor and a well-qualified QA/QC program. Responses also indicated the importance of comprehensive geotechnical data describing the subsurface conditions in which micropiles will be installed.

For the agencies responding, the greatest use of micropiles was for new bridge foundations, followed by projects involving retrofitting existing bridge foundations. Micropiles appear to be versatile as evidenced by their use on a variety of projects involving structures other than bridge foundations. Responses indicated that micropiles have been used exclusively on projects for which other conventional deep foundation approaches would not work. The reasons for this were approximately split between site surface conditions and subsurface conditions. These responses supported the notion that micropiles are particularly suited for difficult ground conditions (i.e. presence of cobbles and boulders, intermediate geomaterials) and sites with restricted work areas having limited space and/or remote access and/or urban, noise and vibration sensitive sites.

Load testing of micropiles is common and appears to be incorporated in all projects. None of the agencies responding indicated a “failure” or lack of capacity with project micropiles that have been load tested, which speaks to the success and high degree of satisfaction of the users. Contracting methods for micropile subcontactors appear to be typical and well established. All agencies have developed specifications and/or special provisions for this technology.

Limitations associated with micropiles involve limited lateral capacity in areas of high seismic demand and the higher cost of installation as compared to conventional deep foundations. The latter limitation is not necessarily applicable in common situations where a conventional deep foundation cannot be used.

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EXECUTIVE SUMMARY

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, however a limited experience base has led to underutilization of a potentially beneficial foundation alternative. To explore a greater use of micropiles, a survey of nine neighboring western state transportation agencies (Idaho, Nebraska, North Dakota, Oregon, South Dakota, Utah, Washington and Wyoming departments of transportation and the Western Federal Lands division of FHWA) on the use of engineered micropiles has been developed and conducted with the results compiled and presented in this report.

The experience of the responding agencies was positive and indicated use of micropiles in situations for which they were intended. The use of micropiles was tied to the availability of qualified contractors. With the Pacific Northwest containing such contractors, use in this area has become common practice and satisfaction is high. In states where population density is lower and local micropile contractors are not available, micropiles have been used less frequently. Responses emphasized the importance of a well-qualified contractor and a well-qualified QA/QC program. Responses also indicated the importance of comprehensive geotechnical data describing the subsurface conditions in which micropiles will be installed.

For the agencies responding, the greatest use of micropiles was for new bridge foundations, followed by projects involving retrofitting existing bridge foundations. Micropiles appear to be versatile as evidenced by their use on a variety of projects involving structures other than bridge foundations. Responses indicated that micropiles have been used exclusively on projects for which other conventional deep foundation approaches would not work. The reasons for this were approximately split between site surface conditions and subsurface conditions. These responses supported the notion that micropiles are particularly suited for difficult ground conditions (i.e. presence of cobbles and boulders, intermediate geomaterials) and sites with restricted work areas having limited space and/or remote access and/or urban, noise and vibration sensitive sites.

Load testing of micropiles is common and appears to be incorporated in all projects. None of the agencies responding indicated a “failure” or lack of capacity with project micropiles that have been load tested, which speaks to the success and high degree of satisfaction of the users. Contracting methods for micropile subcontactors appear to be typical and well established. All agencies have developed specifications and/or special provisions for this technology.

Limitations associated with micropiles involve limited lateral capacity in areas of high seismic demand and the higher cost of installation as compared to conventional deep foundations. The latter limitation is not necessarily applicable in common situations where a conventional deep foundation cannot be used.

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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 has pursued this research project to explore a greater use of micropiles. In particular, the objective of this research project is to gain knowledge of the state-of-practice in neighboring western state transportation agencies regarding the use of micropiles for foundation support and earthen slope repair. This objective has been met by developing, conducting and compiling the results of a survey given to neighboring western state transportation agencies on the use of engineered micropiles.

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.

FHWA (Sabatini et al., 2005) classifies micropiles into two groups, called Case I and Case II micropiles. These types of micropiles are defined in Figures 2 and 3. 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.

FHWA (Sabatini et al., 2005) further categorizes micropiles into 4 types (Type A, B, C and D) and subtypes 1, 2 and 3. Table 1 from Sabatini et al. (2005) defines these types where it is seen that different types of grout placement techniques 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 (Bruce and Juran, 1996). The latest FHWA document was published in 2005 (Sabatini et al. 2005).

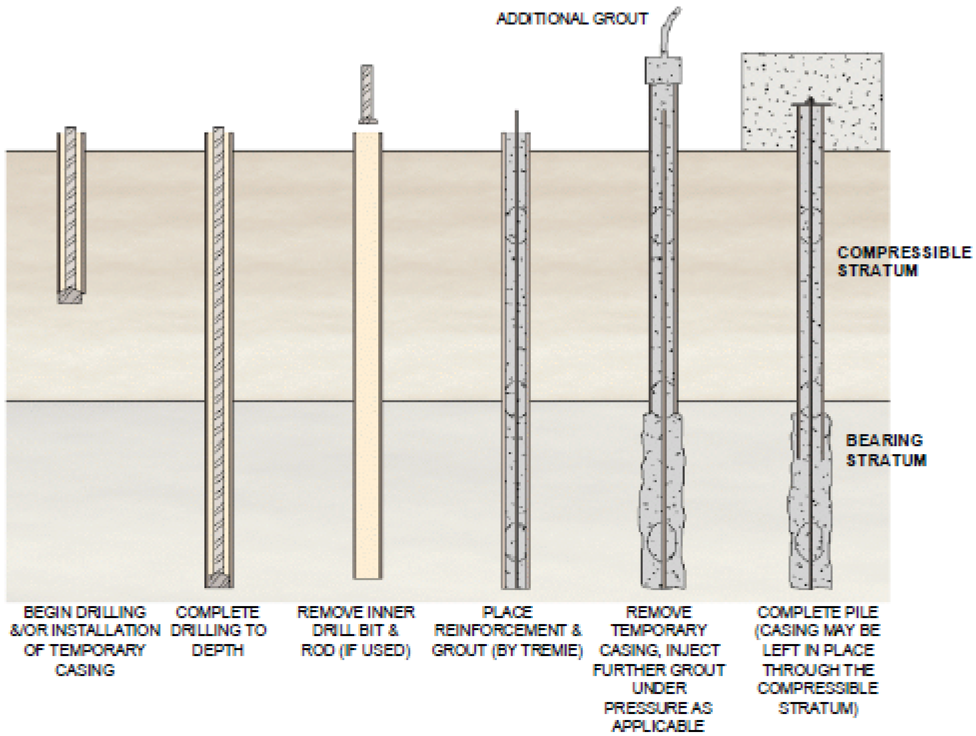

Figure 1: Micropile construction sequence (Sabatini et al. 2005)

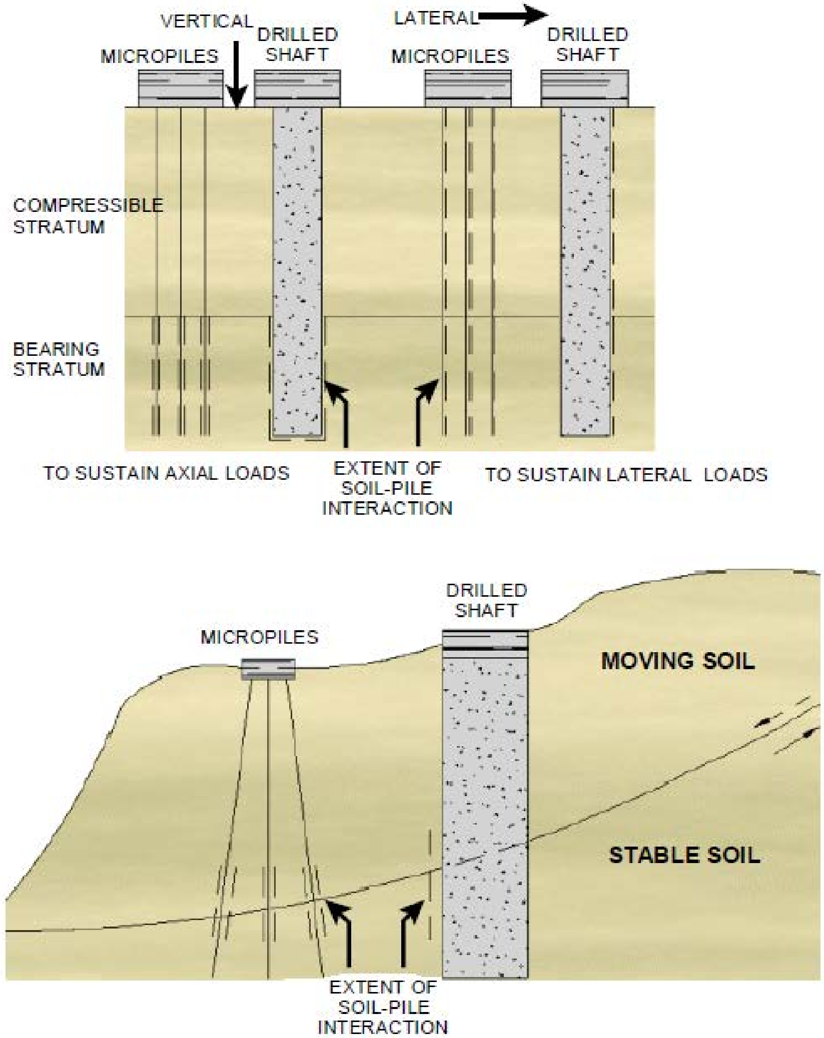

Figure 2: Case I micropiles (Sabatini et al. 2005)

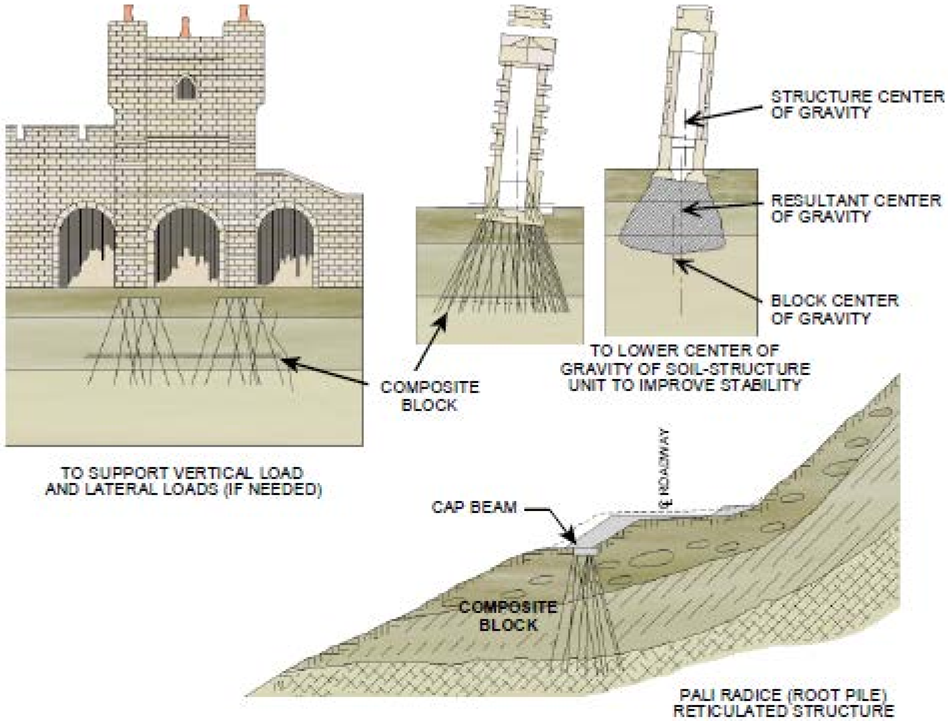

Figure 3: Case II micropiles (Sabatini et al. 2005)

Table 1: Micropile classification based on type of grouting (Sabatini et al. 2005)

Micropile Type and Grouting Method	Sub-type	Drill Casing	Reinforcement	Grout
Type A Gravity grout only	A1	Temporary or unlined (open hole or auger)	None, single bar, cage, tube or structural section	Sand/cement mortar or neat cement grout tremied to base of hole (or casing), no excess pressure applied
	A2	Permanent, full length	Drill casing itself	
	A3	Permanent, upper shaft only	Drill casing in upper shaft, bar(s) or tube in lower shaft (may extend full length)	
Type B Pressure - grouted through the casing or auger during withdrawal	B1	Temporary or unlined (open hole or auger)	Monobar(s) or tube (cages rare due to lower structural capacity)	Neat cement grout is first tremied into drill casing/auger. Excess pressure (up to 1 MPa (145 psi) typically) is applied to additional grout injected during withdrawal of casing/auger
	B2	Permanent, partial length	Drill casing itself	
	B3	Permanent, upper shaft only	Drill casing in upper shaft, bar(s) or tube in lower shaft (may extend full length)	
Type C Primary grout placed under gravity head, then one phase of secondary "global" pressure grouting	C1	Temporary or unlined (open hole or auger)	Single bars or tube (cages rare due to lower structural capacity)	Neat cement grout is first tremied into hole (or casing/auger). Between 15 to 25 minutes later, similar grout injected through tube (or reinforcing pipe) from head, once pressure is greater than 1 MPa (145 psi)
	C2	Not conducted	–	
	C3	Not conducted	–	
Type D Primary grout placed under gravity head (Type A) or under pressure (Type B). Then one or more phases of secondary "global" pressure grouting	D1	Temporary or unlined (open hole or auger)	Single bars or tube (cages rare due to lower structural capacity)	Neat cement grout is first tremied (Type A) and/or pressurized (Type B) into hole or casing/auger. Several hours later, similar grout injected through sleeved pipe (or sleeved reinforcement) via packers, as many times as necessary to achieve bond
	D2	Possible only if regrout tube placed full-length outside casing	Drill casing itself	
	D3	Permanent, upper shaft only	Drill casing in upper shaft, bar(s) or tube in lower shaft (may extend full length)	

3 Research Approach

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 this project has involved developing a series of survey questions designed to assess the use of micropiles within neighboring state departments of transportation and federal agencies. Nine agencies received this survey and included the state departments of transportation in Idaho, Nebraska, North and South Dakota, Oregon, Utah, Washington and Wyoming. One federal agency was included (the FHWA Western Federal Lands Division). The survey consisted of 19 questions and focused on the level of use, types of projects where use has occurred, subsurface conditions when used, site surface conditions, typical costs, cost comparison to other alternatives, availability of contractors, construction methods, construction success, load testing methods, assessment of performance and lessons learned. A copy of the survey delivered to the above agencies is included in Appendix A.

4 Survey Response

Responses were received from all nine agencies. Some agencies provided copies of specifications, special provisions and project plans. Table 2 lists the documents received from each agency. Appendix B provides a compilation of responses for each of the 19 questions. Minor editing of responses was done for the compiled responses listed in Appendix B. Appendix C contains a copy of the responses as received. Appendix D contains copies of specifications, plans and special provisions provided by the responding agencies.

The remainder of this section provides a summary of the responses to each question.

Q1: Please list the name, title and contact information for the person(s) completing this survey from your organization.

All responders were a geotechnical, foundation or bridge engineer or an engineering geologist. For eight of the nine agencies, a single person provided the response. The remaining agency had two people who contributed to the response.

Q2: Does your organization use micropiles for bridge foundations or other geotechnical applications? If you answered “no”, can you provide reasons for the lack of use?

Eight of nine agencies answered “yes” to this question.

The agency that answered “no” to this question cited lack of familiarity, expertise, heavy workload and the absence of a need to consider this foundation alternative. This agency was not required to continue with the survey, hence all remaining summaries of responses refer to eight responders.

Table 2: Documents received from responding agencies

Agency	Documents Received
ID	1. Survey response
NE	1. Survey response 2. Micropile special provision
ND	1. Survey response
OR	1. Survey response 2. Draft specification
SD	1. Survey response 2. Micropile special provision
UT	1. Survey reponse 2. Micropile special provision
WA	1. Survey response 2. Standard specifications for road, bridge and municipal construction 3. Mircopile bid tabs 4. BSP August 2, 2010 5. BSP August 6, 2012 6. Yesler Way project drawings and specifications 7. Yesler Way contract provisions and plans 8. George Sellar bridge project specifications 9. George Sellar bridge contract plans 10. Portland Avenue to Port of Tacoma Road project specifications 11. Portland Avenue to Port of Tacoma Road project plans
WFL	1. Survey response 2. Link to standard specifications
WY	1. Survey response 2. Micropile special provisions Bret Slide/Upper Shell Slide project 3. Micropile special provisions Alpine Junction-Hoback Junction project 4. Micropile special provisions Double nickel slide project

Q3: On how many projects have micropiles been used by your organization in the past 5 years?

Answers to this question ranged from none to 4 times within the last 5 years. The agency answering “none” last used micropiles for a project 12 years ago. Another agency having one project in the last 5 years noted they have had 4 micropile projects since 1998. The agency (Washington DOT) listing the highest use in the last 5 years noted 13 micropile projects since 2000.

Q4: For each project where micropiles were used, list the type of application involved. Examples might be new construction of bridge foundations, retrofitting of bridge foundations, scour protection of shallow foundations, seismic retrofits, slope stability repair, etc.

The number of micropile projects reported by the eight agencies within the past 5 years fall within the following categories:

- Foundations for new bridges: 6 projects
- Retrofitting or underpinning of existing bridge foundations: 4 projects
- Landslide or slope stability repair: 3 projects
- Foundation for a retaining wall: 1 project
- Foundation support for an MSE wall affected by a landslide: 1 project
- Uplift resistance for vault subjected to buoyancy: 1 project
- Temporary structure support for sagging: 1 project

The total number of micropile projects reported by the eight agencies for all periods fall within the following categories:

- Foundations for new bridges: 10 projects
- Retrofitting or underpinning of existing bridge foundations: 5 projects
- Landslide or slope stability repair: 3 projects
- Ferry terminal foundation repair: 2 projects
- Foundation for a retaining wall: 1 project
- Foundation support for an MSE wall affected by a landslide: 1 project
- Uplift resistance for vault subjected to buoyancy: 1 project
- Temporary structure support for sagging: 1 project
- Support of a settling foundation: 1 project
- Bridge abutment instability repair: 1 project
- Spread footing overturning repair: 1 project

From these responses, the greatest use of micropiles is for new foundations for bridges, followed by retrofitting or underpinning existing bridge foundations. The state of Washington noted that they do not generally use micropiles for new construction because their seismic demand is generally too great. The state of Oregon noted that all of their projects (4) were for new foundations in areas of low seismic demand.

Three projects where micropiles were used for landslide or slope instability repair were listed, where two of these were from one state (Wyoming). The state of Oregon noted that they have considered micropiles for landslide repair but have found that micropiles were either technically inadequate (due to the slide plane being excessively deep, resulting in excessive loads on the micropile) or uneconomical relative to other options.

Q5: FHWA (2005) classifies micropiles into two groups, called Case I and Case II micropiles. Excerpts from FHWA (2005) are provided in an attachment defining these two cases (Figure 2-1 and 2-2). FHWA (2005) further categorizes micropiles into 4 types (Type A, B, C and D) and subtypes 1, 2 and 3. Table 2-1 from FHWA (2005) defines these types and is included as an attachment. For the projects listed in item 4, please identify which case, type and subtype of micropile were used. If possible, please explain why this type was used over others.

All agencies reporting use of micropiles fell within Case I. The types of micropiles used are listed in Table 3.

Table 3: Number of agencies reporting use of different types of micropiles

Micropile Type	Number of Agencies Reporting Use
A1	1
A2	2
A3	3
B1	1
B2	1
B3 and D3	1

The reasons for selecting these types was based on subsurface conditions, which are detailed in question 6. The state of Oregon noted that permanent casing to the bearing layer (bedrock) was used to increase lateral capacity of the pile. Gravity grouting was sufficient in the uncased rock socket. The state of Utah noted that pressure grouting was needed to develop greater bond values to reach a desired capacity. The state of Washington has used full depth casing with pressure grouting during extraction of the casing. Washington has also installed post-grout tubes as a safety measure, which would be used in the event that the pile did not have sufficient capacity. Washington noted that while post-grout tubes have been installed, there has not been a need to employ them. Washington also noted that they do not use micropiles for cases where the depth to an adequate bearing layer is large due to insufficient lateral capacity.

Q6: For the projects discussed in item 4, briefly describe the subsurface conditions and how these conditions either precluded the use of other foundation alternatives or were viewed as favorable for micropiles.

For the 8 agencies responding, all noted that a deep foundation was needed either because of subsurface conditions being unfavorable for shallow foundations or because of the potential for scour. Three agencies cited subsurface conditions as a factor leading to the use of micropiles over other deep foundation alternatives. The remaining 5 cited surface conditions as the major factor leading to the selection of micropiles, which is discussed under question 7. The presence of boulders, typically in poor soils that had to be penetrated to reach bedrock, was the principal subsurface condition that led to the use of micropiles.

Q7: For the projects listed in item 4, were there any surface conditions associated with the site that led to the decision to use micropiles? Possible examples of surface conditions may be restricted access, environmental impact in stream channels, and noise and vibration concerns.

Five of the eight agencies responding cited surface conditions as the major factor leading to the selection of micropiles over other deep foundation alternatives. The surface conditions cited include:

- Restricted headroom
- Restricted size of work zone
- Difficult access because of steep terrain where equipment could be lifted by crane and dropped into position, thus eliminating the need for an access road
- Need to reduce environmental concerns (noise, vibration)

Q8: Was Buy America certification required and/or was this a factor in the use of micropiles? Assuming certification was required, did this cause any problems?

Of the eight agencies responding, seven said that Buy America certification was required. Most of these agencies indicated some complications in procuring US made steel materials (casing and reinforcement bars), however all agencies indicated that these complications were resolved and did not prevent construction.

Q9: Could you provide a copy of specifications used on micropile projects?

Of the eight agencies responding, seven provided copies of specifications or special provisions. These copies are contained in Appendix D.

Q10: Please summarize typical costs of micropile installation projects and how these costs compared to other alternatives.

The state of Nebraska gave a cost of $182/ft while Western Federal Lands gave $150 to $200/ft of installed micropile. The state of South Dakota gave a cost of $5905 per installed micropile, Washington gave a cost ranging from $4300 to $36,000 for 10 projects with an average cost of $21,000, and Oregon gave a cost for one project of $5200 per installed micropile. Two states gave comparison costs to driven steel piles with a ratio of micropile cost to steel pile cost ranging from 2.4 to 6.1. Cost for verification load tests were given by four agencies and ranged from $2000 to $34,000 with an average of $15,500. Cost for proof load tests were given by two agencies and ranged from $1400 to 19,200 with an average of $8200. The ten projects listed by the state of Washington and associated costs are included in Appendix D.

Q11: Describe the types of contracting methods that have been used.

Six of the eight agencies responding specifically stated that a conventional design-let (bid)-build method was followed. Several noted that a lowest bid selection approach was taken. Several agencies noted that the contractor is responsible for providing the design where the agency may specify required capacity, minimum pile diameter and casing thickness.

Q12: Describe the status of local contractor availability and level of expertise. How has this factored into decisions regarding micropile use?

The responses to this question indicated that only the states of Washington and Colorado have experienced micropile contractors. Hence, only two agencies (WA and WFL) indicated local contractor availability. The responses indicated that this has not necessarily limited the use of micropiles for projects where other alternatives were limited.

Q13: Is a prequalified contractor list used and what is the process for prequalification?

Seven of the eight agencies responding said they do not use a prequalified contractor list. One agency noted that in their state, micropile contractors are considered to be subcontractors and it is against their state law to have a prequalified list for subcontractors. These seven agencies did note, however, that their specifications and/or special provisions do have experience requirements for the micorpile installer and for QC/QA inspectors. These requirements vary from state to state and typically involve demonstration of a certain number of micropile installations within a given time period.

Q14: What are typical installation times?

The responses to this question showed that installation times are highly dependent on ground conditions and pile length. Two agencies noted a typical values of 3-4 piles (200-250 ft) per day. Another noted 1 hr/pile. The state of Oregon gave time periods associated with different phases of the project.

Q15: Please describe your level of satisfaction with construction efficiency and outcomes and any lessons learned.

All agencies responding noted that they are satisfied with the outcomes of their projects using micropiles. Several noted that micropile projects are more expensive, indicating they would use micropiles only on projects where other methods are not feasible. One agency noted that installation time is longer with micropiles, however this appears to be highly dependent on the contractor's experience as the agency with the most experience noted that installation is quick and they are looking forward to a more wide-spread use of micropiles. Other lessons learned include having to accept that load tests are in tension and do not replicate the true loading condition for the pile, QC/QA is critical for a successful outcome and good geotechnical subsurface data is needed to avoid claims from the drilling contractor.

Q16: Are micropiles used on urgent or emergency projects and if so, what type of contracting methods are used?

Seven of eight agencies noted that they have not had a need to use micropiles for emergency projects. The remaining agency noted that one project was on an urgent timeframe in that the repair needed to be completed before the seasonal road was set to open.

Q17: Are load tests performed? If yes, please describe the methods used and how designs are revised depending on results.

Seven of eight agencies stated that load tests are performed. These agencies noted that verification and proof tests are performed with several noting that ASTM D 3689 specifications were followed for these tests. All tests were performed in tension with results assumed to be applicable to compression. Most agencies indicated that the responsible design party was required to revise the design in the event of a failed test. Designs are not revised should the capacity exceed design requirements. None of the agencies noted a need to revise a design for the projects with which they have been involved.

Q18: How is long term performance of installed micropiles assessed?

Most agencies responding to this question stated that routine biannual bridge inspections were used to assess long term performance. One agency noted that when permanent casing was used, techniques similar to those used for driven steel piles were used to monitor corrosion of the casing. For cases where micropiles were used for slope repair, one agency used inclinometers to monitor slope movement and micropiles instrumented with strain gauges to monitor load transfer.

Q19: Please describe your anticipated frequency of micropile use on future projects.

Seven of the eight agencies who reported previous micropile use indicated they would continue to use micropiles on an as-needed basis. Most agencies indicated future use consistent with past use.

5 Synthesis of Survey Responses

In general, the experience of the responding agencies was positive and indicated use of micropiles in situations for which they were intended. The use of micropiles was very much tied to the availability of qualified contractors. With the Pacific Northwest containing such contractors, use in this area has become common practice and satisfaction is high. In states where population density is lower and local micropile contractors are not available, micropiles have been used less frequently. Not surprisingly, responses emphasized the importance of a well-qualified contractor and a well-qualified QA/QC program. Responses also indicated the importance of comprehensive geotechnical data describing the subsurface conditions in which micropiles will be installed.

For the agencies responding, the greatest use of micropiles was for new bridge foundations. This was followed by projects involving retrofitting existing bridge foundations. Micropiles appear to be versatile as evidenced by their use on a variety of projects involving structures other than bridge foundations. Responses indicated that micropiles have been used exclusively on projects for which other conventional deep foundation approaches would not work. The reasons for this were approximately split between site surface conditions and subsurface conditions. These responses supported the notion that micropiles are particularly suited for difficult ground conditions (i.e. presence of cobbles and boulders, intermediate geomaterials) and sites with restricted work areas having limited space and/or remote access and/or urban, noise and vibration sensitive sites. All agencies have used micropiles falling with the category of Case I. Various types have been installed with selection of these types based on the particular subsurface conditions at the site.

Load testing of micropiles is common and appears to be incorporated in all projects. None of the agencies responding indicated a "failure" or lack of capacity with project micropiles that have been load tested, which speaks to the success and high degree of satisfaction of the users. Contracting methods for micropile subcontactors appear to be typical and well established. All agencies have developed specifications and/or special provisions for this technology.

Limitations associated with micropiles involve limited lateral capacity in areas of high seismic demand and the higher cost of installation as compared to conventional deep foundations. The latter limitation is not necessarily applicable in common situations where a conventional deep foundation cannot be used.

6 Next Steps

The MDT technical panel for this project has discussed follow-on steps to further explore the use of micopiles in the state. MDT has decided to develop an experimental project for an upcoming construction project most likely involving a retrofit of an existing bridge foundation. A scheduled project, for which micopiles would be appropriate, could not be currently identified. Once such a project is identified, MDT will develop specifications and special provisions using as a guide the documents from other states provided as part of this study. The site conditions for the identified project may help identify any research needs or components that would be beneficial to include in the experimental project.

7 References

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8 Appendix A: Survey

Survey of Micropile Use in Neighboring Western States

Date: June 4, 2015

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Introduction

The Montana Department of Transportation (MDT) is considering the use of micropiles in the State. Currently, MDT sees great potential for the use of this technology in retrofitting bridge foundations. Other possible applications include construction of new foundations, seismic retrofits and slope stabilization. MDT is interested in learning from neighboring states about their experiences with design and construction of micropiles for transportation structures and has contracted with Montana State University to conduct this survey. This survey has been sent to DOTs in the states of Idaho, Nebraska, North and South Dakota, Oregon, Utah, Washington and Wyoming and the Western Federal Lands division of FHWA. The results of this survey will be made available to those who have participated when the final report for the project has been written and approved. It is expected that the final report will be available by October 2015. In addition, compiled responses to the survey will be made available to all responders once that phase of the project is completed, which is expected to be in late July 2015.

As background, micropiles are small diameter (generally less than 12 inches in diameter) piles that are constructed by drilling and grouting techniques. The piles are generally reinforced with a single steel reinforcement bar placed in the middle of the pile. Micropiles were first introduced in the US in 1973. The first state-of-the-practice document produced by FHWA was published in 1996. The latest FHWA document was published in 2005.

This survey is designed to allow the responder to provide as much information as they wish. Questions are listed below. This word document is intended to be edited by the responder with responses given below each question and taking as much space as needed. Responders should feel free to direct any questions to Steve Perkins using the contact information on the first page.

MDT and MSU thank you for taking the time to complete this survey. We ask that you have the survey returned to Steve Perkins by July 3, 2015.

Questions

1. Please list the name, title and contact information for the person(s) completing this survey from your organization.

2. Does your organization use micropiles for bridge foundations or other geotechnical applications? If you answered "yes", please continue. If you answered "no", can you provide reasons for the lack of use? If you answered "no", you may stop here.

3. On how many projects have micropiles been used by your organization in the past 5 years?

4. For each project where micropiles were used, list the type of application involved. Examples might be new construction of bridge foundations, retrofitting of bridge foundations, scour protection of shallow foundations, seismic retrofits, slope stability repair, etc.

5. FHWA (2005) classifies micropiles into two groups, called Case I and Case II micropiles. Excerpts from FHWA (2005) are provided in an attachment defining these two cases (Figure 2-1 and 2-2). FHWA (2005) further categorizes micropiles into 4 types (Type A, B, C and D) and subtypes 1, 2 and 3. Table 2-1 from FHWA (2005) defines these types and is included as an attachment. For the projects listed in item 4, please identify which case, type and subtype of micropile were used. If possible, please explain why this type was used over others.

6. For the projects discussed in item 4, briefly describe the subsurface conditions and how these conditions either precluded the use of other foundation alternatives or were viewed as favorable for micropiles.

7. For the projects listed in item 4, were there any surface conditions associated with the site that led to the decision to use micropiles? Possible examples of surface conditions may be restricted access, environmental impact in stream channels, and noise and vibration concerns.

8. Was Buy America certification required and/or was this a factor in the use of micropiles? Assuming certification was required, did this cause any problems?

9. Could you provide a copy of specifications used on micropile projects?

10. Please summarize typical costs of micropile installation projects and how these costs compared to other alternatives.

11. Describe the types of contracting methods that have been used.

12. Describe the status of local contractor availability and level of expertise. How has this factored into decisions regarding micropile use?

13. Is a prequalified contractor list used and what is the process for prequalification?

14. What are typical installation times?

15. Please describe your level of satisfaction with construction efficiency and outcomes and any lessons learned.

16. Are micropiles used on urgent or emergency projects and if so, what type of contracting methods are used?

17. Are load tests performed? If yes, please describe the methods used and how designs are revised depending on results.

18. How is long term performance of installed micropiles assessed?

19. Please describe your anticipated frequency of micropile use on future projects.

NOTE: Table 1 and Figures 1-3 were provided.

9 Appendix B: Compiled Responses to Survey

Provided below are tables showing each of the 19 questions and the responses from each agency. Minor editing has been done to provide reading consistency of the responses.

Agency	**Q1: Please list the name, title and contact information for the person(s) completing this survey from your organization** (*Note: Only the responders title is listed below*)
ID	Geotechnical Engineer
ND	PE, Geotechnical Section Engineer
NE	Geotechnical Engineer
OR	PE, Senior Geotechnical Engineer
SD	Foundation Engineer
UT	Geotechnical Engineer
WA	PE, LEG, Chief Foundations Engineer
WFL	Two responders (1) PE, Senior Geotechnical Engineer, (2) PE Bridge Team Leader
WY	PE, PG, Assistant Chief Engineering Geologist

Agency	**Q2: Does your organization use micropiles for bridge foundations or other geotechnical applications? If you answered "no", can you provide reasons for the lack of use?**
ID	Yes
ND	No. Reasons are familiarity and expertise, current heavy workload (does not necessarily allow for a lot of deviation from normal), current methods have not necessitated consideration of using micropiles.
NE	We have only used them on a couple of local project jobs for rehabilitation of an existing bridge.
OR	Yes
SD	Yes
UT	Yes
WA	Yes. Generally not for new construction. Our seismic demand is generally too great to utilize micropiles exclusively for new construction. Micropiles are more commonly used when retrofitting existing bridge foundations (i.e. when foundations are deemed deficient).
WFL	Yes
WY	Yes

Agency	**Q3: On how many projects have micropiles been used by your organization in the past 5 years?**
ID	None. The last project with micropiles was about 12 years ago.
NE	One
OR	One that I am aware of in the last five years, completed in 2010. Since the first usage within Oregon DOT in 1998, I am aware of four applications with micropiles, all for foundation support of bridges, all of which were water crossings. I have been involved with the in-house delivery of three of those projects, in each case micropiles were used due to concerns for boulders in the manmade fills and the desire to penetrate these fills to support the foundation on/within the underlying bedrock to avoid the need to excavate the poorly consolidated boulder fills (which would have complicated traffic control and shoring needs). Each of the bridge sites were either in a low seismic demand area of the state (and therefore were acceptable for use on multi-span bridges as was the case for Oregon DOT's first application in 1998) or single span bridges which, at the time, were essentially exempt from seismic design criteria relative to lateral loading of the bridge for seismic loads. Our 1998 project used draft specifications from a draft of the 1996 FHWA document referenced above as the design of this project was performed in the period 1995 through 1997.
SD	One project with 2 bridges founded on micropiles
UT	Two
WA	Last 5 years = 4 jobs (2014, 2 – in 2011, and 2010) Other jobs include 2009, 2007, 3 – in 2004, 3 – in 2003, and 2000 for a total of 13 jobs since 2000.
WFL	3 – 1) Isa Lake Bridge underpinning, 2) McDonald Creek Bridge underpinning, and 3) Bradford Wall. 4) Manning Crevice Suspension Bridge – foundation (planned construction 2015)
WY	Three

<table>
<tr><th>Agency</th><th>Q4: For each project where micropiles were used, list the type of application involved. Examples might be new construction of bridge foundations, retrofitting of bridge foundations, scour protection of shallow foundations, seismic retrofits, slope stability repair, etc.</th></tr>
<tr><td>ID</td><td>Foundation for new bridge.</td></tr>
<tr><td>NE</td><td>Retrofit of bridge foundation.</td></tr>
<tr><td>OR</td><td>In each case discussed in 3 above, micropiles were used for the support of new bridges which replaced an existing bridge or box culvert, during the construction of which traffic was permitted to pass in at least a one lane configuration. Each site was also a water crossing and scour potential was a design consideration, typically mitigated with riprap on the fore-slope beneath the bridge. We have evaluated the use of micropiles for slope stability mitigation in the past, but found it to either be technically inadequate (e.g. the slide plane depth was too great therefore the loads on the micropile were greater than could be tolerated with a reasonable number of rows of micropile) or uneconomical relative to other viable solutions.</td></tr>
<tr><td>SD</td><td>New bridge foundation construction.</td></tr>
<tr><td>UT</td><td>New foundations installed beneath existing freeway bridges for I-80 bridge widening projects.</td></tr>
<tr><td>WA</td><td>
<table>
<tr><th>Contract</th><th>Job</th><th>Purpose</th></tr>
<tr><td>008670</td><td>I-5, Portland Avenue To Port Of Tacoma Road – NB HOV</td><td>Uplift resistance for vault subjected to buoyancy</td></tr>
<tr><td>008127</td><td>I-90, Snowshed To Keechelus Dam Phase 1C</td><td>New Unnamed Creek Bridge Foundation Support</td></tr>
<tr><td>008122</td><td>US 2, W of Leavenworth - Slope Stabilization</td><td>Shear elements in landslide repair</td></tr>
<tr><td>007847</td><td>SR 99, Alaskan Way Viaduct - Replacement S Holgate to King St</td><td>Temporary structure support for staging</td></tr>
<tr><td>007677</td><td>SR 285, George Sellar Bridge Additional EB Lane</td><td>Foundation retrofit to support widening</td></tr>
<tr><td>007402</td><td>Yesler Way Vic Foundation Stabilization</td><td>Support a settling foundation</td></tr>
<tr><td>006737</td><td>Friday Harbor Ferry Terminal, Preservation</td><td>Repair trestle for ferry dock</td></tr>
<tr><td>006576</td><td>Shaw Island Ferry Terminal Slip Reconstruction</td><td>Repair trestle for ferry dock</td></tr>
<tr><td>006444</td><td>SR433, Lewis And Clark Bridge 433/1 Deck Replacement</td><td>Solve abutment instability issue</td></tr>
<tr><td>005849</td><td>SR 5, Great Northern Rr Br 5/710 Pin Piles</td><td>Solve overturning issue on spread footing</td></tr>
</table>
</td></tr>
<tr><td>WFL</td><td>2 of 4 projects were underpinning existing bridge foundations (#1 and #2 in question 3).
1 of 4 was foundation for retaining wall (#3 in question 3).
1 of 4 was foundation for suspension bridge abutments (planned fall 2015)</td></tr>
<tr><td>WY</td><td>1) Landslide repair as part of a tie back anchor system, 2) support of an MSE wall which was affected by a landslide, 3) Landslide repair</td></tr>
</table>

Agency	**Q5: FHWA (2005) classifies micropiles into two groups, called Case I and Case II micropiles. Excerpts from FHWA (2005) are provided in an attachment defining these two cases (Figure 2-1 and 2-2). FHWA (2005) further categorizes micropiles into 4 types (Type A, B, C and D) and subtypes 1, 2 and 3. Table 2-1 from FHWA (2005) defines these types and is included as an attachment. For the projects listed in item 4, please identify which case, type and subtype of micropile were used. If possible, please explain why this type was used over others.**
ID	Type A2
NE	Case I. Used because of tight space conditions.
OR	All miropiles used on the bridge projects in 4 above were Case 1 micropiles. In each case the micropiles were essentially of the same design, a Type A3, with gravity grout, permanent casing to the bedrock contact and a central large diameter reinforcing bar which was continuous from the pile head to the bottom of the rock socket. Note that the micropiles were typically used to penetrate a poorly consolidated manmade fill including boulders with an underlying rock contact which providing the bearing support via an un-cased rock socket. In one application there was restricted headroom, the existing bridge, beneath which the interior bent micropile (through native materials) were installed. The Type A3 microplies were used for the reasons dictated by the subsurface conditions. The permanent steel casing was relied upon for the lateral structural capacity available and pressure grouting was not needed as the required capacity was available based on gravity grout within the rock socket length.
SD	Case 1 – Type A3 was used. A Case 1 – Type B3 was also an option for the micropile contractor to utilize if necessary or their installation method required. This type was chosen due to the subsurface conditions of the site and design bearing requirements. A cased section was required through the gravel and cobbles overlaying the Spearfish Formation bedrock. An uncased hole would not have remained open for the placement of the central bar or grout. Also the porous nature of the upper granular section would have likely taken up large amounts of grout if left uncased. It was expected an uncased hole would remain open in the Spearfish Formation which would keep the amount of casing needed for the project to a minimum, reducing costs and allow for the design of the micropiles based on the skin friction between the grout and bedrock formation.
UT	Both projects were Case 1- To sustain axial loads, Type B (pressure grouted during auger withdrawal). Both projects were design build- thus the Design Builder selected this method for its ease of installation, and its low cost.
WA	WSDOT has only used Case 1 - Type B3/D3. Just to be clear we are talking about drilling with casing full depth. Introducing a reinforcing rod inside the casing and pressure grouting through the casing while extracting it. Often the casing will be extracted above its final tip elevation while pressure grouting, then the casing is plunged back down 5 to 10 feet or so in an area where pressure grouting has already occurred. Post grout tubes are cheap we usually have them affixed to the reinforcing bar, just in case testing reveals lower capacity than desired, or in case there is a construction issue, and we need to post grout for some reason. We rarely post grout, or second stage grout. Most often we get capacity without it.
WFL	All projects were Case 1 micropiles. All project had type A3 micropiles. We specified the length and size of permanent casing but leave the type of micropile up to the contractor. They most likely selected this type because it was most economical and most straight forward construction.
WY	1) Class I, Type A, Subtype A2 plus a single bar chosen due to difficult drilling conditions and potential grout loss. 2) Class I Type A, Subtype A1 with a single bar, chosen because the hole would stay open drilling with air. 3) Class I Type B, Subtype B2 with full depth casing and a single bar in center. 11 ⅞”” casing was used on this project and due to the depth of micropiles 80’+ pressure grouting was required.

Agency	**Q6: For the projects discussed in item 4, briefly describe the subsurface conditions and how these conditions either precluded the use of other foundation alternatives or were viewed as favorable for micropiles.**
ID	Micropiles were constructed on a very steep canyon sides. Subsurface materials included about 60 feet of volcanic ash with boulders and then volcanic rock.
NE	Overburden (loess) over limestone and shale bedrock. Favorable for most deep foundations.
OR	As mentioned in 5 above, micropiles were typically used to penetrate a poorly consolidated manmade fill including boulders with an underlying rock contact which providing the bearing support via an un-cased rock socket. In one application there was restricted headroom, the existing bridge, beneath which the interior bent micropile (through native materials) were installed. Alternative considered and dismissed included, spread footings (dismissed due to inadequate capacity and scour concerns), driven pile (dismissed due to concerns with penetrating the boulder fills and headroom) and drilled shafts (dismissed due to concerns with challenges for penetrating the boulder fills and headroom as well as economics and likelihood of construction problems).
SD	Both sites had similar subsurface conditions consisting of gravel and cobbles up to bolder size over laying red silt-clay (Spearfish Formation). At one of the bridge sites the depth of gravel and cobbles was 30 to 40 feet thick. The other was 25 to 40 feet thick. Spread footings were ruled out due to calculated scour. The depth the footings need to be to be below scour was neither economical nor feasible to construct. Driving steel pile through the gravel and cobbles to ensure the tips were below calculated scour depths would have been challenging. After consultation with several large diameter drilled shaft installation companies it was determined the expense (likely 3x's the standard bid price) and anticipated difficulty in setting a casing was too great for shafts to be a feasible option. The result of eliminating typical foundation types utilized by SDDOT resulted in pursuing other options. The subsurface conditions were determined to be favorable for the use of micropiles.
UT	Conditions generally consisted of intermixed stiff to medium cohesive soils and medium dense to dense granular soils, overlying a limestone and shale bedrock. These conditions were considered generally favorable to the design and construction of end bearing micropiles.
WA	We generally develop the bond in decent granular materials, SP, SM, GP, GM, GW. Often SPT blow counts will be anywhere from 15 bpf to refusal. We have glacial till in the area. The upper "cased" portion of the micropiles can be in some really bad stuff. Probably the worst near surface soils we penetrated through was for the SR-99 Yesler Way foundation stabilization. The upper 30 feet or so was a mixture of hydraulic fill, sawdust, and lumber mill scraps placed in 1905, with some bricks and any other handy junk nearby that they tossed in to bulk up the fill, back in the day. The bond for that job was in glacial till. What drives the selection for us most often is depth to bond zone materials. If the depth to decent material gets to large, buckling becomes an issue as micropiles are fairly slender elements. Reticulated Case 2 patterns can help get around that buckling issue, but the design procedure is not as well defined as we would like for highway use and there is little guidance on seismic design for such systems. We prefer straight linear elements that can be modeled as piles or shafts.
WFL	Isa Lake Bridge – Organics and loose silt over bedrock. McDonald Creek Bridge – Deep loose silt and sand. Bradford Wall – Loose landslide debris over bedrock. Manning Crevice Bridge – Founded on rock, Additional bearing capacity and global stability due to possible instabilities of rock mass below abutment

	At all locations micropiles were primarily selected based on the surface constraints rather than the subsurface conditions (Except for the Manning Crevice Bridge). It was determined that micropiles were suitable at all locations based on the subsurface conditions.
WY	1) micropiles were used because the very steep difficult terrain limited the size of equipment that could be used to construct a repair on the slope. 2) Micropiles were chosen because vertical support was needed and drilled shafts and "H" pile were not practical given the limited working space. 3) Micropiles were chosen because given the geometry of slide plane and the terrain below the roadway the tie back anchors required for the landslide repair would have had to be longer than practical to install.

Agency	**Q7: For the projects listed in item 4, were there any surface conditions associated with the site that led to the decision to use micropiles? Possible examples of surface conditions may be restricted access, environmental impact in stream channels, and noise and vibration concerns**.
ID	The steep slopes at the site and lack of access/environmental issues led to the selection of micro piles that can be installed with small and light-weighted equipment, lifted into site with crane so didn't need access road.
NE	Not subsurface. Wanted to eliminate vibration potential from pile driving due to a nearby railroad.
OR	Yes, Micropiles were typically used to penetrate a poorly consolidated manmade fill including boulders with an underlying rock contact which providing the bearing support via an un-cased rock socket. Additionally, avoiding the need to excavate the poorly consolidated boulder fills helped to accommodate traffic control and reduce shoring needs (which in themselves would be difficult in a boulder fill).
SD	The presence of the thick gravel and cobble layer overlaying the bedrock formation that precluded the use of other foundations types typically utilized by the SDDOT.
UT	Yes, clearance beneath the existing bridges (that needed to remain in service during construction) was the only determining factor which led to the MP selection.
WA	Yes. Size of equipment for installation; size of work zone; contractor access; limited headroom concerns; environmental concerns (Noise and Vibration); and size of final foundation all influenced the choice of micropile.
WFL	At all of the sites it was determined that a deep foundation element was needed. For all of those projects micropiles were primarily selected because they required the smallest deep foundation substructure option that could be tied into the existing foundation/retaining wall and space was limited at each site. Micropiles also were favorable for selection because the axial capacity can be determined by a field verification test at a relatively small cost.
WY	In all 3 projects terrain and stream channels prevented the use of a typical "dirt" solution.

Agency	**Q8: Was Buy America certification required and/or was this a factor in the use of micropiles? Assuming certification was required, did this cause any problems?**
ID	No.
NE	Buy America used for steel.
OR	Yes. There were concerns with this requirement as the central reinforcing bars have been foreign made, although typically the value of the central reinforcing bars is very small relative to the overall value of the project so the ratio fell within the permissible limit for non-American made steel usage, so the issue was ultimately resolved each time with a little bit of research.
SD	Buy America certification was required. I am not aware of this causing any problems.
UT	Yes, Buy Am was required. The acquisition of qualified micropile bars and their certification process did present some challenges to the Design Builder (although because both projects were DB, we are not familiar with the details).
WA	Yes. I am pretty sure most if not all the jobs had fed aid money, so all were subject to buy America. We were able to build them all, so while it may have complicated procurement of casings, it did not preclude construction. My gut feel is we probably paid more for US casing, but we have small quantities so the cost difference in total dollars is palatable.
WFL	As a Federal Agency, we follow Buy American – Construction Materials, Subpart 25.2 in the FAR. We have not had any problems with obtaining certifications.
WY	Buy America Certification was required on all the projects. There were no issues with projects 1 and 2. For project 3 the contractor had some difficulty getting enough 11 ⅞" domestically produced casing.

Agency	**Q9: Could you provide a copy of specifications used on micropile projects?**
ID	N/A.
NE	Attached.
OR	Yes, although it may be more useful to provide you with the most recent version of our micropile specification, since we have improved them with each usage. I have attached the most recent version I am aware of.
SD	Yes, attached. We are planning on making updates and revisions based on our current experience prior to the use in another project.
UT	Yes, I located the one Project's special provision.
WA	Yes. Provided with survey in e-mail.
WFL	Yes. Micropiles are covered in Section 567 of our Standard Specifications, available here: http://flh.fhwa.dot.gov/business/resources/specs/
WY	

Agency	**Q10: Please summarize typical costs of micropile installation projects and how these costs compared to other alternatives**
ID	Not provided.
NE	$182.09/ Lineal Ft. Typical H-Pile and Pipe-Pile at the time ranged from $30 to $42 per foot.
OR	Micropiles are typically more expensive than spread footings and driven pile, although they may be competitive with drilled shafts in some cases. Typically the use of miropiles (or any foundation type for that matter) is driven by the subsurface conditions, project constraints such as scour, staging, traffic control, physical site access restrictions (underground/overhead utilities, adjacent structures, waterways, environmentally sensitive areas, etc.). In my experience micropiles are typically chosen as a "last" option due to the economic costs and typically only when other foundation types end up excluded for technical and/or logistical reasons. In 24 year, being associated with hundreds of bridge, retaining wall and landslide mitigation designs, I'm aware of 4 applications of micropiles, all for bridge foundations with in Oregon DOT. Costs for the most recent project I worked on in 2010 are as follows: Furnish Micropile Equipment - Lump Sum $29,700, Furnish and Install Micropiles - Each $5,200, Micropile Proof Load Test - Each $1,870, Micropile Verification Load Test – Each $6,050, Micropile Length Variation – Foot $107, total bid cost was $165,058 for micropile related items. Whereas had a conventional driven pile foundation been suitable it would have cost about $70,000.
SD	I only have bid prices for the one project and they are as follows: Micropile (136 piles) – $5,905.00 per pile Micropile Verification Load Test (2 tests) – $19,000.00 per test Micropile Proof Load Test (11 tests) – $1,400.00 per test I do not have estimated costs for the other foundation types since they were determined not to be feasible due to construction issues more so than economics.
UT	Individual project element costs are not available to us for design build projects. But we imagine it was a less expensive option that other available methods for these two projects (such as driven pile-supported grade beams).
WA	See bid tab sheet provided with survey response.
WFL	Micropile costs usually range between $150 - $200 / lineal foot. Micropile load verification tests usually range between $2000 - $15,000 / each.
WY	The cost of micropile installation is fairly similar to other types of mechanical earth stabililization (tie back anchors etc.) For a rule of thumb for mechanical ground stabilization for landslides we estimate approximatley 1 million dollars per 100' of roadway stabilized.

Agency	**Q11: Describe the types of contracting methods that have been used**
ID	Contractor designed the constructed the micropiles.
NE	Typical Design, Let, Build.
OR	Owner controlled, contractor designed. We specific the loads and, when applicable, minimum casing diameter and wall thickness as well as a minimum bending moment capacity within a specified distance of the top of the miropile. The Contractor provides details, engineered and stamped calculations and shop drawings for the Agency's review and both verification and proof load testing is required to confirm the Contractor's design and the geotechnical capacity.
SD	Design / Bid / Build based on lowest bidder. The micropile contractor is a subcontractor of the general contractor.
UT	Design build only for our two MP projects.
WA	We use Design-bid-build contracting, but the micropile contractor is responsible to determine the bond length and grout pressures necessary to attain our required resistance. Our specifications or plans state ultimate resistance, minimum diameter, and minimum casing thickness to make sure we have enough shear, moment, and buckling resistance.
WFL	Three of the referenced contracts that have used micropiles have been design – bid – build. Two projects were low bid and the other project was done using a Task Order Contract. The Manning Crevice Bridge is a Construction Management General Contractor (CMGC) contract.
WY	All of the WYDOT projects have been design/bid/build projects.

Agency	**Q12: Describe the status of local contractor availability and level of expertise. How has this factored into decisions regarding micropile use?**
ID	Local contractor did not have experience with micropiles. The project was constructed with contractor from out of state.
NE	Closest contractor is in Colorado.
OR	Contractor availability is always a factor is specifying a particular methodology. In this case we are fortunate to have several contractors in Washington who are familiar with micropile construction.
SD	South Dakota does not have any micropile contractors locally within the state. Current contractor is out of Colorado. The subsurface conditions throughout the state are favorable for the use of other foundation types. This has been more of a factor for not using micropiles than the lack of local contractor availability or level of expertise.
UT	The number of local contractors with even some MP experience is very limited in Utah. This will factor into our future decisions for selection of this approach.
WA	Seattle has a large number of contractors that are members of the ADSC/DFI group and also the ISM International Society for Micropiles (http://www.ismicropiles.org/). We are actually pretty lucky in having a number of contractors nearby who can do this work.
WFL	We feel there are plenty of contractors available in the region that can successfully install micropiles. Our specifications include contractor qualifications. Availability of expertise has not influenced our decision to use micropiles on any project.
WY	There are no micropile specialty contractors in Wyoming so micropiles are typically only used when there is no other viable alternative.

Agency	**Q13: Is a prequalified contractor list used and what is the process for prequalification?**
ID	Yes.
NE	Must submit list of 3 projects over last 5 years of similar project and references. Contractor shall have own engineer. Driller and supervisor have minimum of two years experience with same contractor. See special provisions.
OR	No. On the first project we attempted this and found it to be a time consuming process that resulted in one prequalified contractor, clearly we couldn't go to bid with a set of specs that only had one qualified micropile contractor. Currently our specifications do include requirements for the firm performing the micropile installation (5 projects in the last 5 years including 100 or more micropile, along with references for the same). There are also experience requirements for on-site supervisors and drill operators, as well as the Contractor's design engineer.
SD	Did not use a prequalified contractor list, requirements were based on experience and are listed in the attached special provisions.
UT	No, and None. But we should consider a prequel process in the future.
WA	We don't prequalify. It is actually against WA law for us to prequalify subs, and micropiles are usually constructed by subs. We do however have experience requirements that we include in our contracts.
WFL	No
WY	There is no prequalification list. The special provision for micropile items will typically have an minimum experience requirement for contractors doing the specialty work they are evaluated and approved on an individual project basis.

Agency	**Q14: What are typical installation times?**
ID	About 1 pile per day.
NE	Unknown.
OR	The lead time is typically about two months in terms of the submittal process. The construction process for production is fairly quick perhaps two weeks for a typical single span bridge, although staging of the construction (typical for traffic passage requirements), typically requires production micropile installation two times over the duration of the project, which would be no different than any other foundation type for a staged project. The verification microplile installation, testing and test reporting and review take about two weeks ahead of the production work and the proof load testing adds a day in the field for each test and about a week for the testing results submittal and review (which can delay the concrete pour for the pile cap, since that could be an issue if the proof load tests don't pass).
SD	Typically 3 to 4 piles per day depending on overall depth. This corresponds to approximately 200 - 250 feet per day of micropile installation.
UT	When things were moving smoothly, it seems they were installing about 3 to 4 piles per shift. They were somewhat efficient in how they stagger their locations though, so as to most effectively do the MP load testing.
WA	About an hour.
WFL	Highly variable based on the subsurface conditions.
WY	Installation times are highly variable depending on depth, drilling conditions and type of pile.

Agency	**Q15: Please describe your level of satisfaction with construction efficiency and outcomes and any lessons learned.**
ID	We are satisfied with the construction efficiency and performance of the micropile foundation so far.
NE	Happy with results but heard it was more expensive than traditional deep foundations.
OR	In general, I believe micorpiles are a good option in the "right" conditions (see 10 above) and I am largely pleased with my experience using them. They are more expensive and take longer than say a driven pile foundation, but if a driven pile foundation was feasible that's what would have been used, so it's not really a fair comparison. Lessons learned are covered in each of the items addressed above and in the evolution of our specifications. With each project we revise the micropile specs (as they are devolved for the next project) to address weaknesses in the process that we discover, since even though the specs have been around for about 18 years, we've only used them a handful of times. Typically the weaknesses revolve around scheduling and time frames as well as on-site drilling revisions a Contractor wants to make that is not addressed in the design or the verification testing construction procedures.
SD	Satisfied, micropiles have proven to be a viable foundation option with the subsurface conditions located at these sites.
UT	Construction efficiency- 5 and 7; Outcomes 3 and 7; LL- You can't have enough QC/QA inspection performed by qualified personnel. Our consultant inspector really saved our bacon in catching some significant installation problems (such as with their grout mixing process).
WA	Lesson learned -- testing in tension is much easier then testing in compression, but you need to live with the fact that tension testing really does not model the behavior well for a compression element. Overall we have been happy with the use of micropiles. They are fast and easy to install. Our contractors are competent and want to do a good job, and I want to use them more in new construction, mainly for smaller structures. Things like retaining walls, large three sided culverts 10 to 25 ft span, noise walls, and sign supports.
WFL	We are satisfied with industry efficiency. Recent improvements in drill tooling provide more methods for a drill contractor to efficiently penetrate variable subsurface conditions.
WY	The end product on all the projects have been satisfactory. The biggest issues that have caused claims were grout loss and difficult drilling conditions. It is important to have as much geotechnical data as possible for the contractor so that they can be prepared for the worst possible drilling conditions.

Agency	**Q16: Are micropiles used on urgent or emergency projects and if so, what type of contracting methods are used?**
ID	No.
NE	None so far.
OR	No, I have not used micropiles in an urgent or emergency project in my experience. I am aware of a contracting firm called GSI that does use what they call micropile for such projects, although they provide a design build service essentially and typically use such application for the support of retaining walls in/on landslides
SD	Not to date.
UT	No, not to date.
WA	We have not had a need for micropiles on an emergency job yet.
WFL	The Task Order Contract that was used was somewhat of an emergency in order to complete the necessary repairs before the road was open to public traffic. The project was in a National Park where we normally utilize Task Order Contracts.
WY	No

Agency	**Q17: Are load tests performed? If yes, please describe the methods used and how designs are revised depending on results.**
ID	Verification and proof tests (pull out test) were performed to verify pile capacity
NE	Performed verification and proof load tests.
OR	Yes, see 9, 10 and 14 above. The owner's design aspects are not changed based on test results. If necessary, the Contractors design aspects (such as the geotechnical bond) might be, but I have yet to see such a circumstance.
SD	Yes – done according to ASTM D3689 – Standard Test Methods for Deep Foundations Under Static Axial Tensile Load. To date there has not been a need for a revised design based on results of the load tests.
UT	Yes- verification and proof testing in accordance with the ASTM standards. Insufficient verification test results mean they have to re-design the MP's accordingly. For field proof tests, they are to immediately proof test another MP with the particular footing. Where necessary, the Contractor must modify the design, the construction procedure or both; and the modifications may require them replacement piles incorporating them at no more than 50% of the max load attained.
WA	We do tension tests to verify resistance, and assume that compression resistance will be even higher than what is measured in tension. The bond zone is contractor designed. We have not had a case where the contractor modifies his design to be more efficient based on the test results. Pretty much, when the first anchor passes, they install the rest the same way. We are not doing testing for optimization, we do it for confirmation and if the anchor has more resistance than needed… great! I am not aware of an anchor that failed yet. Our specs say that if one does, the contractor WILL revise the bond length or grout procedure, and replace the failed anchor.
WFL	Verification tests are used to ensure that the length of the bond zone achieves the design axial capacity.
WY	No load tests were performed.

Agency	**Q18: How is long term performance of installed micropiles assessed?**
ID	The micropiles have been 12 years old and still perform satisfactory.
NE	Biannual bridge inspection.
OR	For the life of the structure? Or do you mean the length of time for the proof and verification load tests? If the load testing period about one to two hours depending on the creep that occurs during the load hold period. See the attached specification for details.
SD	Long term performance is being assessed based on the overall performance of the structure over time. No instrumentation to monitor the micropile was included during construction.
UT	There was no program set up for LT performance monitoring. But no significant issues have been noted at either bridge site in their 5 years since construction.
WA	We are not doing anything other than our typical two year bridge inspections.
WFL	Long term corrosion of permanent casing is evaluated using the same procedures as driven piles.
WY	For projects 1 and 2 there were slope inclinometers installed to monitor long term movement. For project 3 there were slope inclinometers installed and strain gauges attached to select micropiles to confirm design assumptions made as to the transfer of load from the soil to the micropile.

Agency	**Q19: Please describe your anticipated frequency of micropile use on future projects.**
ID	Not now.
NE	Occasional.
OR	As needed, perhaps once every few years where site conditions and logistics dictate. Recently considered microplies very seriously for a project, but ended up going with a different (but somewhat similar) technology and will be using 3' diameter thick wall steel casings installed with a rotary percussive system, essentially very large micropile that will be specified as drilled shafts, with a rock socket below the base of the casing providing the geotechnical capacity. Micropiles were determined not to be suitable due to "new" seismic design standards loading which micropiles could not accommodate.
SD	As required by subsurface conditions and/or design requirements. At this time there are four bridge foundations currently being designed for fall 2016 letting.
UT	Possibly one project every 2 to 3 years.
WA	Use will only increase. We will have more retrofit jobs as we widen bridges for capacity improvements and as part of our Bridge Seismic Retrofit Program. Our seismic retrofit program has been phased due to funding caps. First, we fixed deficient seat widths and installed restrainers. Then we went through and column jacketed all the single column bridges. We are working on jacketing multiple column bridges now. The next phase, assuming we get more funding, will be to start going after foundation retrofits. We deferred that as the budget is small and we can jacket a lot of bridges for what we would spend on a foundation retrofit job.
WFL	We anticipate that our future use of micropiles will remain similar to what it has been in the past.
WY	Based on past history it may be expected to have a micropile project once every 2-3 years.