June 2020 ABC-UTC Webinar Featured Presentation: Design and Construction of High-Capacity Micropiles in ABC Projects		
#	**Questions**	**Responses**
	Design	
1	What programs can be used for micropile design?	No special software is required for micropile design. Calculations can be performed in a spreadsheet using the guidance in the AASHTO LRFD Bridge Design Specifications, 8th Ed.
2	Do you have any example design spreadsheets for sharing?	See the response to Question 1.
3	Are there any seismic load limitations in bridge construction applications with micropiles?	This was discussed in the Q&A. No, there are no seismic load limitations.
4	What is the seismic performance of micropiles?	This was discussed in the Q&A. Micropiles offer good seismic performance provided the designer considers soil liquefaction and the strength of the threaded casing joints in the design.
5	Are steel micropiles resistant in the marine environment?	This question was addressed in the Q&A. Micropile steel has the same issues as any other steel pile in a marine environment.
6	Can micropiles be used to stabilize building foundations?	Yes. Micropiles are used to stabilize foundations, which was their original design intent.
7	Do you have experience using macropiles with typical sizes of 18 to 21 inch outside diameter? Are there any concerns or constraints in construction when using these size piles?	Yes, we have installed macropiles, defined as larger than 12 inches in diameter. We do not have any concerns with using them.
8	Have micropiles been used on integral abutments?	The presenters have no direct knowledge of integral abutments founded on micropiles. In general, if a structure can be founded on piles, it can be founded on micropiles, understanding that micropiles are more flexible due to their small diameter, and understanding that the flexibility needs to be included in the design of the micropiles.

9	What is the possibility of using very long 200-ft-deep micropiles, and what would be the ratio of diameter to depth?	We have installed 7 inch diameter and 9-5/8 inch diameter micropiles to depths in excess of 200 feet.
10	What are some considerations for using micropiles in areas with shallow, hard bedrock?	Micropiles are perfect for shallow, hard bedrock, particularly when considering the cost of a pile socketed into bedrock.
11	What are the maximum capacity and uplift for these types of piles?	The maximum capacity is limited by either the structural capacity or the geotechnical capacity of the given pile. The geotechnical capacity, for a given bond stress, is a function of the drill hole diameter and bond length. However, the practical limitation for bond length is 40 to 50 feet.
12	Would you consider using 100 ksi rebar to reduce rebar congestion?	We routinely use 150 ksi (fy=120 ksi) reinforcement in micropiles. Rebar reinforcement typically consists of a single bar only, so there is no rebar congestion.
13	Can you discuss cases where micropiles are not recommended?	There is not really a case where micropiles are not recommended. In practical terms, micropiles should not be recommended when another deep foundation construction technique is more cost effective.
14	How are the geotechnical capacities incorporated into load carrying capacities?	See the response to Question 11.
15	Can you rely on any friction between the overburden soil and casing? Do you recommend using plunge length of casing into rock?	Resisting friction in the cased/unbonded zone is typically ignored; however, downdrag in this zone would be evaluated as an applied load. The plunge length can be part of the bond zone as long as the drilling/grouting process assures that enough grout cover is provided between the side of the drill hole and the casing.
16	How do you decide the load capacity and unbonded length of the pile?	It starts with a typical geotechnical resistance (use AASHTO preliminary design values), then determine the number/layout of piles mindful of spacing requirements. The length of the unbonded or cased zone (AASHTO nomenclature) is governed by the depth to the top of the bond/uncased zone.

17	How do you know if the improvement that was made was really effective, and if the desired improvement has been achieved?	Verification and proof tests (verification on sacrificial piles and proof on production piles) are used to confirm the bond zone resistance with equipment and installation techniques that are expected for the project.
18	How feasible is the use of micropiles at the present time?	Micropiles are installed on public and private projects around the country every day.
19	Can you comment on any limitations or feasibility in using micropiles?	The primary limitation is the unit installation cost, as micropiles are relatively expensive and are usually selected when the installation of other deep foundation solutions become impractical or installation costs make micropiles attractive for the project.
20	How is the buckling capacity of the micropile considered, and how does the micropile resist the lateral load?	This was addressed in the presentation and Q&A audio. Buckling is a function of the unbraced length. Lateral confinement is provided by even the softest/loosest soil such that the unbraced length is zero. Vertical micropiles resist lateral loads with the same soil/structure interaction as other deep foundations and are analyzed in the same manner. If additional resistance is required, then an oversize casing diameter, concentric (double casing), and/or battered micropiles should be used. Micropiles can be installed at aggressive angles measured from vertical, 30 degrees is not uncommon. Strength of the threaded joint must be evaluated.
21	Can you comment on micropile buckling and micropile connections?	See the response to Question 20.
22	What are the key points of interest in designing micropiles for lateral loads combined with axial loads?	Micropile casing threaded joints are weak in bending and tension, so the connection needs to be evaluated carefully. Oversized casing, concentric casing, joint reinforcement, and specifying a minimum depth of the first joint (typically cannot be deeper than 20 feet from the working grade at time of installation) are methods that are used to address lateral/axial load combinations in micropiles.
23	Are there any new / innovative options for micropiles, and are there ways to provide increased bending stiffness / strength?	See the response to Question 22.

24	What grout-to-ground bond stresses are used in Florida's saturated silty fine sands?	For preliminary design, refer to the grout-to-ground bond stress Table C10.9.3.5.2-1 in the AASHTO LRFD Bridge Design Specifications, 8th Ed.
	Construction	
25	Do you have the ability to install piles on steep slopes?	Yes, micropiles can be installed on steep slopes.
26	How much clearance under existing bridges is required to install micropiles?	The minimum overhead clearance is 8 feet.
27	Can you comment on micropile operations around active railroads with and without low clearance?	This was addressed in the presentation Q&A audio. Micropiles are a deep foundation technique recognized by the railroads and the AREMA specifications. Installation has the same restrictions as any other work near or over an active railway.
28	Can you cover equipment / drill rig options?	This was addressed in the presentation.
29	What is the typical crew needed for the installation, and how fast is it possible to install micropiles?	Crew size will vary regionally. A typical crew operating in the southeastern United States is 7 to 8 people.
30	Are any forms of static and / or dynamic capacity tests performed on the piles after installation?	Static testing was addressed in the presentation. The ASTM static deep foundation load testing standards are applicable to micropiles. The presenters have heard of some use of PDA (Pile Driving Analyzer) testing for micropiles, but it is not widely used.
31	Which method of load testing do you prefer to verify pile capacity for bridge code compliance?	Load testing was addressed in the presentation. Tension testing is the preferred method.
32	Are there difficulties with grout circulation and constructability with multiple levels of casing? Please share best practices. For quality assurance, do you use crosshole sonic logging (CSL) or pile integrity testing (PIT)?	The grout is injected to the bottom of the drill hole with a tremie pipe and pump. Generally, there is only one casing and a single bar, so there are no issues similar to pulling casing for drilled shafts that warrant crosshole sonic logging (CSL) or pile integrity testing (PIT).

33	How much grout quantity overage is acceptable before additional investigation is required?	Grout quantity overage was addressed in the Q&A audio. A nominal excess grout quantity is assumed by the contractor. Should the ground conditions indicate that excessive grout takes may occur, then the contract documents should indicate the nominal excess grout factor and then include a unit price in the bid documents when this is exceeded.
34	Do you ever use self-consolidating concrete in micropile construction?	This was addressed in the Q&A audio. Micropiles use neat cement grout (no aggregate). Thoroughly mixed and agitated grout should not be subject to settling.
35	Can you propose pressure grouting in soft clay conditions?	Generally micropiles, like all deep foundations, should bypass soft clay deposits. Pressure grouting in clay was addressed in the Q&A audio. The tube-a-manchette post-grouting method was described in the audio. This corresponds to the Type D grout-to-ground bond stress shown on slide 16.
36	Is there a particular material specification you recommend for the steel micropiles, including any corrosion protection specs?	The material specifications were addressed in the presentation. Corrosion protection was discussed in the Q&A audio.
37	What are the construction safety protocols for using micropiles?	There are no construction safety protocols specific to micropiles. Normal construction safety practices should be used.
38	What is the LTIR (Lost Time Incident Rate) while working with micropiles?	There is no Lost Time Incident Rate (LTIR) specific to micropiles, as specialty contractors installing micropiles typically install other types of geotechnical construction techniques.
39	What lessons learned did the Georgia DOT have from this project with micropiles?	The Georgia DOT gained experience in using micropiles with low headroom conditions. This has opened up a number of opportunities on future projects where micropiles will be used.
	Cost	
40	What is the typical installed cost range for micropiles?	Installed cost ranges were addressed on slide 21 of the presentation.

41	What is the unit cost of micropile vs steel HP piles?	This was addressed on slide 21 of the presentation and in the Q&A audio. Micropiles can be 50 to 100% more expensive than driven steel piles. However, on a unit price basis, micropiles can be less expensive than driven piles if predrilling and/or socketing is required to meet the design tip elevation.
42	What is the cost difference per 100 tons between micropiles and conventional steel piles?	Micropile cost was addressed on slide 21 of the presentation. See the response to Question 41.
43	What is the cost range of micropiling per sq.ft. of footing area to use by an estimator when evaluating different design options?	General costs were addressed in the Q&A audio. It is not possible to address specific cost ranges due to the structural and geotechnical variables of each project.
44	How can you reduce the cost of this type of construction?	This was discussed in the Q&A audio. The two biggest cost saving items are the use of mill secondary piling for the micropiles and the use of tension tests instead of compression tests for the micropile load tests.
45	How are claims by the contractor addressed or resolved?	This is project specific and would most likely involve a differing site condition than given in the contract documents. A comprehensive geotechnical evaluation is the best way to limit the chance of these types of claims on a project.
	Questions during Webinar	
46	What is the lowest headroom that the micropile rig can work effectively?	The minimum clearance is 8 feet.
47	Is there a history of micropile applications on RR (railroad) projects in general and high speed train projects specifically (worldwide)? Are there any technical concerns for not using micropiles on such projects?	See the response to Question 32. Applications to railroads were discussed in the Q&A audio. We do not have any concerns with using micropiles on these types of projects.

48	Are galvanized steel casing pipes ever used for micropile construction?	This was addressed in the Q&A audio. Corrosion protection of the steel casing would be significantly damaged during the drilling process. The only way to incorporate intact corrosion protection would be to install the micropile similar to a temporary casing of a drilled shaft. This would significantly increase the unit price due to a much slower installation process. To address corrosion, we recommend using a thicker and/or larger diameter casing.
49	If vertical clearance is no problem but horizontal is (say, for a divided highway-type situation), what kind of load test would be recommended?	A tension load test is always preferred.
50	Can you remove the casing for low headroom construction?	If required, the entire drill casing can be completely removed during the grouting process. While not discussed in the presentation, this would be similar to a Type E hollow-bar micropile, as shown in Section 10.9.1 of the AASHTO LRFD Bridge Design Specifications, 8th Ed.
51	Are you aware that the Commercial Metals Co. entered the threaded bar market this past year? Their product is manufactured in Cayce, SC.	New manufacturers are always welcome. Thank you for this information.
52	How reliable is the side friction on the plunge length when there is a minimum annular thickness of cement, if any, between the steel casing and rock? I see many designers considering the plunge length as part of the bond length. Is this an acceptable practice?	See the response to Question 15.
53	Can you recommend a design method or example for the load plate at the top of the micropile where it attaches to the footing?	Design of the load plate is similar to the design of a column base plate.
54	How deep can your low headroom rig drill with typical pile sizes, and how big a pile can be used?	We have low-headroom hydraulic drill equipment that can enter a room through a standard doorway with the capability of installing a 9-5/8 inch diameter micropile into bedrock to a depth of 100 feet.
55	How has the price of micropiles changed over time?	Micropile costs have changed over time as discussed in the Q&A audio. The price has decreased due to increases in production as a result of better drilling tools and equipment.

56	Is it typical that payment of a micropile is by "EACH" regardless of design-build or design-bid-build for the item?	No. Load bearing geotechnical elements should not be bid per each due to variability in the ground conditions from one location to another. Micropiles are usually paid per linear foot.
57	Can you briefly explain why a compression test is much more expensive than a tension test?	This was discussed on presentation slides 32 and 41. A safe configuration for a compression load test is 4 reaction piles per test pile resulting in 5 piles installed per compression test versus 1 pile installed per tension test.
58	What was the typical overall casing length of the Georgia DOT example you discussed?	For the Georgia DOT Courtland Street Bridge project, the average, minimum, and maximum casing length was 63.7 ft, 20.0 ft, and 90.0 ft, respectively. The average, minimum, and maximum pile length was 79.6, 36.0 ft, and 109.5 ft, respectively.
59	Why retract the steel casing back? Is that only for bonding? And how is corrosion addressed on the steel casing?	The steel casing is retracted to expose the bond zone to the grout. However, on the Georgia DOT's Courtland Street project, the casing terminated at the top of bedrock, then a smaller diameter hole was drilled for the bond zone. Regarding corrosion, this was addressed with sacrificial steel using a larger diameter and/or thicker casing.
60	Why do we need to extend the casing to the bonding zone? Why can we not determine what we need based on the lateral analysis?	See the response to Question 59.
61	For the Georgia DOT Courtland Street Bridge project, what was the UCS (uniaxial compression strength) of the rock?	The bedrock material was a gneiss with uniaxial compression strength (UCS) varying from 5,620 to 16,050 psi. Foliation (banding) of gneiss in the Atlanta area is generally about 30 degrees from horizontal. The banding is a plane of weakness which tends to result in a lower UCS.
62	What measures do you take to stop communications between micropiles while drilling?	Communication refers to drilling fluid (air/water/slurry) from one drill hole entering an adjacent drill hole through voids, fractures, preferential flow paths, etc., in gravelly or karstic conditions, for instance. It can be mitigated by changing the drilling and grouting sequence, that is each hole would be grouted at completion of drilling. Adjacent holes would be drilled after the initial grout set. Alternatively, the drill hole can be drilled/grouted then redrilled the following day.

63	Do you have experience with micropile communication and how to avoid it?	See the response to Question 62.
64	How do you take care of inter-communication between adjacent piles while grouting?	See the response to Question 62.
65	What determined the location of tension-resisting micropiles versus compression-resisting micropiles on the Courtland Street structure?	The pile layout was determined by the bridge designer. The different size footings were mainly chosen to avoid the many utilities that were on the project. The smaller footings tended to have uplift and required tension piles.
66	What does one use for micropile spacing in a group arrangement?	The AASHTO LRFD Bridge Design Specifications, 8th Ed., require micropile design center-to-center spacing not be less than 30 inches or 3 micropile diameters, whichever is greater.
67	Using the LRFD (Load and Resistance Factor Design) method, what is the tension load test criteria? Do you test it to ultimate (nominal) capacity, or to more or less than that?	The load test, whether tension or compression, is tested to the nominal (ultimate) capacity. The test could be run to a higher load to evaluate the true ultimate geotechnical bond capacity, provided the structural capacity of the pile can sustain the higher load.
68	Where can one find the Special Provisions for micropiles?	The special provision mentioned in the presentation was a project specific specification and is included on the ABC-UTC Monthly Webinar webpage. Note that Appendix C of the FHWA micropile manual referenced in the presentation (slide 10) includes a guide micropile specification.
69	Is it necessary to compute an equivalent spring constant for micropile foundations for the superstructure analysis?	The presenters are not aware of any differences in analysis from a driven pile to a micropile-supported superstructure. Basically, if you are using spring constants to analyze a driven pile, then you can use appropriate spring constants to analyze a micropile.
70	What is the limit of batter angle for a micropile?	As discussed in the presentation, micropiles can have much more aggressive batter angles than any other deep foundation element. Micropile batter angles up to 45 degrees have been used.
71	If socketed into rock, why not use compression capacity and do compression testing?	As discussed in the presentation, testing in tension provides an equal resistance to testing in compression. The main advantage is the cost savings for tension testing as shown in the case study.

72	Is there a minimum pile spacing of 2.5 x diameter for micropiles?	See the response to Question 66.
73	Do you have experience with micropile design in liquefiable soils, or is this not acceptable?	This was addressed in the Q&A. Micropiles can be used in liquefiable soils as long as the analysis includes buckling in the liquefied soil. Mitigating liquefaction can include several ground improvement techniques. The South Carolina DOT has very good guidance on ground improvement techniques in their geotechnical manual (https://www.scdot.org/business/geotech.aspx). One of the techniques SCDOT uses to mitigate the effects of liquefaction is earthquake drains.
74	Can micropiles be used in a full integral abutment with a single row of piles?	See the response to Question 8.
75	How can the lateral capacity of micropiles be increased?	One method that increases the lateral capacity of micropiles is to add a larger concentric steel pipe, as shown in the presentation on slide 34.
76	Are there any benefits in using micropiles in liquefiable soils?	There are no significant benefits to using micropiles in liquefiable soils unless difficult ground conditions make micropiles a cost-effective option.
77	How deep can micropiles be used?	See the response to Question 9.
78	What is the cost of testing per micropile?	The cost per test depends on the type of test (tension preferred, as discussed on slide 32) and the load required.
79	Integral abutments should have flexible foundations, and all vertical piles (battered piles are not generally used in an integral abutment). Consequently, the micropiles would be subject to significant bending. Can they handle significant bending?	As discussed in the presentation, due to their small diameter and threaded casing, micropiles are not particularly strong in bending.
80	Are dynamic load tests suitable for use with micropiles?	See the response to Question 30

81	Since the specialty contractor is involved, who is the designer of record for micropiles?	The designer of the structure will specify the number, load, spacing, penetration of the top of micropile into the pile cap, and casing size for the micropiles. From the bottom of pile cap, the specialty contractor is the micropile designer of record.
82	Does strength selection for casing depend on soil / rock resistance? If the soil or rock resistance is comparatively less, then do you go for less strength for casing material? Fy = 80 ksi for casing is really high strength.	The casing strength is independent of the ground conditions. The strength of the API (American Petroleum Institute) N-80 (80 ksi) casing handles the stress applied by the drill during the drilling and installation process.
83	Why is grout used instead of concrete?	Due to the small diameter of a micropile, a cement-aggregate mixture cannot be pumped through a nominal 1-inch diameter tremie tube.
84	Do you account for down drag in the design?	Downdrag of compressible material in the cased/unbonded zone would be added to the design load. This is covered in the AASHTO LRFD Bridge Design Specifications, 8th Ed.
85	Can you comment on constructability in artesian or confined aquifer conditions in bedrock?	Drilling for a micropile is no different than other drilled foundation elements when encountering artesian conditions. Pre-grouting of the drill hole followed by re-drilling can be used successfully in artesian conditions.
86	Do the micropiles work with liquefiable soils? If so, what are the conditions and recommendations for this use?	This was discussed in the presentation Q&A. See the responses to Questions 4, 73, and 76.
87	Do you use supplementary cementitious materials (SCMs) in the grout?	No. Typically we only use neat cement.