September 13, 2021

DJ&A PC
3203 S Russell Street
Missoula, MT 59801

WFLHD Getechnical Report 18-21

Addendum to WFLHD Geotechnical Report 05-21

Attn: Mr. Paul Druyvestein, P.E.
P: (406) 721-4320 Ext. 105
E: pauld@djanda.com

Re: WFLHD Geotechnical Engineering Report No. 05-21 Addendum
Charles M Russell Refuge Repairs
Site 6 Bridge Foundation
Fergus, Petroleum and Phillips Counties, MT
Terracon Project No. C4205037

Dear Mr. Druyvestein:

We have completed the supplemental WFLHD Geotechnical Engineering Report No. 05-21 services associated with the above-referenced project. These additional services were requested by DJ&A following review of our May 26, 2021 report. That report included the results of our geotechnical and materials engineering work on five sites within the Charles M Russell Refuge (CMR) in eastern Montana. This addendum letter addresses Terracon's value engineering efforts associated with optimizing foundation design for the new bridge to be located at Site 6 within the CMR, and is intended to memorialize our review of the revised loading conditions, performance of additional deep foundation modeling and analysis conducted by Terracon, and revised recommendations.

We appreciate the opportunity to be of service to you on this project. If you have any questions concerning this report or if we may be of further service, please contact us.

Sincerely,
Terracon Consultants, Inc.

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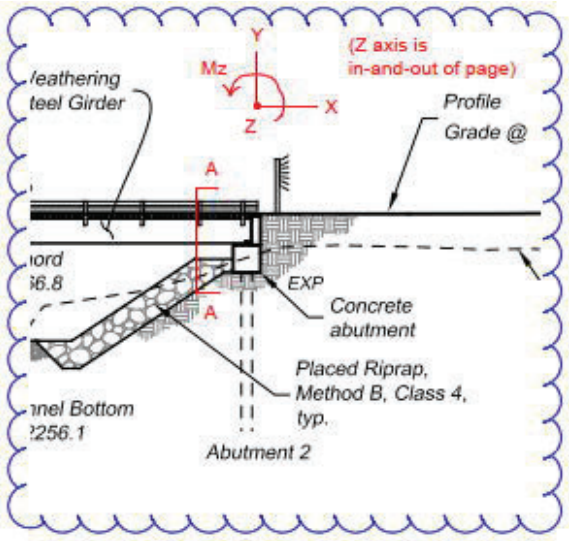
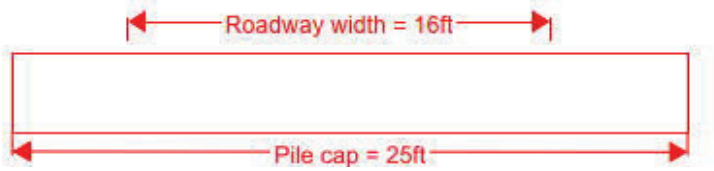
BRIDGE 6 FOUNDATION DESIGN

This addendum report presents the results of supplemental engineering services provided to DJ&A and conducted in support of finalizing the foundation design for the CMR Site 6 bridge foundation. The original foundation design from our May 26, 2021 report included driven wooden piling, based on structural loads developed by Terracon. After re-evaluating foundation alternatives with structural loads provided by DJ&A, we developed a drilled micropile foundation alternative that utilized 11.875" x 0.5 wall pipe sections. Terracon and DJ&A discussed that initial micropiles foundation alternative, and DJ&A inquired as to the possibility of reducing the pile size if the assumption was made that the abutment could accommodate part of the lateral load in passive resistance, reducing the lateral load acting on the pile group, and we agreed. DJ&A then developed revised structural loads (shown below), and Terracon then analyzed those load cases in an effort to develop a micropile foundation that could use a smaller (and more readily available) micropile size.



Preliminary loads on abutment:	Fx	Fy	Fz	Mz	Mx
Service:	35k	164k	5k	100k-ft	276k-ft
Strength I:	61k	250k	0k	165k-ft	457k-ft
Strength III:	34k	107k	6k	80k-ft	53k-ft

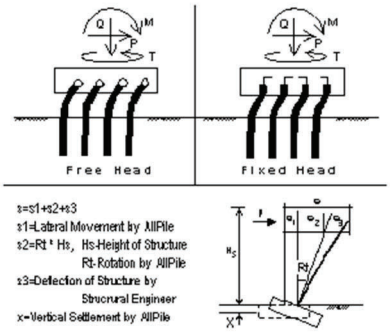


In our analysis of the revised micropile foundation, like our evaluations of the previous two piling alternatives, we employed the computer program AllPile to analyze the vertical and lateral capacities of the proposed 7 inch x 0.500 inch N-80 threaded steel casing. (N-80 is a common oilfield tubular steel product that has become a common material for micropiling due to its high [80,000 psi] minimum yield strength.)

For the purposes of analysis, we first de-rated the section to a yield strength of 65,000 psi (the effective yield stress for the section through the threads), based on proprietary third-party testing data of yield for a threaded and fully grouted N-80 micropile. We also evaluated the potential for pile section loss due to corrosion, based on our experience with pile corrosion analyses for other projects in eastern Montana with similar high plasticity soil types, and de-rated the section thickness based on the corrosion potential for the section. We then analyzed a micropile section with a corroded outside diameter of 6.850 inches and an internal diameter of 6.000 inches, using all of the load cases, but focusing on the critical Strength I load case shown above. Our analyses assumed that the micropile section would be socketed at least 3 feet into the sandstone bedrock encountered at the site, and that the micropile would be installed according to the recommendations discussed in the paragraphs below. We further assumed a single row of five (5) micropiles, with a center-to-center spacing of 60 inches (5 feet). The results of our vertical analyses are summarized below:

VERTICAL ANALYSIS

Figure 1



Micropile (MiniPile)

Loads:
Load Factor for Vertical Loads= 1.0
Load Factor for Lateral Loads= 1.0
Loads Supported by Pile Cap= 0 %
Shear Condition: Static

Vertical Load, Q= 250.0 -kp
Shear Load, P= 61.0 -kp
Moment, M= 0.0 -kp-f

Profile:
Pile Length, L= 34.0 -ft
Top Height, H= -4.2 -ft
Slope Angle, As= 0
Batter Angle, Ab= 0

Group and Boundary Condition:
Fixed Head
Sx= 60 -in
Sy= 6.8 -in
Nx= 5
Ny= 1

Soil Data:

Depth -ft	Gamma -lb/f3	Phi	C -kp/f2	K -lb/i3	e50 or Dr %	Nspt
0	124.9	0.0	0.89	183.6	1.07	7
3	127.1	0.0	1.04	236.2	0.98	8
7	120.8	0.0	0.69	116.0	1.25	6
20	127.1	0.0	1.04	236.2	0.98	8
23	134.2	0.0	3.25	1142.4	0.49	26
30	132.9	0.0	2.70	900.2	0.55	22
37	131.9	0.0	1.91	569.5	0.67	15
38	127.6	6.0	21.00	91.5	0.18	3

Pile Data:

Depth -ft	Width -in	Area -in2	Per. -in	I -in4	E -kp/i2	Weight -kp/f
0.0	6.850	11.5	21.5	51.0	29000	0.058
34.0						

Group Vertical capacity:
Total Ultimate Capacity (Down)= 799.936-kp Total Ultimate Capacity (Up)= 563.711-kp
Total Allowable Capacity (Down)= 799.936-kp Total Allowable Capacity (Up)= 563.711-kp
OK! Qallow > Q

Group Settlement Calculation:
At Xallow= 1.00-in Qallow= 99999.00-kp
At Q= 250.00-kp Settlement= 0.03279-in

Note: If the program cannot find a result or the result exceeds the upper limit. The result will be displayed as 99999.

So, under the Strength I load conditions, utilizing the 5-pile group, the settlement is less than ¼-inch (0.03 inches).

A summary table of lateral performance output for the shafts is summarized below. These data assume a vertical load of 50 kips and a lateral load of 12,200 pounds:

Max Hor. Deflection, in.	Max Mom, in-lbs	Max Stress, psi
.231E-00	-.310E+06	.252E+05

The maximum lateral deflection is 0.23 inches, or less than the acceptable limit of 0.5 inches usually applied for the lateral loading of steel piling. Likewise, the maximum stress in any of the shaft alternatives is 25,200 psi, or 0.38 Fy of the corroded 65,000 psi section, which we consider acceptable for the Strength I conditions.

To satisfy the design intent of the micropile design concept discussed herein, we make the following recommendations associated with the micropile construction:

1. The micropile casing shall be 7-inch x 0.500-inch N-80 steel casing conforming to the requirements of API N-80 specifications. If threaded, the casing shall utilize a thread pattern that achieves at least 65,000 psi yield strength through the threads when grouted internally.
2. The casing shall not be welded or torch-cut for any reason; such action will significantly reduce the allowable yield stress of the micropile section.
3. Each abutment shall include five (5) micropiles installed at a center-to-center spacing not less than 60 inches.
4. The micropiles shall be socketed a minimum of 3 feet into the sandstone encountered at the project.
5. Once the minimum socket depth is achieved, the micropiles shall be tremie grouted using a neat cement grout with a minimum 28-day compressive strength of 4,500 pounds per square inch (psi). Grout shall be installed until grout return is observed up the outside of the micropiles.
6. The minimum kerf width (the overcut over the exterior casing diameter) shall be at least 0.375 inches to allow surface grout return along the exterior of the casing.