GEOLABS, INC.

Geotechnical Engineering and Drilling Services

December 20, 2016
W.O. 7417-00(A)(Add.)

Mr. Brian Chang
State of Hawaii
Department of Land & Natural Resources
1151 Punchbowl Street
Honolulu, HI 96813

ADDENDUM
GEOTECHNICAL ENGINEERING EXPLORATION
IAO VALLEY STATE MONUMENT FLOOD REPAIRS
JOB NO. J45CM41A
INTERIM REMEDIAL MEASURES
WAILUKU, MAUI, HAWAII

Dear **Mr. Chang:**

This addendum to our report entitled "Geotechnical Engineering Exploration, Iao Valley State Monument Flood Repairs, Job No. J45CM41A, Interim Remedial Measures, Wailuku, Maui, Hawaii", dated December 1, 2016 provides our geotechnical engineering recommendations for the design of the micropile foundation alternative for the new temporary intermediate pier planned at the existing pedestrian bridge at the project site. Previously, spread footing design recommendations were provided.

MICROPILE FOUNDATIONS

Based on the information provided, we understand it is desired to provide an alternative foundation system consisting of micropiles to support the new temporary intermediate pier footing at the existing pedestrian bridge. The load supporting capacity of the micropile foundation would be derived primarily from skin friction between the micropile and the dense gravelly cobbles and boulders anticipated below the new pier footing.

A micropile consists of a small diameter (usually less than 12 inches) drilled and grouted pile with steel reinforcing. The micropile foundation typically is constructed by drilling a borehole, placing reinforcing steel in the hole, and grouting the borehole. Micropiles are desirable because they can be installed readily in access restrictive environments and in numerous soil types and ground conditions. In addition, installation of the micropiles generally causes minimal disturbance to the adjacent structures, the adjacent soils, and the environment.

We understand the project will be designed based on Load and Resistance Factor Design (LRFD) methods. Based on AASHTO LRFD Bridge Design Specifications, 2010 Edition (2010 AASHTO LRFD), the following structural loads were provided by the project structural engineer for the micropile foundations based on the Strength I Limit State condition.

SUMMARY OF STRUCTURAL LOADS	
LRFD Limit State	Factored Axial Load Demand (kips)
Strength I Limit State	18

We understand a micropile system with a minimum grout bulb diameter of 3 inches is being considered at the pedestrian bridge due to limited work area available. Based on the foundation load demand on the micropile foundations and the subsurface conditions anticipated at the existing pedestrian bridge, we recommend designing each micropile based on an ultimate compressive load capacity of 32 kips based on a resistance factor of 0.55 for the 3-inch diameter micropiles.

Due to scour considerations and to avoid surcharging the existing intermediate pier foundation, we recommend that permanent casing be used for the upper 8 feet below the new pier footing. The permanent casing should have an inside diameter (ID) of at least 3 inches.

In order to achieve the design load resistance imposed on the micropile foundations, the micropiles would need to extend to a depth of at least 22 feet below the bottom of the planned pier footing. The micropiles would derive its vertical support primarily from skin friction between the grout and the surrounding gravelly cobbles and boulders below the permanent casing. We understand a reinforcing steel bar consisting of a Grade 60 No. 8 all-threaded reinforcing bar with a cross sectional area of 0.79 square inches is being considered. Since the micropiles are used in a temporary application, epoxy coated or stainless steel bars are not required. The following table provides a summary of the micropile recommendations for ease of reference.

CASED MICROPILE SYSTEM RECOMMENDATIONS	
Ultimate Compressive Load Capacity	32 kips
Micropile Unbonded/Cased Length	8 feet
Diameter of Micropile Bonded Length	3 inches minimum
Micropile Bonded Length	14 feet minimum
Center Reinforcing Bar (Full Depth)	No. 8 (ASTM A615 Grade 60)

CASED MICROPILE SYSTEM RECOMMENDATIONS	
Grout Minimum Compressive Strength	4,000 psi (water-cement ratio of 0.50 or less)
Notes: 1. The ultimate capacity of a single pile was derived with a reduction factor of 0.55 2. Bonded Zone Length is the length of micropile below the bottom of permanent casing	

Settlements of the micropiles will result primarily from elastic compression of the micropile member and subgrade response. We estimate the total settlement of the micropile-supported foundations to be 0.5 inches or less with differential settlements between micropiles not exceeding about one-half of the total settlement. We believe these settlements are essentially elastic and should occur as the loads are applied.

It should be noted that the bond stress between the grout bulb and the soil is highly dependent on the drilling procedures and the grouting methods employed by the contractor to install the micropile. Therefore, the bond stress between the grout bulb and the soil may vary considerably between different contractors and micropile foundation systems. In order to determine whether the contractor's methods of micropile installation are adequate and to confirm the load carrying capacity of the installed micropiles, we recommend performing a pullout test (proof test) on a selected production micropile. We recommend testing a minimum of one micropile for pullout. In general, the purpose of the pullout test on the installed micropiles is to fulfill the following objectives:

- To examine the adequacy of the methods and equipment proposed by the contractor to install the micropiles to the depths required.
- To confirm or modify the estimated minimum depth of the micropiles by determining the ultimate grout-to-soil bond stress.
- To assess the contractor's method of drilling and grouting.

The pullout test should consists of subjecting the micropile to at least 150% the Strength I Limit State design load of 18 kips. The micropile should be loaded in about 12.5% design load increments, and each load should be held for at least 5 minutes. The maximum test load should be held for a minimum of 10 minutes. Based on experience with similar projects, we recommend conducting the pullout tests no earlier than 7 days after completion of the micropile installation and after grout has attained a minimum compressive strength of 4,000 psi, whichever later. Pullout test on the selected micropile is an integral part of the design of the micropile foundation system. Therefore, we recommend conducting the pullout test under the observation of a Geolabs representative.

CLOSURE

We appreciate the opportunity to be of continued service to you on this project. If you have questions or need additional information, please contact our office.

Respectfully submitted,

GEOLABS, INC.

By _____
Andrew J. Felkel, P.E.
Project Engineer

By _____
Gerald Y. Seki, P.E.
Vice President

GERALD Y. SEKI
LICENSED PROFESSIONAL ENGINEER
No. 5635-C
HAWAII, U.S.A.

THIS WORK WAS PREPARED BY
ME OR UNDER MY SUPERVISION.

_____ 4-30-18
SIGNATURE EXPIRATION DATE OF THE LICENSE

GS:AJF

(3 Copies to Addressee)

h:\7400Series\7417-00(A).add.ajf1