# SECTION 3. DISCUSSION AND RECOMMENDATIONS

Our field exploration generally encountered a pavement structure consisting of about 6 inches of Portland cement concrete overlying 12 inches of gravelly sand fill. Below the pavement, stiff fill material was encountered at a depth of approximately 4 feet followed by stiff to hard residual soil extending to a depth of about 15 feet below the existing ground surface. Underlying the residual soil, very dense saprolite was encountered at a depth of approximately 21.5 feet followed by medium hard to hard basalt rock formation extending to the maximum depth explored of about 28 feet below the existing ground surface. We did not encounter groundwater in the boring drilled at the time of our field exploration.

We recommend supporting the new traffic signal poles on cast-in-place concrete drilled shaft foundations. Based on the subsurface conditions encountered, for traffic signal poles with mast arm lengths of 40 feet or less, we believe the Standard Plan TE-33A.1 and 33A.2, Type II Traffic Signal Standard by the State of Hawaii – Department of Transportation, Highways Division may be used for the design of the drilled shaft foundations.

The Type II Traffic Signal Standard does not include recommendations for traffic signal poles with mast arm lengths greater than 40 feet. Structural loading information for the 50-foot mast arm traffic signal pole was not available at the time this report was prepared. Therefore, in-house structural loading information from similar projects was used to develop preliminary foundation recommendations. Geolabs should be forwarded the final structural loading information when it becomes available to develop final foundation recommendations for the project.

Detailed discussions and recommendations for the design of foundations, utility trenches, and other geotechnical aspects of the project are presented in the following sections.

## 3.1 <u>Traffic Signal Pole Foundations</u>

Based on the information provided, we understand that new traffic signal poles with mast arm lengths of up to 50 feet are planned to replace the existing traffic signal poles at the Kahuapaani Street and Ulune Street intersection. Based on the typical loading demands and anticipated subsurface soil conditions, we recommend supporting the new traffic signal poles on single cast-in-place drilled shaft foundations.

In order to develop the required bearing and lateral load resistances, the proposed new traffic signal pole structures may be supported by a foundation system consisting of cast-in-place concrete drilled shafts. Based on the subsurface conditions encountered, for traffic signal poles with mast arm lengths of 40 feet or less, we believe the Standard Plan TE-33A.1 and 33A.2, Type II Traffic Signal Standard by the State of Hawaii – Department of Transportation, Highways Division may be used for the design of the drilled shaft foundations.

We did not encounter groundwater at the time of our field exploration. Therefore, we recommend the following drilled shaft diameters and lengths for the proposed traffic signal pole foundations in accordance with TE-33A.2, Type II Traffic Signal Standard Drilled Shaft Foundation Schedule for a Level Ground Condition – Above Ground Water Table.

| **STANDARD TRAFFIC SIGNAL POLES<br>DRILLED SHAFT FOUNDATIONS FOR LEVEL GROUND CONDITIONS** | | |
|---|---|---|
| **Mast Arm Length**<br>(feet) | **Drilled Shaft Diameter**<br>(inches) | **Drilled Shaft Length**<br>(feet) |
| 12 | 24 | 6 |
| 25 | 30 | 6 |
| 38 | 30 | 11 |

The Type II Traffic Signal System and Standard does not include recommendations for traffic signal poles with mast arm lengths greater than 40 feet. Structural loading information for the 50-foot mast arm traffic signal pole was not available at the time this report was prepared. Therefore, in-house structural loading information from similar projects was used to develop preliminary foundation recommendations. Geolabs should be forwarded the final structural loading information when it becomes available to develop final foundation recommendations for the project.

The following structural loads were utilized to design the preliminary cast-in-place concrete drilled shaft foundation for the 50-foot mast arm traffic signal pole.

| 50-FOOT MAST ARM TRAFFIC SIGNAL POLE PRELIMINARY STRUCTURAL LOADS | | | |
|---|---|---|---|
| **Axial Load** (kips) | **Resultant Shear Force** (kips) | **Resultant Bending Moment** (kip-feet) | **Torsion** (kip-feet) |
| 2.5 | 5 | 100 | 100 |

Based on the typical dimensions of the base plate and anchor bolts, we envision that a 36-inch diameter cast-in-place concrete drilled shaft would be required for the proposed 50-foot mast arm traffic signal poles. The cast-in-place concrete drilled shafts would derive vertical support principally from skin friction between the shafts and the surrounding soils. Our preliminary recommendations pertaining to the drilled shaft capacities are presented in the following table.

| 36-INCH DIAMETER DRILLED SHAFT FOUNDATION | | |
|---|---|---|
| **Shaft Length** (feet) | **Allowable Compressive Load Capacity Per Shaft** (kips) | **Ultimate Uplift Load Capacity Per Shaft** (kips) |
| 12 | 226 | 238 |

The allowable compressive load capacity for the drilled shaft is to support dead-plus-live loads and may be increased by up to one-third (⅓) when considering transient loads, such as wind or seismic forces.

Uplift loads may be resisted by a combination of the dead weight of the drilled shaft and shear along the shaft surface area and adjacent soils. The uplift load capacity provided in the table above should be used only for transient loading conditions. For sustained loading conditions, the uplift load capacity should be reduced further using a factor of safety of 2.0. The project structural engineer should check the capacity of the drilled shaft in tension.

The load-bearing capacities of the drilled shafts will depend largely on the consistency of the soils. Because local variations in the subsurface materials likely will occur, it is imperative that our representative is present during the shaft drilling operations to confirm the subsurface conditions encountered during the drilled shaft construction and to observe the installation of the drilled shafts. In addition, contract documents should include provisions (unit prices) for additional drilling and extension of the drilled shafts during construction to account for unforeseen subsurface conditions. The subsequent subsections address the design and construction of the drilled shaft foundations, which include the following:

- Lateral Load Resistance
- Foundation Settlements
- Drilled Shaft Construction Considerations

#### 3.1.1 Lateral Load Resistance

The lateral load resistance of the drilled shafts is a function of the stiffness of the surrounding soil, the stiffness of the shafts, allowable deflection at the top of the shafts, and the induced moment in the shafts. The lateral load analyses were performed using the program LPILE 2018 for Windows, a microcomputer adaptation of a finite difference laterally loaded deep foundation program originally developed at the University of Texas at Austin. The program solves for deflection and bending moment along a deep foundation under lateral loads as a function of depth. The analysis was carried out with the use of non-linear “p-y” curves to represent soil moduli. The lateral deflection was then computed using the appropriate soil moduli at various depths.

Based on the assumed preliminary structural loads, results of our lateral load analyses for the concrete drilled shaft foundation are presented in the following table. The top of the shaft was assumed to be free against rotation.

| SUMMARY OF LATERAL LOAD ANALYSES | | | | |
|---|---|---|---|---|
| **Shaft Length** (feet) | **Maximum Lateral Deflection** (inches) | **Maximum Shear** (kips) | **Maximum Induced Moment** (kip-feet) | **Depth to Maximum Moment** (feet) |
| 12 | 0.16 | 24.7 | 113.2 | 3.8 |
| NOTE: Analyses based on concrete compressive strength of 4,000 psi and a minimum of 1% longitudinal steel reinforcement. | | | | |

### 3.1.2 Foundation Settlements

Settlement of the drilled shaft foundation will result from elastic compression of the shaft and subgrade response of the foundation embedded in the subsurface soils. Total settlement of the drilled shaft is estimated to be on the order of less than 0.5 inches. We believe that a significant portion of the settlement is elastic and should occur as the loads are applied.

### 3.1.3 Drilled Shaft Construction Considerations

In general, the performance of the drilled shafts will depend significantly upon the contractor's method of installation and construction procedures. The following conditions would have a significant effect on the effectiveness and cost of the drilled shaft foundations.

The load-bearing capacities of the drilled shaft depend, to a significant extent, on the frictional resistance between the shaft and the surrounding soils. Therefore, proper construction techniques, especially during the drilling operations, are important. The contractor should exercise care in drilling the shaft hole and in placing concrete into the drilled hole.

The subsurface materials generally consist of medium dense and stiff fill material overlying stiff residual soil, very dense saprolite, and basalt rock formation with depth. The residual and saprolitic soils encountered within the depth of the drilled shaft may contain cobbles and boulders. Therefore, some difficult drilling conditions may be encountered and should be expected in these soils. The drilled shaft contractor will need to have the appropriate equipment and tools to drill through the cobbles and boulders that may be encountered during drilled shaft installation operations.

Based on our field exploration and the estimated length of the drilled shaft, groundwater is generally not expected in the drilled hole during the shaft installation work. Due to the relatively short length of the drilled shaft, concrete placement using the free fall method should be acceptable. In the event of seasonal rainfall and/or perched groundwater, water may be encountered in the drilled hole and concrete placement by tremie method would be required.

A low-shrinkage concrete mix with a high slump (6 to 9-inch slump range) should be used to provide close contact between the drilled shaft and the surrounding soils. In addition, the concrete should be placed promptly after drilling (within 24 hours after drilling of the holes) to reduce the potential for softening of the sidewalls of the drilled hole.

It is imperative that a Geolabs representative is present at the project site to observe the drilling and installation of the drilled shafts during construction. Although the drilled shaft design is primarily based on skin friction, the bottom of the drilled hole should be relatively free of loose materials prior to placement of the concrete. Therefore, it is necessary for Geolabs to observe the drilled shaft installation operations to confirm the assumed subsurface conditions.

## 3.2 Utility Trench

We anticipate that underground utilities, such as new electrical lines, may be installed for the project. In general, good construction practices should be utilized for the installation and backfilling of the trenches for the new utilities. The contractor should determine the method and equipment to be used for trench excavation, subject to practical limits and safety considerations. In addition, the excavations should comply with the applicable federal, state, and local safety requirements. The contractor should be responsible for trench shoring design and installation.

In general, we recommend providing granular bedding consisting of 6 inches of open-graded gravel (ASTM C33, No. 67 gradation) under the pipes for uniform support.

Free-draining granular materials, such as open-graded gravel (ASTM C33, No. 67 gradation), should also be used for the initial trench backfill up to about 12 inches above the pipes to provide adequate support around the pipes. It is critical to use this free-draining material to reduce the potential for formation of voids below the haunches of pipes and to provide adequate support for the sides of the pipes. Improper trench backfill could result in backfill settlement and pipe damage.

The upper portion of the trench backfill from the level 12 inches above the pipes to the top of the subgrade or finished grade may consist of select granular fill material. The backfill material should be moisture-conditioned to about 2 percent above the optimum moisture content, placed in maximum 8-inch level loose lifts, and mechanically compacted to at least 90 percent relative compaction. In areas where trenches will be in paved areas, the upper 3 feet of the trench backfill below the pavement finished grade should be compacted to no less than 95 percent relative compaction. Mechanical compaction equipment should be used to compact the backfill materials. Compaction efforts by water tamping, jetting, or ponding should not be allowed.

Select granular fill should consist of non-expansive granular material, such as crushed coralline and/or basaltic materials. The material should be well-graded from coarse to fine with particles no larger than 3 inches in largest dimension and should contain between 10 and 30 percent particles passing the No. 200 sieve. The material should have a laboratory California Bearing Ration (CBR) value of 20 or more and should have a maximum swell of 1 percent or less when tested in accordance with ASTM D1883.

### 3.3 Design Review

Preliminary and final drawings and specifications for the project should be forwarded to Geolabs for review and written comments prior to bid solicitation for construction. This review is necessary to evaluate conformance of the plans and specifications with the intent of the foundation and utility trench recommendations provided herein. If this review is not made, Geolabs cannot be responsible for misinterpretation of our recommendations.

## 3.4 Post-Design Services/Services During Construction

Geolabs should be retained to provide geotechnical engineering services during construction. The critical items of construction monitoring that require "Special Inspections" include the following:

1. Observation of the drilled shaft foundation installation
2. Observation of utility trench excavation and compaction

A Geolabs representative also should monitor other aspects of earthwork construction to observe compliance with the design concepts, specifications, or recommendations and to expedite suggestions for design changes that may be required in the event subsurface conditions differ from those anticipated at the time this report was prepared. Geolabs should be accorded the opportunity to provide geotechnical engineering services during construction to confirm our assumptions in providing the recommendations presented herein.

If the actual exposed subsurface conditions encountered during construction differ from those assumed or considered herein, Geolabs should be contacted to review and/or revise the geotechnical recommendations presented herein.

END OF DISCUSSION AND RECOMMENDATIONS