AGENCY OF TRANSPORTATION **OFFICE MEMORANDUM**

To: Ken Robie, Roadway Project Manager

LAR CCB

From: Laura Ripley, Geotechnical Intern via Christopher C. Benda, P.E., Soils and Foundations Engineer

Date: July 26, 2012

Subject: Cabot-Danville FEGC-F-028-3(26) - Hooker Brook Geotechnical Recommendations

1.0 INTRODUCTION

We have completed our geotechnical analysis for the spread footing foundation of a precast arch for Bridge No. 88 over Hooker Brook on US Rt. 2 in Cabot, VT. This analysis was requested by Michael Cruz of Green International Affiliates, Inc (Green) in an email dated June 5th, 2012. This request specified an update to load and resistance factor design (LRFD) requirements of the previous recommendations performed by GEI Consultants in accordance with allowable stress design (ASD) criteria. The geotechnical analysis was performed according to 2010 AASHTO LRFD Bridge Design Specifications.

2.0 ANALYSIS

Boring logs were provided in the geotechnical report from Mike Cruz of Green dated July 6th, 2012. These were completed by VTrans on November 11th, 2001. There were four borings (B-201, B-202, B-203, B-204) advanced, one on each corner of the bridge.

2.1 Soil Parameters

Due to the similarity of the materials on site and elevation of strata, one soil profile was used to evaluate both abutments. The ground surface elevation was located at EL 1448, and the results showed that a layer of gravelly silty sand extended for about 10 feet, which was underlain by 10 feet of medium dense silt followed by 33 feet of dense silt. Bedrock was not encountered in any of the borings, so it was assumed the dense silt layer extended further in the analysis. The bottom of footing location (at EL 1439) was used for analysis purposes, as proposed on the bridge section provided by Green on June 25th, 2012.

2.2 Groundwater Conditions

The groundwater level was located at EL 1444, according to the boring results. The provided ordinary high water (OHW) was located at EL 1447.6, according to provided plans from Green. Bearing capacity calculations require the water level location at the highest expected elevation. In order to account for this in a conservative analysis, the water level was assumed to be located at the ground surface (EL 1450).

2.3 Bearing Resistance Analysis

The bearing resistance in both strength and service limit states were assessed. The service condition considered a footing embedment of 0 feet to account for potential scour or conditions during construction. The strength limit state accounted for a footing embedment of 6 feet to account for the distance from the ground surface elevation to the bottom of footing. The corresponding resistance factors, summarized in Table 1, were applied to the nominal bearing resistance; as per 10.5.5.1 of the 2010 AASHTO LRFD Bridge Design Specifications. Sections 10.5.2 and 10.5.3 of AASHTO outline all design states relevant to spread footing design and their respective resistance factors. Eccentricity should be considered for settlement and bearing resistance design of spread footings by using effective footing widths based on AASHTO Section 10.6.1.3. Table 1 shows the appropriate resistance factors for various design states. The effective footing width was used for all analyses in this report, which accounts for eccentricity, or e, with Equations 1 and 2; based on AASHTO Section 10.6.1.3.

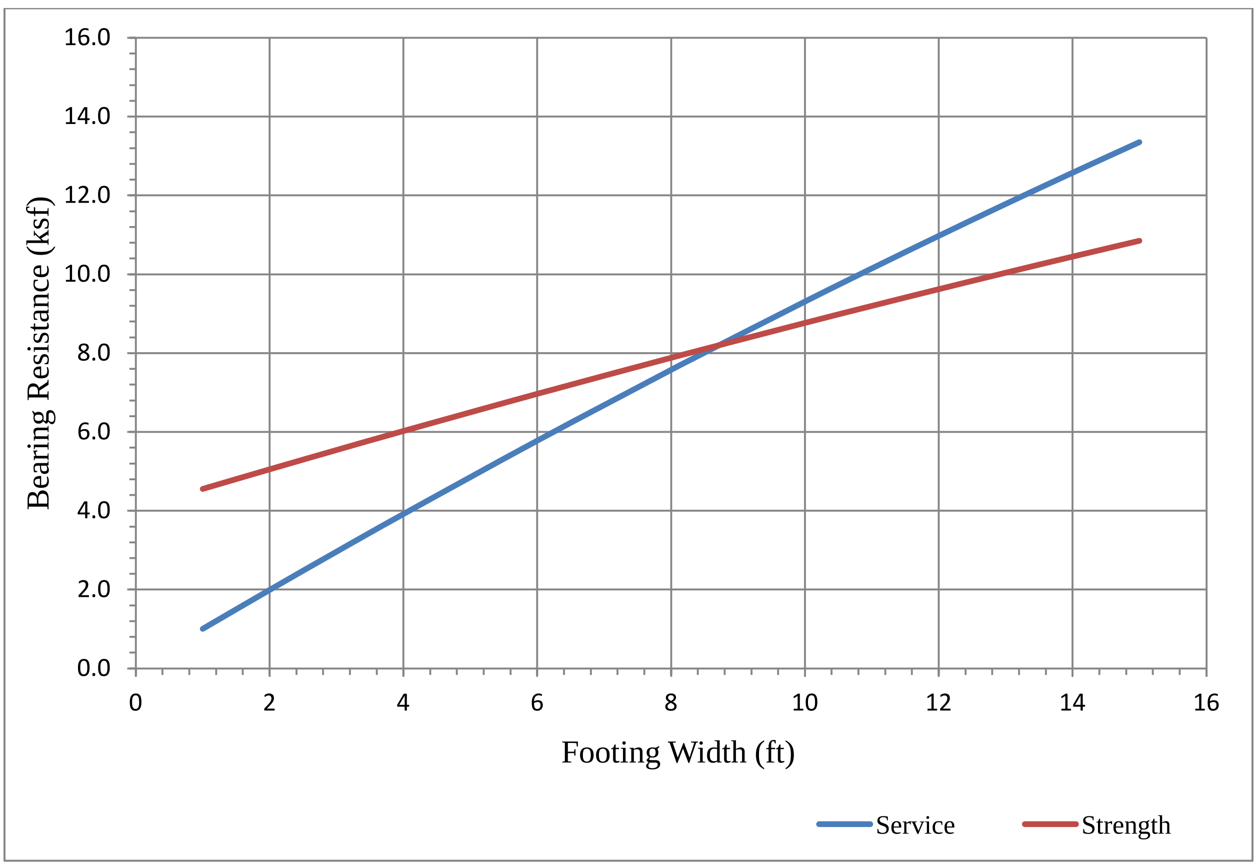
Foundations on soil: $|e| \leq b/4$ Equation 1
Effective footing width: $B' = B - |e|$ Equation 2

Table 1. Summary of resistance factors.

Design State	Resistance Factor, φ
Settlement	1.0
Scour	1.0
Extreme	1.0
Bearing Resistance	0.45
Sliding	0.80

Based on the soil profile developed from the borings and empirical relationships with SPT values from the dense silt bearing stratum, it was determined that the gravelly sandy silty had a friction angle (φ) of 33° and a density (γ) of 115 lbs/ft^3. Figure 1 displays the effective footing width versus factored bearing resistance for both strength and service limit states. The corresponding bearing resistances for an effective footing width of 8.25 feet were 8.0 ksf and 7.8 ksf for the strength and service conditions, respectively.

Figure 1. *Effective* footing width vs. bearing resistance (factored).



2.4 Settlement Analysis

The settlement was calculated for the proposed footing according to Hough's Method, outlined in AASHTO Section 10.6.2.4.2. This method is used for normally consolidated cohesionless soils, and depth and inclination correction factors were not applied

3.0 FOUNDATION RECOMMENDATIONS

The requested design information includes the subsurface and groundwater conditions, foundation recommendations, and construction considerations based on LRFD design specifications.

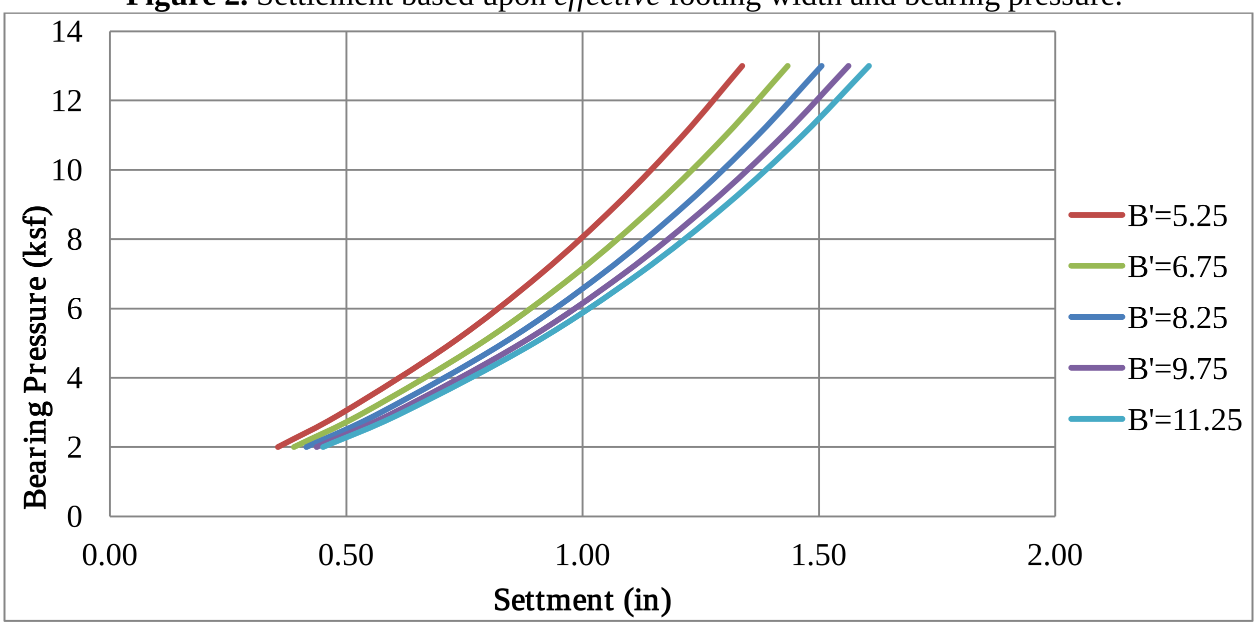
3.1 Bearing Resistance Recommendations

Factored bearing resistances were calculated for various footing widths and can be found in Figure 1. **We recommend using a conservative value of 7.5 ksf for design with an effective footing width of 8.25 feet in order to satisfy the governing service design conditions.** These calculations are based on the geometric and geotechnical assumptions outlined in AASHTO Section 10.6.3, as well assumed footing width that corresponds with the provided factored loads.

3.2 Settlement Recommendations

Soil settlement values were calculated based upon the provided footing width with a varying bearing pressure. Due to the cohesionless soil condition, the settlement is expected to occur during and immediately after construction. Figure 2 displays the values for settlement for effective footing widths in a range from 5.25 to 11.25 feet.

Figure 2. Settlement based upon *effective* footing width and bearing pressure.



The settlement at the maximum bearing pressure of 7.5 ksf was found to be 1.1 inches, for the assumed effective footing width of 8.25 feet. It is expected that the actual bearing pressure will be approximately 6.0 ksf, which corresponds to a settlement of 0.9 inches at an effective footing width of 8.25 feet.

3.3 CONSTRUCTION CONSIDERATIONS

3.3.1 Cofferdams/Temporary Earthwork Support

The Contractor should be reminded that Section 208.07 of VTrans' *2006 Standard Specifications for Construction* indicates that "The Contractor shall prepare detailed plans and a schedule of its operation for each cofferdam specified in the Contract. The design and structural details of the cofferdam shall be signed, stamped, and dated by a Professional Engineer (Structural or Civil)."

3.3.2 Construction Dewatering

At the time of the subsurface investigation, the groundwater level was located at approximately EL 1444, while the proposed bottom of footing was at EL 1439. Due to this differential, temporary construction dewatering may be required to construct the foundations, at each abutment. Temporary dewatering may also be necessary to limit disturbance to and maintain the integrity of the bearing surface.

Temporary dewatering can likely be accomplished by open pumping from shallow sumps, temporary ditches, and trenches within and around the excavation limits. Sumps should be provided with filters suitable to prevent pumping of fine-grained soil particles. The water trapped by the temporary dewatering controls should be discharged to settling basins or an approved filter "sock" so that the fine particles suspended in the discharge have adequate time to "settle out" prior to discharge. All effluent, or discharge, should comply with all applicable permits and regulations.

Sumps and trenches should lie outside a 1V:1H line extending downward and outward from the edge of the footing. Installation and operation of the Contractor's dewatering system should be integrated with other earthwork operations and sequence of cutting, filling, foundation construction, and backfilling.

3.3.3 Placement and Compaction of Soils

Fills should be placed systematically in horizontal layers not more than 12 inches in thickness, prior to compaction. Cobbles larger than 8 inches should be removed from the fill prior to placement. Compaction equipment should preferably consist of large, self-propelled vibratory rollers. Where hand-guided equipment, such as a small vibratory plate compactor, is used the loose lift thickness shall not exceed 6 inches. Cobbles larger than 4 inches should be removed from the fill prior to placement.

Embankment fills should be compacted to a dry density of at least 90% of the maximum dry density determined in accordance with AASHTO T-99. Granular Backfill for Structures, or other select materials placed within the roadway base section shall be compacted to a dry density of 95% of the maximum dry density determined in accordance with AASHTO T-99.

3.3.4 Roadway/Embankment Design

There are no suspected geotechnical problems with the roadway or embankment design, with the assumption that standard Agency construction practices are utilized.

4.0 SOIL DESIGN PARAMETERS

Table 2 highlights the geotechnical design parameters of the foundation bearing soil as well as regularly specified aggregates. These values should be used when designing the substructure units. It is recommended that values of K_o be used for calculating earth pressures where the structure is not allowed to deflect longitudinally, away from or into the retained soil mass. Values for K_a should be utilized for an active earth pressure condition where the structure is moving away from the soil mass and K_p where the structure is moving toward the soil mass.

Table 2. Engineering properties of construction materials.

	703.01A - Granular Borrow	**704.08 - Granular Backfill for Structures**	**In-situ Gravelly Sandy Silt**
Density (lb/ft^3):	130	140	115
Internal Friction Angle, φ	32	35	33
Coefficient of Friction, f			
- concrete cast against	0.50	0.55	0.40
- soil against formed	0.40	0.45	0.31
Active Earth Pressure	0.31	0.27	0.30
Passive Earth Pressure	3.22	3.69	3.39
At-Rest Earth Pressure	0.47	0.43	0.46

4.0 CONCLUSIONS

This report has been prepared for Bridge No. 88, which crosses Hooker Brook on US Rt 2 in Cabot, VT. Computer generated boring logs are attached and available in the M:\Projects\78d347\MaterialsResearch folder.

If any further analysis is needed or you would like to discuss these recommendations, please contact us at (802) 828-2561.

Attachements: Boring Logs (4)

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Electronic Read File/WEA
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