VERMONT
VTrans

Materials & Research Engineering Instructions MREI 10-01

Distribution: Structures, Director PDD, Assistant Director PDD, PDD Section Managers, Chief of Contract Admin., Director Ops., Assistant Director Ops., Consultants

Approved: _____ **Date**: March 9, 2010
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Subject: **Geotechnical Design Procedures for Mast Arm and Overhead Sign Support Foundations**

Administrative Information:

Effective Date: This Materials & Research Engineering Instruction (MREI) shall be considered effective from the date of approval.

Superseded MREI: None.

Exceptions: No exceptions are noted at this time.

Disposition of MREI Content: The content of this MREI will be incorporated into a future VTrans Soils & Foundations Engineering Manual.

1.0 Purpose:

The purpose of this MREI is to standardize VTrans' foundation designs for overhead structures such as signal or sign bridges, mast arms, and strain poles during plan (preliminary and final) development or construction.

2.0 Technical Information:

In general, the design of mast arms and strain poles is performed in accordance with **AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 2009 5th Edition.** Furthermore, this document dictates the design of foundations for these structures to be conducted in accordance with **AASHTO Standard Specifications for Highway Bridges 17th Edition, 2002.**

3.0 Overview:

The Agency's process for the foundation design of overhead structures is typically conducted in two stages; preliminary and final design stage.

Developer or Contractor (both are hereafter referred to as Contractor) foundation designs are typically developed entirely within the construction phase. The final foundation type is selected by the Contractor and the design of this foundation is provided by the Contractor for the Agency's review and acceptance.

4.0 Procedure:

4.1 Subsurface Investigation:

1. As a minimum, drill one boring for each overhead structure foundation element. The boring should be drilled in close proximity to the proposed foundation location. Perform continuous Standard Penetration Test (SPT) sampling from a depth of 2 to 12 ft and then again at 15, 20, and 25 ft depths. .At a minimum, SPT values should be corrected for overburden pressure and hammer energy. Develop a soil profile for each foundation location. For each soil layer provide information regarding the following soil parameters;

   c – cohesion, in psf
   ϕ – internal friction angle, in degrees
   γ – unit weight, in pcf
   k – soil modulus, in pci
   f – friction factor, no units
   K_o – At-rest earth pressure coefficient, no units

2. Prepare a preliminary geotechnical report documenting the subsurface investigation, soil profile, groundwater table, and soil parameters at each foundation location.

4.2 Agency Projects - Contractor/Supplier Design:

Perform the analyses described below while complying with the guidelines given in **Section 4.4**.

1. Review the results of the subsurface investigation and the soil parameters for each soil layer as outlined in the Preliminary Geotechnical Report.

   Identify the structural loads acting at the top of each foundation, i.e., at the anchor bolt elevation: Axial (P), Shear (V), Overturning Moment (M), and Torsion (T). Primarily, only mast arm foundations will be exposed to torsional loads.

2. Select a foundation type for analysis.

   There are two types of foundations that are predominantly constructed to support overhead structures; drilled shafts and spread footings. If spread footings are constructed they are usually square footings. However, circumstances such as utility locations may necessitate the use of rectangular spread footings or require the use of drilled shafts. Spread footings on rock may use grouted rock anchors to resist applied loads. Drilled shaft foundations are typically equal to or less than 36 inches in diameter unless soft ground conditions exist.

3. Perform a bearing capacity analysis to ensure that anticipated bearing pressures do not exceed the maximum allowable bearing capacity. Calculate the eccentricity and effective footing widths for spread footing foundations.

   The factor of safety for use in bearing capacity calculations shall be 3.0. Use bearing capacity equations provided in AASHTO Standard Specifications for Highway Bridges 17th Edition, 2002, Section 4.4.7.1.1. The bearing capacity shall be adjusted accordingly for footings located on, near or within a slope.

   Effective footing widths should be used for all design calculations. The effective footing width, B' is equal to the nominal, or constructed, footing width, B, reduced by a value equal to two times the calculated eccentricity or $B' = B - 2e$.

4. Perform overturning and sliding analyses.

   Deep Foundations: Drilled Shafts and Driven Piles: Check to ensure that the embedment depth provided for drilled shaft or driven piles is sufficient to prevent overturning or excessive horizontal movement (sliding) of the foundation. For spread footing foundations ensure that eccentricity is within acceptable limits and that factor of safety against sliding is acceptable.

   For drilled shaft type foundations, the Brom's method, as outlined in AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 2009 5th Edition, Section 13.6.1.1, can be used to verify embedment depths. For Brom's analyses, use an undercapacity factor equal to 0.7 and an overload factor of 2.1.

   Alternatively, a more detailed lateral load analysis can be performed. An example of a more detailed analysis is a p-y method of analysis utilizing the LPile software program or a similar software program that considers soil-structure interaction. Deflections due to combined loading on the structure shall be limited to 0.5 inches at the ground surface.

Shallow Foundations: The calculated eccentricity values for footings on soil should be designed so that the eccentricity, e, of the loading is less than 1/6 of the footing dimension in any direction. [Ref. 4, Section 4.4.7.1.1.1] For spread footings on bedrock the eccentricity should be limited to ¼ of the footing dimension in any direction. [Ref. 3, Section 6.4.1]. Overturning is not considered to be an issue for eccentricity values within these ranges.

The required factor of safety used for sliding analyses shall be 1.5.

5. Compute anticipated settlement of each foundation.

   Excessive vertical settlements must be accounted for so that the foundation can be constructed to the desired elevation, however, differential settlement, i.e., movements that would cause the structure to tip, present more of a serviceability concern. Where concerns like this may exist, consider undercutting the foundation and placing 1 to 2 feet of stone under the foundation to decrease the loads applied to the in-situ foundation soil. Settlement analyses should be conducted using the Hough method as outlined in the GEC N0. 6, Shallow Foundations, Section 5.3.4.

   Limit overall vertical settlement to 2". Limit differential settlement to 1". Significant foundation rotation due to differential settlement should be communicated to the design engineer as the camber of the horizontal support (mast arm) could be designed to account for the anticipated foundation movement.

   ***Discussion**: For an 8' wide footing that suffers a 1" differential settlement on any one corner -this translates to a slope at the foundation elevation of 0.125"/ft. "For a Group I load combination (dead load only) the slope at the top of the vertical supports with moment load applications shall be limited to 30mm/m (0.35"/ft)." [Ref. 1 Section 10.4.2.1] This means 30 to 40% of the allowed movement is due to differential settlement.*

6. Perform analyses for torsion to ensure that the torsional factor of safety meets or exceeds 1.1. The Beta method shall be used for drilled shaft type foundations and the Florida Structural Design Office Method for spread footing foundations. Other methods may be used as approved by the VTrans Soils and Foundations Engineer.

7. Document the design results and calculations in a concise summary report.

4. 3 Developer/Contractor Projects:

The following requirements apply to Developer or Contractor projects that are required to comply with Agency specifications and are outside the normal VTrans project development process.

1. The Contractor shall submit the final design loads, detail construction methods and provide supporting calculations demonstrating compliance with **Sections 4.2** as outlined above. The Agency will decide whether to accept the Contractor's design or request changes to the design.

2. Ensure that the Contractor has submittal a set of drawings to the Agency in accordance with **Section 5.0**.

3. Contractor needs to schedule their work to allow for a period of 10 working days to allow for proper Agency review.

4.4 Design Guidelines:

1. The vertical offset is the distance from the ground surface to the top of the foundation. This is assumed to be 6" unless otherwise depicted.

2. Assume that the groundwater table (GWT) is at the ground surface unless a different GWT can be reasonably determined from a subsurface investigation, monitoring wells, or laboratory moisture contents.

3. Neglect a minimum of the upper 2 feet of soil surrounding the foundation for contributions to torsion and skin friction resistance. This is due to potential for future disturbance. *Note: The use of a "sonotube" as a form may negate or reduce skin friction resistance for design purposes.*

4. A minimum depth of 5 feet to the bottom of spread footing foundations on soil shall be used to mitigate the potential for movement from frost effects.

5. To simplify calculations of torsion for square footings the square footing is assumed to be circular, i.e, an 8 ft wide square footing is modeled as an 8 ft diameter. This is a conservative assumption.

6. Uplift (negative contact pressure) of a spread footing is restricted. The footing must have a minimum contact pressure exceeding 0 psf. In extreme cases where the footing width and cost is excessive the Agency may choose to allow uplift on one corner only. However, the designer will have to document the contact pressure at all four corners.

5.0 VTrans Plan Review Requirements:

Ensure that the design drawings and/or plans include, but are not limited to, the following;

1. a reference to follow the design guidance in MREI 10-01.

2. the calculated ultimate bearing capacity along with the factor of safety used for design purposes or the calculated ultimate shaft or pile capacity along with the design factor of safety.

3. cross sections showing location of any overhead structures depicting the proximity to any adjacent slopes, existing or proposed infrastructure, and utilities. These cross sections should also depict the foundation elements.

4. a series of construction notes that will ensure that the structure(s) are constructed in accordance with the current edition of the VTrans Standard Specifications for Construction.

5. an appropriate engineering scale.

6.0 References:

1. AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals, 2009 5th Edition.

2. VTrans Excel Spreadsheets – Mast Arm and Strain Pole Foundation Design Spreadsheets are retained in the MREI Tool Box Folder under the Soils and Foundations Folder on the Materials & Research Section's G:Drive.

3. FHWA GEC No. 6 Shallow Foundations

4. AASHTO Standard Specifications for Highway Bridges 17th Edition, 2002

7.0 Implementation:

The content of this MREI will be implemented immediately for all projects utilizing overhead structures.

8.0 Transmitted Materials:

None.