Structural Engineering Guidance No. 10-10

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Distribution: All Engineering Resources

SUBJECT: SIDE RESISTANCE DESIGN FOR ROCK SOCKETS

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Effective Date: Immediately for Jobs Not Turned In To Review Section

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Background and Purpose:

In order to promote a uniform design practice for determining the Minimum Nominal Axial Compressive Resistance (Side Friction), MNACRSF, to be reported on the bridge plans for rock sockets, structural engineering guidance is required to explain how to interpret and use the rock layer friction resistances and elevations reported in the Foundation Investigation Geotechnical Report (FIGR). Further, a general design procedure is also given using this guidance.

This guidance provides terminology, explanation and a general design procedure.

Guidance:

RECALL THAT:

Elevations at which the side resistance of a rock socket that are useable for design and the MNACRSF for each layer shall be reported on the Foundation Data Table for rock sockets in accordance with August 17 Structural Engineering Guidance 10-09.

TERMINOLOGY:

Information provided in the FIGR for Drilled Shafts.

Anticipated Tip of Casing (ATOC) - *Elevation of the tip of the permanent casing to be embedded and sealed in rock and as described in Missouri Standard Specifications Sec 701, See April 14 Structural Engineering Guidance 10-02.*

Anticipated Top of Sound Rock (ATOSR) - *Elevation at which the top of sound rock is anticipated and estimated as 1 foot higher in elevation than ATOC, See April 14 Structural Engineering Guidance 10-02; Useable rock layer elevations for developing side resistance will always be less than this elevation from 1 to 5 feet generally.*

“Elevation From-To” – *Elevation ranges in the FIGR that represent the useable lengths of rock available for development of side resistance.*

Nominal Axial Compressive Resistance (Side Friction), NACRSF  - *Reported as “Nominal Side Resistance” or similarly in the FIGR and is the available nominal (ultimate) side resistance useable for rock socket design. The NACRSF is the lesser of the frictional resistance of either rock or socket concrete and determined in accordance with AASHTO LRFD 10.8.3.5.4b. Geotechnical Section will report the NACRSF for each layer available and useable, and possibly identify the controlling material. Elevations provided are given in ranges. The combination of the nominal side resistance(s) and the elevation(s) of the rock layer(s) are used to determine the diameter and length of rock socket required. This term represents capacity available and is the maximum value of compressive resistance available.*

Minimum Nominal Axial Compressive Resistance (Side Friction), MNACRSF  - *Required nominal axial compressive resistance equal to the maximum factored loads divided by the side resistance factor. This term represents demand required and is the minimum value of compressive resistance that is required.*

Side Resistance Factor – *Recommended side resistance factor given by Geotechnical Section in the FIGR.*

Nominal Tip Resistance – *Reported as “Nominal Bearing Resistance” or similarly in the FIGR. Drilled shafts may only be designed for end bearing with approval from the Structural Project Manager or Structural Liaison Engineer.*

EXPLANATION:

An efficient design is realized when the available nominal side resistance is fully utilized with the result that the MNACRSF that is to be reported on the Foundation Data Table will be close to or equal to the nominal side resistance recommended in the FIGR. There are situations where this cannot be realized where rock sockets are extended deeper for reasons other than axial strength criteria and the MNACRSF will be less, examples of which could include the following:

EXTENDING SOCKETS:

1. Anomalous or ineffective rock layers like voids or seams where nominal side resistance should be reduced or disregarded which may not be recorded on the FIGR (Contact Geotechnical Section for review.)
2. Rounding socket length
3. Minimum socket length requirement according to AASHTO LRFD
4. Minimum socket diameter controlled by column/shaft diameters
5. Sloping rock stratigraphy
6. Lateral loading
7. Site variability
8. Combining useable elevation ranges and using the lesser nominal side resistance for some or all of the ranges
9. Extending a socket deeper than reported data available on FIGR (Contact Geotechnical Section for review.)

NOTE: Special situations should be addressed to the Structural Project Manager or Structural Liaison Engineer, and forwarded to the Development Section for updating guidance.

Geotechnical Section typically disregards the upper 1 to 5 feet generally of the rock socket as unusable, examples of which could include the following:

UNUSABLE ROCK:

1. anticipated disturbed rock from keying permanent casing into rock for stability and/or sealing of 1 foot or more
2. weathered rock conditions
3. presence of cracks or crevices or cavities
4. low RQD values
5. site variability where adding some extra length could provide a benefit at locations where no soundings were performed

The elevation ranges given on the FIGR are to be used for developing geotechnical resistance and shall be noted on the bridge plans.

The NACRSF reported in the FIGR is the maximum side resistance useable for the development of side resistance (for each rock layer) and it shall not be exceeded. It is based on the actual rock conditions from coring presuming it is at the location of the proposed socket. The MNACRSF is the side resistance computed after the length and diameter of the socket is determined using the elevation ranges provided in the FIGR and may not exceed the NACRSF. Report the MNACRSF on the bridge plans. In some cases, the MNACRSF may equal the NACRSF especially if there are multi-layers of rock.

GENERAL DESIGN PROCEDURE:

Axial load side friction design only.

1. Based on the shaft diameter required, use 6” less for the diameter of socket (EPG 751.37.1.1)
2. If a single rock layer is reported in the FIGR, use NACRSF given in the FIGR and determine the length of the socket required as the maximum factored loads divided by the product of the side resistance factor multiplied by the NACRSF multiplied by the diameter of the socket. Determine the practical length considering rounding and other incidental unusable rock criteria for extending the socket, or perhaps a reason that is not shown.
3. Determine MNACRSF as the maximum factored loads divided by the product of the resistance factor multiplied by the useable socket circumferential area (the useable length multiplied by the circumference of the shaft).
4. Report the top of rock socket in accordance with April 14 Structural Engineering Guidance 10-02 and the bottom of rock socket elevation as the top of useable rock socket elevation minus the computed design length of socket. Report MNACRSF in the Foundation Data Table for each socket.
5. If multiple rock layers are reported in the FIGR, begin by using NACRSF given in the FIGR for the upper layer as required. For example,
   1. Compute the nominal resistance of the socket extending through the entire upper layer using NACRSF multiplied by the socket circumferential area and side resistance factor for the upper layer. For this layer, MNACRSF =NACRSF.
   2. Compute the residual portion of the maximum factor load not resisted by the upper layer as the maximum factored load minus the capacity of the upper layer as calculated in step a.
   3. Where socket extends into a second lower layer, determine the additional length required as in step 2 above and after determining the practical length considering rounding and other incidental unusable rock criteria, determine MNACRSF as in step 3 if no more than two layers are penetrated. If more than two layers are penetrated, continue in this fashion until the resistance is fully developed.
   4. Follow step 4 except report MNACRSF in the Foundation Data Table for each rock layer of each socket.
   5. Note: It is possible that different layers may have different side resistance factors. Use accordingly.

DO NOT DO THE FOLLOWING: (Consult with the Geotechnical Section if considering. Approval of the Structural Project Manager or Structural Liaison Engineer is required before considering.)

1. Do not average the NACRSF of individual rock layers from the FIGR in the event that the actual rock stratigraphy is different in the field where, for example, a weaker layer may be more predominant which would mean that the socket length reported on the bridge plans could be undersized, or where a stronger rock layer is more predominant which would mean the socket length reported on the bridge plans is over designed;
2. Do not determine MNACRSF using elevations other than those given in the FIGR;
3. Do not average MNACRSF using elevations other than shown in the FIGR. For example, do not use the entire rock socket length as reported on the bridge plans which is not 100 percent useable for resistance;
4. Do not modify the side resistance factors given in the FIGR for the individual rock layers.

Suggestions and recommendations concerning this guidance or procedure should be directed to the Development Section for review and updating the Engineering Policy Guide.