Drilled Shaft Design

Design Manual
Chapter 200
Geotechnical Design
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Drilled shafts may be used to directly support bridge substructure components, light towers, sign structures, and other transportation structures. Drilled shafts should be designed according to the Iowa DOT LRFD Bridge Design Manual (BDM) Section 6.3.

Geotechnical design of drilled shaft foundations should be conducted as specified in the AASHTO LRFD Bridge Design Specifications Article 10.8 (most current version). The geotechnical resistance of each of the soil layers is estimated by the Soils Design Section using information in the S4 Event (see Section 200B-4), which contains the soil boring logs and rock coring information needed for bridge foundation design, and the SPS sheet (which is developed from the Situation Plan) that identifies the boring locations and the subsurface profile information. Office of Bridges and Structures (OBS) typically requires that drilled shafts for bridge support be socketed into rock. If soil-supported shafts are to be used, they must be approved by the Soils Design Section and OBS Chief Structural Engineer. OBS typically does not support abutments on drilled shafts.

Quick Tips:

- The Office of Bridges and Structures does the actual final drilled shaft design. In doing so, OBS relies on the Soils Design Section for a soils design package, S4 event, containing the boring logs, locations of the borings, soil descriptions, and recommendations used for drilled shaft design.
- OBS typically requires that drilled shafts for bridge support be socketed into rock.
- The Iowa DOT has accumulated test data for drilled shafts socketed in shale and limestone. The test data currently are available to designers from the Soils Design Section and OBS.
- OBS rarely supports abutments on drilled shafts.

Interaction Between Soils and OBS in Drilled Shaft Design

As stated above, the Soils Design Section does not perform the actual drilled shaft design (i.e., does not determine the final shaft size, shaft length, number of shafts, etc). Instead, most of this final design effort is done by Office of Bridges and Structures (OBS) based in part on the information, recommendations, etc. contained in the Soils Design Section's S4 submittal. The subsections that follow discuss efforts that may involve both the Soils Design Section and OBS, and those efforts may relate to input, recommendations, etc. from both the Soils Design Section and OBS. However, OBS has the primary involvement, and OBS does essentially all items in which the Bridge Design Manual (BDM) is referenced.

Design Requirements

Drilled shaft design is performed by OBS using the Soils Design Section's S4 package. Drilled shaft foundations should be designed at the Service Limit State to meet the tolerable movements for the structure. Service Limit State design of drilled shaft foundations includes the evaluation of settlement due to static loads, downdrag loads if present, and lateral deformation. Drilled shafts should be designed at the Strength Limit State to resist the compressive, uplift, and lateral loads, as well as settlement.

In most instances at Iowa DOT, the drilled shaft design for axial load is based on the side friction capacity in the rock socket, but the contribution from end bearing may be added to the side friction capacity under the following two conditions:

- The estimated settlement does not exceed 0.25 inches at the Service Limit State, and

- The estimated settlement does not exceed 1 inch at the Strength Limit State, which is defined as a load 2.5 times the service load.

If either settlement limitation is exceeded, the needed geotechnical resistance may be obtained by side friction from a deeper socket.

Geotechnical Resistances

The Soils Design Section is responsible for presenting the subsurface data and subsurface profile information, and accompanying recommendations, in a manner that OBS can use in drilled shaft design. The Soils Design Section summarizes the nominal and factored geotechnical resistances for all soil and rock layers. OBS uses this information combined with the structural loadings to determine the required tip elevation and drilled shaft diameter.

Axial Capacity (Uplift and Compression)

Use the soils design package information and AASHTO LRFD Specifications Section 10.8 (most recent copy) to develop the nominal geotechnical resistances of each soil and rock layer. The Soils Design Section recommends that the designer use Drilled Shafts: Construction Procedures and LRFD Design Methods, Publication No. FHWA-NHI-10-016 by Brown et al. as a design guide. If any of the guidelines contained in the FHWA publication conflict with guidelines in BDM 6.3 or the AASHTO LRFD Specifications, the designer should consult with the Soils Design Section and OBS. If appropriate, consideration can be given to using existing subsurface information from As-Built plans for the existing structure at the site, or other sources to develop the nominal resistances. Proper engineering judgment should be used when using older subsurface information.

The nominal side and end bearing resistance of drilled shafts may also be developed based on the results of historical or design phase load test data from the anticipated load bearing soil/rock strata. In order to use historical load test data, the characterized project site soil/rock profile should be similar to the soil/rock profile at the load test site. The Soils Design Section will need to review and approve the use of load test data for development of drilled shaft capacity. Load testing that can be used to determine nominal side and end geotechnical resistance include Osterberg, Statnamic, or dynamic (Apple) load tests.

Grooving of the sidewalls of rock sockets for drilled shafts is typically desired and specified in softer rocks such as Pennsylvanian age shale, siltstone, mudstone, and sandstone. This can include Pennsylvanian deposits with thin limestone stringers provided those stringers are not thick enough or significant enough to control the basic grooving operation. However, grooving is not to be specified in harder rocks such as limestone or dolomite/dolostone because grooving in these harder materials is simply not possible. Grooving is not to be specified for any portion of a drilled shaft in soil. The designer always should consult the Soils Design Section to discuss and determine grooving of the rock sockets in drilled shafts.

If permanent or temporary casing is required, do not consider any side friction capacity over the length of the casing. Permanent casing should not extend more than 1 foot into rock.

Lateral Capacity

Lateral analysis of drilled shaft foundations is conducted to establish the load distribution between the superstructure and foundations for all limit states, and to estimate the deformation in the foundation that will occur due to those loads. The Soils Design Section typically provides the soil descriptions, design profiles, and required soil input parameters that are used by OBS in the lateral foundation analysis performed with LPILE (i.e., COM624). Lateral analysis should account for factors such as scour, proximity of retaining walls, and seasonal moisture changes of the soil (i.e., shrinkage, resulting in gapping around drilled shaft).

Geotechnical Resistance Factors

Use the geotechnical resistance factors outlined in AASHTO LRFD Specifications Section 10.5.5 (most recent copy) to determine the factored geotechnical resistances of each soil and rock layer.

References

1. AASHTO, 2012, LRFD Bridge Design Specifications, American Association of State Highway and Transportation Officials, Sixth Edition, Washington, D.C., USA.
2. Brown, D. A., Turner, J. T., and Castelli, R. J., 2010. Drilled Shafts: Construction Procedures and LRFD Design Methods. Report No. FHWA NHI-10-016. Washington: Federal Highway Administration (FHWA).

Chronology of Changes to Design Manual Section:

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