Proposed Changes to Section 10

Changes are being proposed in six (6) articles:

- 10.4.2 – Subsurface Exploration
- 10.4.6 – Selection of Design Properties
- 10.5.5 – Resistance Factors
- 10.8.1 – General
- 10.8.2 – Service Limit Design
- 10.8.3 – Strength Limit Design
Subsurface Exploration Programs

Recommended updated to Table 10.4.2-1 to clean up language on minimum depth of exploration. Currently, the specification says:

“For shafts supported on or extending into rock, a minimum of 10 ft. of rock core, or a length of rock core equal to at least three times the shaft diameter for isolated shafts or two times the maximum shaft group dimension, whichever is greater, shall be extended below the anticipated shaft tip elevation to determine physical characteristics of rock within the zone of foundation influence.”

Subsurface Exploration Programs

May be unrealistic for drilled shaft groups

“maximum” to “minimum”

Added some discussion to Table 10.4.2-1 on minimum number of explorations, and differentiating between design and construction needs
Table 10.4.2-1 —Subsurface Exploration

Additional guidance provided in the table regarding design versus construction needs for explorations:

Additional wording:

“To reduce design and construction risk due to subsurface condition variability and the potential for construction claims, at least one exploration per shaft should be considered for large diameter shafts (e.g., greater than 5 ft in diameter), shafts socketed into bedrock”

10.4.6.4—Rock Mass Strength

• Future recommendation to update Article to replace Rock Mass Rating (RMR) with Geological Strength Index (GSI) as developed by Hoek et. al., for correlation to the Hoek-Brown strength properties of fractured rock mass
• Has implications in many other places of the specification (e.g., spread footings)
• Drilled shaft design articles will reference specific documents and information where needed
10.5.5.2—Strength Limit States

In Article 10.5.5.2.4—Drilled Shafts:
The definition of a "site" for purposes of assessing variability to justify resistance factor selection has been updated.

References to 10.5.5.2.3 have been removed so as to not have driven pile references to dynamic testing and signal matching analysis

Discussion added to C10.5.5.2.4 related to importance of understanding site variability

Downdrag

• There have been significant changes suggested for Articles 10.8.1.6.2-Downdrag (general discussion) and 10.8.3.4-Downdrag (strength limit design)

• Stand-alone provisions have been proposed for drilled shafts to better differentiate them from driven piles
Downdrag

- Considers that service limit state will control since in many cases the side resistance in the settling layer would have to reverse (act upward) in order to achieve a strength limit state in compression
- For shafts bearing in soil, downdrag only considered at strength and extreme limit state only if shaft settlement is less than the failure criterion
- Downdrag occurs in response to relative downward movement and may not exist if shaft response to axial load exceeds vertical deformation of soil

Downdrag

- Downdrag occurs in response to relative downward movement
- May not exist if shaft response to axial load exceeds vertical deformation of soil
- Analysis requires consideration of:
  - Shaft load-settlement behavior
  - Time period over which non-permanent components of load occur
**Downdrag**

Additional guidance added to Article 10.8.1.6.2 and 10.8.3.4, and to C10.8.3.4 to differentiate downdrag for shafts with tip bearing soil versus shafts that bear in rock or very dense strata (structurally controlled)

10.8.2.4 remains unchanged as language is not different from what is currently for driven piles (though wording may be added)

Committee needs to look at where guidance has been added to ensure clarity for the user

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**10.8.2.2.2 - Settlement of Single Drilled Shaft**

FHWA GEC 10 has incorporated a simple normalized model of average load-displacement behavior based on field load test data (Chen and Kulhawy, 2002).

Average observed behavior is used as a very approximate guide for estimating axial displacement under service load conditions

Represents a 1st order estimate that considers the average behavior
Normalized Load-Displacement Model

Currently in Article 10.8.2.2.2

From O’Neill and Reese, 1999

Hypothetical Load-Displacement Model

From O’Neill and Reese, 1999
Updated Load-Displacement Model

Proposed for C10.8.2.2.2
- Settlement of Single Drilled Shaft

Adapted from Chen and Kulhawy, 2002

Settlement of Single Drilled Shaft

Alternate simplified approach for estimating settlement of a single drilled shaft currently proposed for C10.8.2.2.2

Based on analysis of a worldwide database of compression load tests on straight-sided shafts including those used to develop O’Neill and Reese curves

Developed as a way to provide consistent interpretation of load test results
10.8.2.2.3 - Intermediate Geo Materials (IGMs)

Proposed to redefine IGM’s in C10.8.2.2.3 and eliminate cohesionless IGM as a category of geomaterial

The term Cohesionless IGM was used previously by O’Neill and Reese (1999) to describe granular tills or granular residual soils with $N_{10}$ greater than 50 blows/ft

Addresses designer confusion with results when trying to interpret whether very dense cohesionless soils (e.g. $N=50$) were to be considered cohesionless or IGM.

10.8.2.3 - Horizontal Movement of Shafts and Shaft Groups

• Proposed change is related to guidance on shafts in rock

• Guidance added to both Article 10.8.2.3 and C10.8.2.3 to consider both the intact shear strength of the rock and the rock mass characteristics

• Currently no information on this in specifications
10.8.2.3 - Horizontal Movement of Shafts and Shaft Groups

- For fractured rock, unconfined shear strength of intact rock is no longer meaningful

- For fractured rock masses, guidance is given for assessing the rock strength using the GSI and characterizing the rock mass as a $c$-$\phi$ material

- Once strength parameters are developed, a user specified p-y curve should be derived a p-y method of analysis.

10.8.3.5.1b—Estimation of Drilled Shaft Resistance in Cohesive Soils

- Modify Figure 10.8.3.5.1b-1 (exclusion zones)

- Do not arbitrarily neglect side resistance over one diameter above shaft tip; modify Article 10.8.3.5.1b and commentary to reflect this change
10.8.3.5.2—Estimation of Drilled Shaft Resistance in Cohesionless Soils

Re-write Article 10.8.3.5.2b and C10.8.3.5.2b to replace the depth-dependent $\beta$ method with more rational method that relates side resistance to state of effective stress acting at the soil-shaft interface

Delete Equation 10.8.3.5.2c-2 (tip resistance in cohesionless IGM) from Article 10.8.3.5.2c—Tip Resistance
Design for Axial Side Resistance – Cohesionless Soil

\[ f_{SN} = \beta \sigma'_v \]  
‘Beta method’

• Current AASHTO guidance – Article 10.8.3.5.2

\[ \beta = 1.5 - 0.135 (z)^{0.5} \]

• Proposed Method for Nominal Unit Side Resistance in Cohesionless Soils

\[ f_{SN} = \sigma'_v K \tan \phi' \]

10.8.3.5.4—Estimation of Drilled Shaft Resistance in Rock

• Revise Articles 10.8.5.3.4b and C10.8.5.3.4b to reflect larger database of load test data

• Replace Rock Mass Rating (RMR) with Geological Strength Index (GSI) for correlation to Hoek-Brown strength parameters for use in bearing capacity analysis of fractured rock mass in 10.8.5.3.4c and C10.8.3.5.4c

• Changes to C10.8.3.5.4d regarding use of combined side resistance and end bearing for rock sockets
10.8.3.5.4b—Side Resistance

- Current AASHTO guidance (Horvath and Kenney, 1979) – Article 10.8.3.5.4
  
  \[ f_{SN} = 0.65 \alpha_E p_a (q_u/p_a)^{0.5} \]

- Proposed Method for normal rock sockets (Kulhawy et al., 2005)
  
  \[ f_{SN} = C p_a (q_u/p_a)^{0.5} \]

10.8.3.5.4d—Combined Side and Tip Resistance

- Guidance added to C10.8.3.5.4d to assist with design decision to omit side or base resistance
- Focused on quality construction practices for cleaning shafts and load tests for including base resistance
- Focused on analysis of load test results that have not shown brittle behavior along the shaft sidewall
Comments on Resistance Factors

At this time, it is not recommended to adjust resistance factors to accommodate proposed design changes. Proposed changes are based on inclusion of additional load test data or more rational approaches and are seen as an improvement.

10.8.3.9.3—Reinforcement

Edit commentary for consistency with recommendations in FHWA GEC 10 regarding minimum clear spacing between bars and constructability issues often encountered with shear reinforcement for seismic design.

FHWA GEC 10 Reference: Chapter 8 Rebar Cages
Thanks!

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