U.S. Department of Transportation
Federal Highway Administration

Revisions to AASHTO LRFD Bridge Design Specifications – Drilled Shafts and MSE Walls (2013)

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AASHTO SCOBS passed a large Agenda Item updating various Articles in Section 10 related to Drilled Shaft Design

Impetus for Changes to Section 10

Update serves to better represent the state of practice including:

- Advances in construction equipment and procedures
- Updates to design methodologies

Advances incorporate:

- Routine design and construction of large diameter shafts
- Analysis of more comprehensive load test databases
- Recent research results to address design gaps

Changes to Section 10

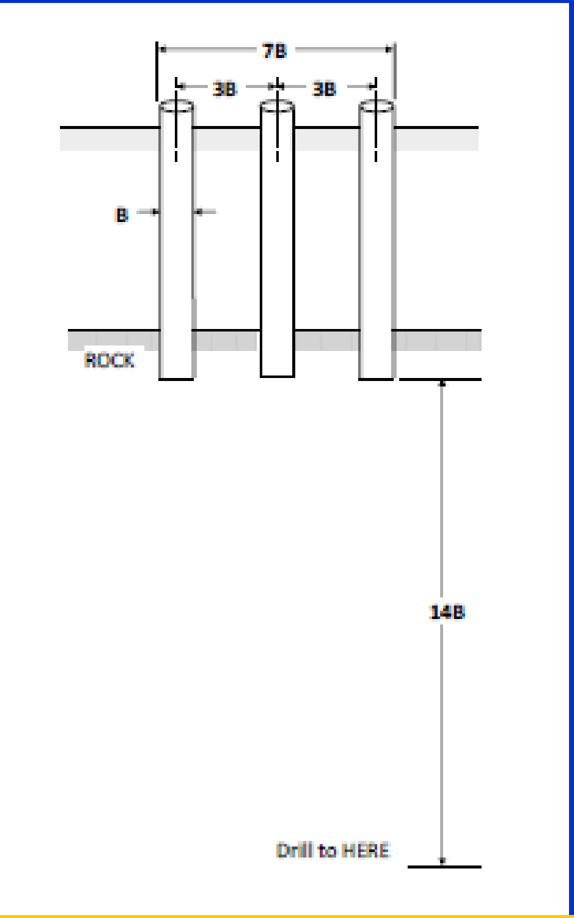
Ten (10) key changes were proposed in six (6) articles of Section 10:

- 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

Table 10.4.2-1 has been adjusted to:

- Correct a problem with potentially excessive exploration depths for drilled shaft groups
- Address potential design and construction risk due to subsurface variability and construction claims on large diameter shafts socketed in rock



Assessing Rock Mass Strength

- Replaced Rock Mass Rating (RMR) with Geological Strength Index (GSI) as developed by Hoek et. al. in Article 10.4.6.4
- Applies for all of Section 10 except as noted for Spread Footing design in Article 10.6
- GSI provides a more direct correlation to the Hoek-Brown strength parameters than the RMR
- Design procedures for spread footings in rock have been developed using the RMR system
- Reference to Sabatini et al (2002) is provided for RMR

Intermediate Geo Materials (IGMs)

IGM's have been redefined in C10.8.2.2.3 to eliminate cohesionless IGM as a category of geomaterial

The term Cohesionless IGM was used in O'Neill and Reese (1999) to describe granular tills or granular residual soils with N^1_{60} 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.

Downdrag

- There have been significant changes made to Articles 10.8.1.6.2-Downdrag (general discussion) and 10.8.3.4-Downdrag (strength limit design)
- 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 (Service Limit State) remains unchanged as language is not different from what is currently for 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

Horizontal Movement of 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

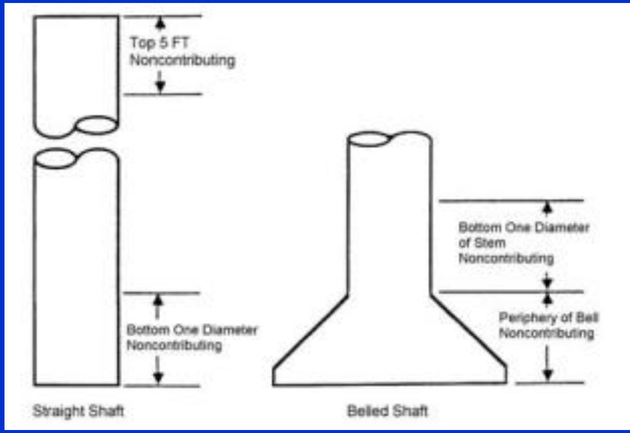
- Currently no information on this in specifications for drilled shafts

Horizontal Movement of Shafts in Rock

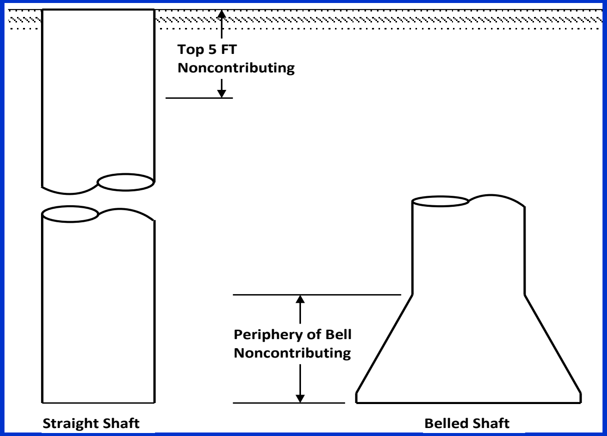
- For fractured rock, unconfined shear strength of intact rock is not meaningful
- For fractured rock masses, guidance is given for assessing the rock strength using the GSI and characterizing the rock mass as a c-ϕ material
- Once strength parameters are developed, a user specified p-y curve should be derived a p-y method of analysis.

Estimation of Drilled Shaft Resistance in Cohesive Soils

- Modify Figure 10.8.3.5.1b-1 (exclusion zones)
- Modified Article 10.8.3.5.1b and commentary to not arbitrarily neglect side resistance over one diameter above shaft tip



O'Neill and Reese, 1999



Brown et. al., 2010

Estimation of Drilled Shaft Resistance in Cohesionless Soils

Re-wrote Article 10.8.3.5.2b and C10.8.3.5.2b to replace the depth-dependent β 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

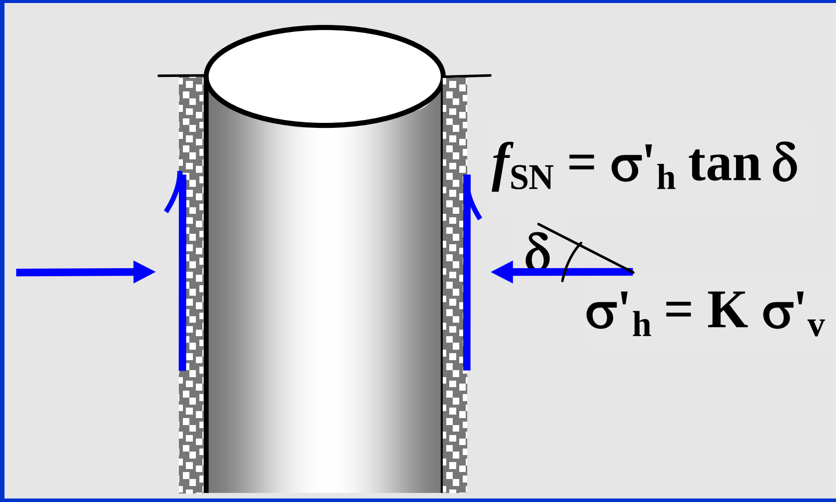
$f_{SN} = \beta\, \sigma'_v$ *'Beta method'*

- Previous AASHTO guidance – Article 10.8.3.5.2

$$\beta = 1.5 - 0.135\,(z)^{0.5}$$

- Updated Method for Nominal Unit Side Resistance in Cohesionless Soils

$$f_{SN} = \sigma'_v\, K \tan\delta$$



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

Side Resistance - Rock

- Previous AASHTO guidance (Horvath and Kenney, 1979) – Article 10.8.3.5.4

$$f_{SN} = 0.65\alpha_E p_a (q_u/p_a)^{0.5}$$

- Current method for normal rock sockets (Kulhawy et al., 2005)

$$f_{SN} = C p_a (q_u/p_a)^{0.5}$$

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

AASHTO SCOBS passed 9 Agenda Items updating various Articles in Section 11 related to MSE Wall Design

AASHTO/FHWA MSE Wall Task Force

- Task force initiated in 2012 to assist in future decision making for AASHTO and FHWA
- Made up of broad range of subject matter expertise from academia, consulting, FHWA, state DOTs, and industry
- Aid in the update and revision of AASHTO MSE Wall Sections
- Develop a strategic plan for AASHTO and FHWA for advancing topics in MSE Wall design

AASHTO/FHWA MSE Wall Task Force

- Task Force developed a strategic plan of immediate, near-term, and long term issues to be addressed in AASHTO
- Immediate issues were considered “low hanging fruit” and were advanced to the T-15 committee for consideration
- Near-term and long term issues were determined to require additional effort and time to move foward

Strength Limit State – Internal Stability

- Replaced Figure 11.10.6.2.1-2 to be alignment with FHWA GEC 11 and limit the equivalent surcharge when reinforcement lengths are greater than 0.7H
- Added Figure 11.10.6.3.2-1 to reduce complexity of determining vertical stress needed for pullout resistance

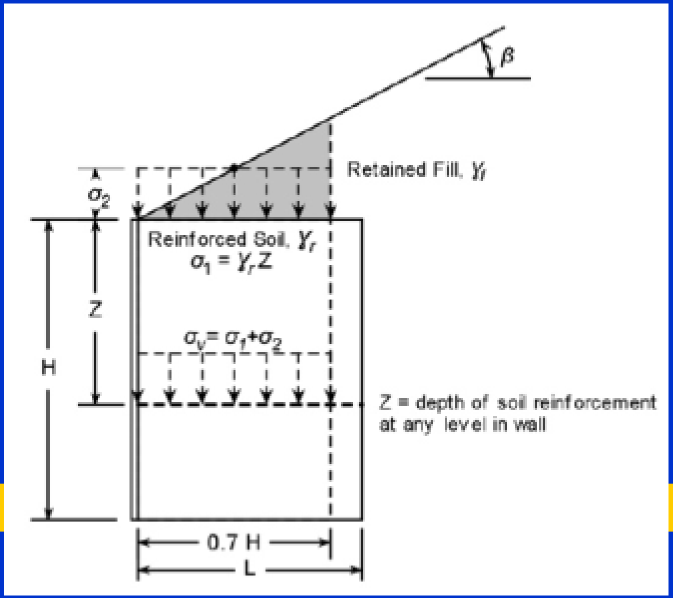
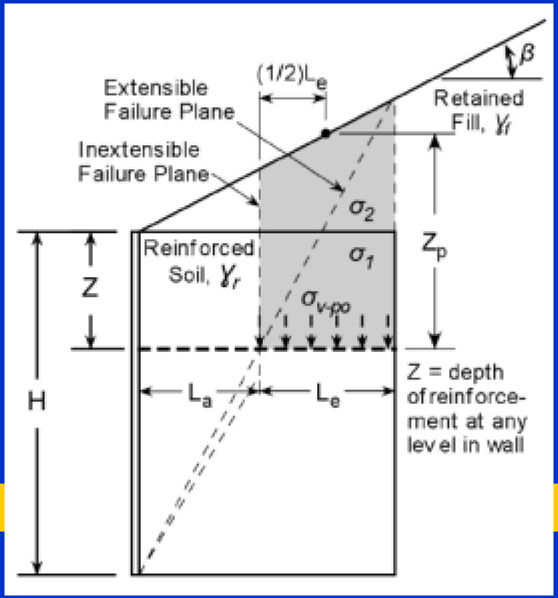


Figure 11.10.6.2.1-2

Figure 11.10.6.3.2-1



Strength Limit State – Internal Stability

- Added language to Article C11.10.11 for analysis of spread footings on top of reinforced soil zone
- Based on FHWA GEC 11, the following values of bearing resistance may be used to be consistent with current successful practice:
  - For service limit state, bearing resistance = 4 ksf to limit vertical movement to less than approximately 0.5 inches
  - For strength limit state, factored bearing resistance = 7 ksf

Service Limit State – Internal Stability

Adjusted the maximum vertical spacing in Article 11.10.6.2.1 to accommodate large facing blocks. This addresses research on walls constructed with gabion baskets for which S_v = 40 inches

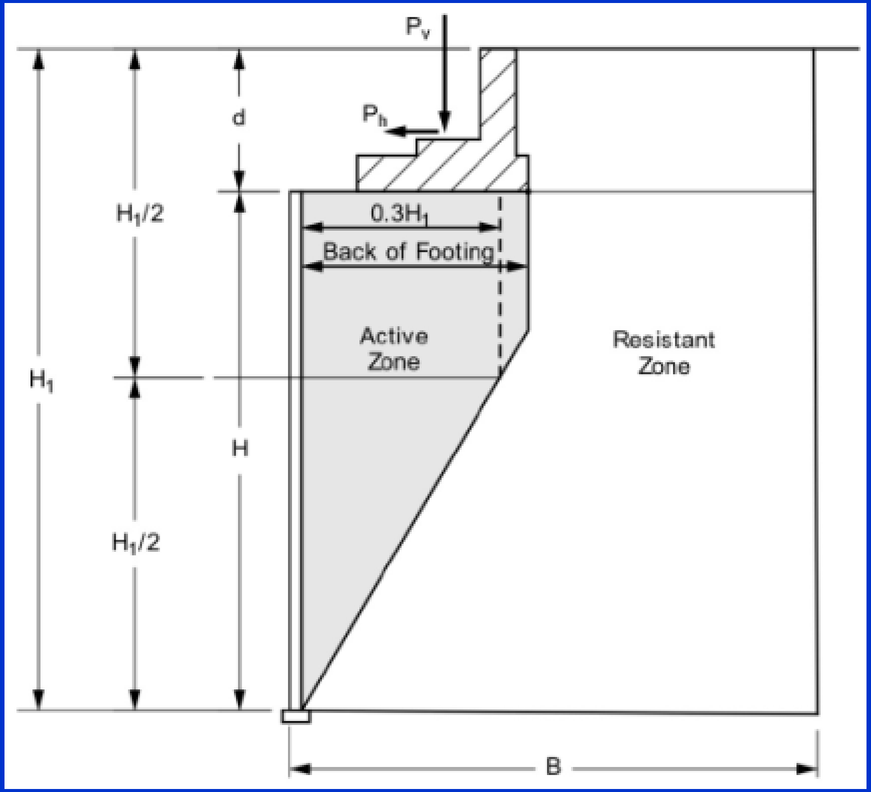
Strength Limit State – External Stability

- Language added to Article C11.6.2.3 to clearly define a structural element on a slope justifying a resistance factor of 0.65

- Articles 11.10.5.3 and C11.10.5.3 have been adjusted to consider the location and type of reinforcement (continuous vs. discontinuous) in evaluation of sliding stability

Materials and Other Issues

- Language added to Article 11.10.6.4.2a to explicitly state that corrosion loss rates apply only to galvanized steel.
- Article C11.10.11 revised to remove the 22 foot minimum reinforcement length requirement for abutments
- Figure 11.10.10.1-2 revised



Materials and Other Issues

Updated Figure C11.11.1-1 to include other prefabricated modular gravity walls

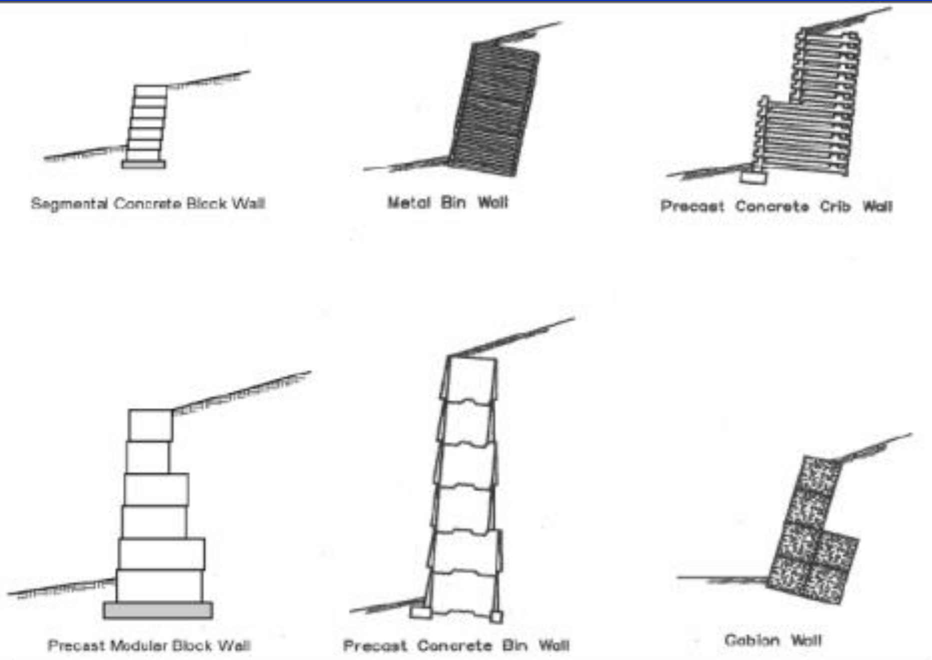


Figure C11.11.1-1—Typical Prefabricated Modular Gravity Walls

Thanks!

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