FOUNDATIONS AND RETAINING WALLS UPDATE

Alexander B.C. Dettloff, P.E.
State Foundations Engineer
ODOT Office of Geotechnical Engineering
Common Review Issues

Spread Footing Scour

Bridge Design Manual Revisions
COMMON REVIEW ISSUES

- 1929 to 1988 Datum Conversion
- Load Factors on Inclined Loads
- Bearing Values in Plan Notes
- Limit Equilibrium Bearing Resistance
- Depth Correction Factor, $d_q$
COMMON REVIEW ISSUES

- Inclination Factors, $i_c, i_q, i_\gamma$
- Bedrock Bearing for Spread Footings and Drilled Shafts
- Cohesive Sliding Resistance
- Drivability Hammer Selection
- Rock Core Unit versus Lithology
1929 to 1988 Datum Conversion

- ODOT Historic Borings drilled prior to June 1993 were originally surveyed under National Geodetic Vertical Datum of 1929 (NGVD 29).
- Borings drilled thereafter are surveyed under North American Vertical Datum of 1988 (NAVD 88).
- The difference within Ohio is typically negative 0.4 to 0.7 feet.
COMMON REVIEW ISSUES

○ 1929 to 1988 Datum Conversion
  ○ Convert elevations for all borings drilled prior to June 1993 for display on Soil Profile Sheets and for use in analyses.
  ○ The National Geodetic Survey federal agency website has an online conversion tool for any given location in the United States at: http://www.ngs.noaa.gov/cgi-bin/VERTCON/vert_con.prl.
COMMON REVIEW ISSUES

- Load Factors on Inclined Loads
  - Inclined loads on retaining walls and abutments (typically EH and LS) can have multiple load factors with respect to stabilizing or destabilizing influence.
COMMON REVIEW ISSUES

○ **Load Factors on Inclined Loads**
  
  ○ Inclined loads are often broken into horizontal and vertical components for mathematical convenience in the calculations.
  
  ○ However, inclined loads do not have **actual** horizontal and vertical components; do not use separate maximum and minimum load factors for the respective components of these loads.
COMMON REVIEW ISSUES

○ Load Factors on Inclined Loads

  ○ Treat each inclined load as a single load, which either serves to stabilize or destabilize the structure, then apply the same load factor (either maximum or minimum) to both the horizontal and vertical components of the load.

  ○ This also applies to live load surcharge (LS) load applied for Strength Ia Limit State (sliding and eccentricity).
COMMON REVIEW ISSUES

- Load Factors on Inclined Loads
  - Strength Ia Limit State:

\[ \gamma_{LS} = 0 \]
\[ LS \]
\[ \gamma_{LS} = 1.75 \]
\[ LS \]
\[ \delta \]
\[ LS_{v} \]
\[ LS_{h} \]
COMMON REVIEW ISSUES

○ Bearing Values in Plan Notes
  ○ BDM Plan Note 606.5-1:
    ○ FOUNDATION BEARING RESISTANCE: ___ footings, as designed, produce a maximum Service Load pressure of ___ kips per square foot and a maximum Strength Load pressure of ___ kips per square foot. The factored bearing resistance is ___ kips per square foot.
  ○ Ensure that the values of maximum Service Load pressure, maximum Strength Load pressure, and factored bearing resistance in the Plans match the values in the Structure Foundation Exploration Report!
COMMON REVIEW ISSUES

- Limit Equilibrium Bearing Resistance
COMMON REVIEW ISSUES

- Limit Equilibrium Bearing Resistance
COMMON REVIEW ISSUES

- Limit Equilibrium Bearing Resistance
COMMON REVIEW ISSUES

- **Limit Equilibrium Bearing Resistance**
  - Build a full external stability model of the wall
  - Analyze first for Sliding and Eccentricity (Strength Ia)
  - Then determine Eccentricity (e) and Effective Footing Width \( (B' = B - 2e) \) at Strength Ib (Bearing)
  - Use \( B' \) and \( \sigma_v \) from Strength Ib to start L.E. analysis \( (\sigma_{vo}) \)
  - Do not allow development of failure surface beyond effective footing width \( B' \)
  - Adjust \( \sigma_v \) until \( FS = 1.000 \) \( (\sigma_{vf} = q_n) \)

- **Factored Bearing Resistance:** If \( \varphi_b q_n \geq \sigma_{vo} \) then **OK.**

- **Capacity-Demand Ratio:** \( CDR_b = \varphi_b q_n / \sigma_{vo} \)
COMMON REVIEW ISSUES

- Depth Correction Factor, $d_q$
  - Table 10.6.3.1.2a-4 in the AASHTO LRFD Bridge Design Specifications is confusing and has a limited range of applicability (only $\phi_f = 32^\circ$ to $42^\circ$ and $D_f/B = 1$ to $8$)
  - Instead, use the Hansen (1970) equation:
    - $d_q = 1 + 2 \tan \phi_f \left(1 - \sin \phi_f\right)^2 \arctan \left(D_f/B'\right)$
  - This is the basis of Table 10.6.3.1.2a-4
COMMON REVIEW ISSUES

- Depth Correction Factor, \( d_q \)
COMMON REVIEW ISSUES

- Inclination Factors, $i_c$, $i_q$, $i_γ$
  - The load inclination factors are generally not used.
  - In an inclined, eccentric loading, the inclination of the load is taken care of in the eccentricity and effective footing width calculations ($B' = B - 2e$); therefore use of load inclination factors less than one would be overly conservative.
COMMON REVIEW ISSUES

- Inclination Factors, $i_c$, $i_q$, $i_\gamma$
  - Load inclination factors are only used in the case of an inclined, centric loading (where the resultant load passes through the center of the footing).
COMMON REVIEW ISSUES

- Bedrock Bearing for Spread Footings and Drilled Shafts
  - Per LRFD 10.6.3.2, typically use the RMR Method (Carter and Kulhawy, 1988):
    - Do not assume water under moderate or severe pressure. This method was developed for tunneling (deep in rock), not surface bearing. Only assume moist or dry joint water conditions.
COMMON REVIEW ISSUES

- Bedrock Bearing for Spread Footings and Drilled Shafts
  - RMR Method (Carter and Kulhawy, 1988):
    - Do not assume a slickenside or soft gouge joint condition, unless this is definitively revealed in the rock exploration. We would generally not put a foundation on this if we could help it.
**COMMON REVIEW ISSUES**

- **Bedrock Bearing for Spread Footings and Drilled Shafts**
  - **RMR Method (Carter and Kulhawy, 1988):**
    - Base joint spacing on discontinuities in the rock. Bedding may or may not coincide with a discontinuity. Ignore mechanical breaks. SGE Table 600-14 gives good guidance on Degree of Fracturing versus joint spacing.
COMMON REVIEW ISSUES

- Bedrock Bearing for Spread Footings and Drilled Shafts
  - RMR Method (Carter and Kulhawy, 1988):
    - In general, this method is very conservative for near-surface bedrock bearing in Ohio, as it is designed for tunnel roof support in deep rock.
    - It is okay to make less conservative assumptions.
COMMON REVIEW ISSUES

- Bedrock Bearing for Spread Footings and Drilled Shafts
  - If the RMR Method does not work for a spread footing, consider the following:
    - If the rock does not have adverse jointing that will result in a structural failure (this is typically the case in Ohio), then:
      - Analyze the rock as a soil, with Terzaghi/Vesic bearing capacity equations as a lower-bound solution.
COMMON REVIEW ISSUES

- Bedrock Bearing for Spread Footings and Drilled Shafts
  - For Terzaghi/Vesic bearing capacity equations, use Bieniawski (1989) to assume effective $c'$ and $\phi'$ values:
    - $\phi' = \frac{RMR}{2} + 5$ (degrees)
    - $c' = 0.104 \times RMR$ (ksf)
  - Set a limit of $q_n \leq q_u$ (the uniaxial compressive strength of the rock).
COMMON REVIEW ISSUES

- Bedrock Bearing for Spread Footings and Drilled Shafts
  - The RMR Method (and recent GSI Method) are extremely conservative for drilled shaft rock socket end-bearing resistance.
  - LRFD Equation 10.8.3.5.4c-2 applies only for socket length <1.5B, or for adverse jointing, open solution cavities (voids), or clay-filled seams within 2B below the bottom of the rock socket.
COMMON REVIEW ISSUES

- Bedrock Bearing for Spread Footings and Drilled Shafts
  - Adverse jointing that will result in a structural failure is quite rare in Ohio.
  - And we would never found a drilled shaft on a known void or clay-filled seam.
  - So typically, use LRFD Equation 10.8.3.5. 4c-1 for rock socket end-bearing:
    - $q_p = 2.5q_u$
COMMON REVIEW ISSUES

- Cohesive Sliding Resistance

For footings that rest on clay, where footings are supported on at least 6.0 in. of compacted granular material, the sliding resistance may be taken as the lesser of:

- the cohesion of the clay, or
- one-half the normal stress on the interface between the footing and soil, as shown in Figure 10.6.3.4-1 for retaining walls.

The following notation shall be taken to apply to Figure 10.6.3.4-1:

\[ q_s = \text{unit shear resistance, equal to } S_u \text{ or } 0.5 \, \sigma'_{v_s}, \text{ whichever is less} \]
\[ R_\tau = \text{nominal sliding resistance between soil and foundation (kips) expressed as the shaded area under the } q_s \text{ diagram} \]
\[ S_u = \text{undrained shear strength (ksf)} \]
\[ \sigma'_{v_s} = \text{vertical effective stress (ksf)} \]

Figure 10.6.3.4-1—Procedure for Estimating Nominal Sliding Resistance for Walls on Clay
Cohesive Sliding Resistance

11.6.3.2—Bearing Resistance

- Where the wall is supported by a rock foundation:

  the vertical stress shall be calculated assuming a linearly distributed pressure over an effective base area as shown in Figure 11.6.3.2-2. If the resultant is within the middle one-third of the base:

  \[
  \sigma_{v_{\text{max}}} = \frac{\sum V}{B} \left( 1 + 6 \frac{e}{B} \right) \quad (11.6.3.2-2)
  \]

  \[
  \sigma_{v_{\text{min}}} = \frac{\sum V}{B} \left( 1 - 6 \frac{e}{B} \right) \quad (11.6.3.2-3)
  \]

  where the variables are as defined in Figure 11.6.3.2-2. If the resultant is outside the middle one-third of the base:

  \[
  \sigma_{v_{\text{max}}} = \frac{2 \sum V}{3 \left( B/2 - e \right)} \quad (11.6.3.2-4)
  \]

  \[
  \sigma_{v_{\text{min}}} = 0 \quad (11.6.3.2-5)
  \]
**COMMON REVIEW ISSUES**

○ **Cohesive Sliding Resistance**

11.6.3.2—Bearing Resistance

- Where the wall is supported by a rock foundation:

  The vertical stress shall be calculated assuming a linearly distributed pressure over an effective base area as shown in Figure 11.6.3.2-2. If the resultant is within the middle one-third of the base:

  \[
  \sigma_{v_{\text{max}}} = \frac{\sum V}{B}\left(1 + 6 \frac{e}{B}\right) 
  \]
  (11.6.3.2-2)

  \[
  \sigma_{v_{\text{min}}} = \frac{\sum V}{B}\left(1 - 6 \frac{e}{B}\right) 
  \]
  (11.6.3.2-3)

  Where the variables are as defined in Figure 11.6.3.2-2. If the resultant is outside the middle one-third of the base:

  \[
  \sigma_{v_{\text{max}}} = \frac{2 \sum V}{3[(B/2) - e]} 
  \]
  (11.6.3.2-4)

  \[
  \sigma_{v_{\text{min}}} = 0 
  \]
  (11.6.3.2-5)
COMMON REVIEW ISSUES

Drivability Hammer Selection

- Use a Delmag D19-42 hammer as the default for WEAP driveability analyses.
- This is the heaviest hammer commonly available in Ohio: ≈ 43,000 ft-lb.
- Heavier hammers would usually need to be mobilized in long-distance, and are unlikely unless necessary.
- You can also investigate a minimum hammer energy.
COMMON REVIEW ISSUES

- Rock Core Unit versus Lithology
  - Interbedded rock is reported with RQD for the unit/run, and descriptors for each lithology (rock type) within the unit.
  - Often one rock type is much stronger or more competent than the other.
  - Use a weighted average of the characteristics of the interbedded lithologies, based on the percent occurrence of each lithology in the unit, for rock bearing.
## SPREAD FOOTING SCOUR

- **BDM vs L&D Manual regarding Spread Footing Foundations**

<table>
<thead>
<tr>
<th>Bridges (BDM)</th>
<th>Spread Footings on Soil</th>
<th>Spread Footings on Erodible Rock</th>
<th>Spread Footings on Non-Erodible Rock</th>
<th>Driven Pile Foundations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>7' below Thalweg Elevation</td>
<td>On Rock, Dowels for Lateral</td>
<td>202.2.3.2.h</td>
</tr>
<tr>
<td>Three-Sided Culverts (L&amp;D Vol.2)</td>
<td>See OGE HEC-18, HEC-23</td>
<td>HEC-18, HEC-23</td>
<td>HEC-18</td>
<td>BDM, HEC-23</td>
</tr>
</tbody>
</table>

- **Multiple-span three-sided culverts are considered as bridges**
SPREAD FOOTING SCOUR

o BDM Spread Footings on Rock
  o New BDM Section 305.2.1.2.b (footings within the 100-yr flood plain) describes scour resistant (non-erodible) rock:
    o $Q_u \geq 2,500$ psi (“slightly strong” rock)
    o Slake Durability Index, SDI $\geq 90\%$
    o Rock Quality Designation, RQD $\geq 65\%$
    o Total Unit weight $\geq 150$ pcf
  o Rock Mass Strength Properties:
    o Rock Mass Rating, RMR $\geq 75$ (or...)
SPREAD FOOTING SCOUR

- BDM Spread Footings on Rock
  - Scour resistant (non-erodible) rock:
    - Rock Mass Strength Properties:
      - GSI ≥ 75 with Good or better Joint Surface and Massive or Blocky Structure
    - Erodibility Index, K ≥ 100
    - For interbedded rock formations, consider only the weaker material.
    - No Ordovician bedrock formation may be considered as scour resistant rock.
SPREAD FOOTING SCOUR

- BDM Spread Footings on Rock
SPREAD FOOTING SCOUR

- BDM Spread Footings on Rock

  - HEC-18, FHWA-HIF-12-003 Erodibility Index (K) for strong and durable rocks (Quarrying and Plucking):
  
  - Critical Stream Power, Eq. 7.38
    - \( P_c = K^{0.75} \) (kW/m\(^2\))

  - Approach Flow Stream Power, Eq. 7.39
    - \( P_a = 7.853\rho(\tau/\rho)^{1.5} \) (W/m\(^2\)), where
      - \( \rho = 1000 \) kg/m\(^3\)
      - \( \tau = \) Stream Bed Shear (Pa)
SPREAD FOOTING SCOUR

○ BDM Spread Footings on Rock
  ○ HEC-18, Erosion and Shear Stress
    ○ Stream Bed Shear, Eq. 4.5
      ○ \( \tau = (n \frac{V}{K_u})^2 \left( \frac{\gamma_w}{y^{1/3}} \right) \) (psf or Pa), where
        ○ \( n \) = Manning n, (0.040 for rough rock)
        ○ \( V \) = flow velocity (fps or m/s)
        ○ \( K_u \) = 1.486 US units, 1 for SI units
        ○ \( \gamma_w \) = 62.4 pcf or 9,800 N/m³
        ○ \( y \) = depth of flow (ft or m)
**SPREAD FOOTING SCOUR**

- **BDM Spread Footings on Rock**
  - **HEC-18, Erodibility Index (K), Eq. 4.17**
    - \( K = M_s K_b K_d J_s \), where
      - \( M_s = \) Intact rock mass strength parameter
        - \( M_s = Q_u \) for \( Q_u \geq 10 \) MPa, or
        - \( M_s = (0.78)Q_u^{1.05} \) for \( Q_u < 10 \) MPa
      - \( K_b = \) Block size parameter = \( RQD/J_n \)
      - \( K_d = \) Shear strength parameter = \( J_r/J_a \)
      - \( J_s = \) Relative orientation parameter
BDM Spread Footings on Rock

Erodibility Index (K) Example

- Poor Rock with $Q_u = 250$ psi $= 1.72$ MPa
- RQD = 10%, $J_n = 5$
- $J_r = 1$, $J_a = 5$, $J_s = 0.4$
- $M_s = (0.78)Q_u^{1.05} = 0.78(1.72)^{1.05} = 1.38$
- $K_b = \frac{RQD}{J_n} = \frac{10}{5} = 2$
- $K_d = \frac{J_r}{J_a} = \frac{1}{5} = 0.2$
- $K = M_s \times K_b \times K_d \times J_s = 0.221$
SPREAD FOOTING SCOUR

- **BDM Spread Footings on Rock**
  - **Erodibility Index (K) Example**
    - Appalachian Creek with velocity of flow $V = 15$ fps, and depth $y = 5$ ft
    - $\tau = (n \frac{V}{K_u})^2 \left(\frac{\gamma_w}{y^{1/3}}\right)$
      - $= (0.04 \times 15 / 1.486)^2 (62.4/5^{1/3})$
      - $= 5.95$ psf $= 285$ Pa

- **Approach Flow Stream Power, Eq. 7.39**
  - $P_a = 7.853 \rho (\tau/\rho)^{1.5}$
    - $= 7853 (285/1000)^{1.5} = 1195$ W/m$^2$
    - $= 1.195$ kW/m$^2$
**SPREAD FOOTING SCOUR**

- **BDM Spread Footings on Rock**
  - Erodibility Index (K) Example
    - Critical Stream Power, Eq. 7.38
      - \[ P_c = K^{0.75} = 0.221^{0.75} = 0.322 \text{ kW/m}^2 \]
      - \[ P_a = 1.195 \text{ kW/m}^2 > P_c = 0.322 \text{ kW/m}^2 \]
      - Therefore, scour (plucking) occurs
    - Rearranging Eq. 7.38 for minimum K:
      - \[ K_{\text{min}} = P_a^{4/3} = 1.195^{4/3} = 1.268 \]
      - \[ K = 0.221 < K_{\text{min}} = 1.268 \]
      - Therefore, scour (plucking) occurs
BDM Spread Footings on Rock

- Erodibility Index (K) Example
  - Rearranging Eq. 7.39 for critical scour:
    - \( \tau_c = \left( \frac{P_c}{7.853 \rho} \right)^{2/3} \rho \)
    - \( \tau_c = \left( \frac{322}{7853} \right)^{2/3} \times 1000 = 119 \text{ Pa} \)
    - \( \tau = 285 \text{ Pa} > \tau_c = 119 \text{ Pa} \)
    - Therefore, scour (plucking) occurs

- As scour occurs, depth \( y \) increases and flow velocity \( V \) decreases, so shear \( \tau \) decreases, and eventually scour stops
SPREAD FOOTING SCOUR

- BDM Spread Footings on Rock
  - However, this is for open-channel flow
  - For additional bridge pier “horseshoe vortex” turbulence, use Equation 7.40:
    \[ \frac{P}{P_a} = 8.42e^{-0.712\left(\frac{y_s}{b}\right)} \], where
    - \( y_s \) = scour depth, \( b \) = bridge pier width
  - This equation magnifies stream power at the bridge pier \( P \) with respect to the approach flow \( P_a \) by up to 8.42 times.
  - \( P \) lessens as scour depth \( y_s \) increases
BDM Spread Footings on Rock

Continued Example at bridge pier:

Bridge Pier Column, b = 3.0 feet

As before,

Approach flow \( P_a = 1.195 \text{ kW/m}^2 \), and

Critical power \( P_c = 0.322 \text{ kW/m}^2 \)

\[
\frac{P}{P_a} = 8.42e^{-0.712\left(\frac{y_s}{b}\right)}, \text{ Eq. 7.40}
\]
SPREAD FOOTING SCOUR

○ BDM Spread Footings on Rock

○ Continued Example at bridge pier:

<table>
<thead>
<tr>
<th>$y_s$ (ft)</th>
<th>$b$ (ft)</th>
<th>$y_s/b$</th>
<th>Eq. 7.40 $P/P_a$</th>
<th>$P$ (kW/m²)</th>
<th>$P/P_c$</th>
<th>$P&gt;P_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>3</td>
<td>0.000</td>
<td>4.820</td>
<td>5.754</td>
<td>17.853</td>
<td>Yes</td>
</tr>
<tr>
<td>1.00</td>
<td>3</td>
<td>0.333</td>
<td>3.802</td>
<td>4.539</td>
<td>14.081</td>
<td>Yes</td>
</tr>
<tr>
<td>2.00</td>
<td>3</td>
<td>0.667</td>
<td>2.998</td>
<td>3.580</td>
<td>11.106</td>
<td>Yes</td>
</tr>
<tr>
<td>3.00</td>
<td>3</td>
<td>1.000</td>
<td>2.365</td>
<td>2.824</td>
<td>8.760</td>
<td>Yes</td>
</tr>
<tr>
<td>4.00</td>
<td>3</td>
<td>1.333</td>
<td>1.865</td>
<td>2.227</td>
<td>6.909</td>
<td>Yes</td>
</tr>
<tr>
<td>5.00</td>
<td>3</td>
<td>1.667</td>
<td>1.471</td>
<td>1.756</td>
<td>5.449</td>
<td>Yes</td>
</tr>
<tr>
<td>6.00</td>
<td>3</td>
<td>2.000</td>
<td>1.160</td>
<td>1.385</td>
<td>4.298</td>
<td>Yes</td>
</tr>
<tr>
<td>7.00</td>
<td>3</td>
<td>2.333</td>
<td>0.915</td>
<td>1.093</td>
<td>3.390</td>
<td>Yes</td>
</tr>
<tr>
<td>8.00</td>
<td>3</td>
<td>2.667</td>
<td>0.722</td>
<td>0.862</td>
<td>2.674</td>
<td>Yes</td>
</tr>
<tr>
<td>9.00</td>
<td>3</td>
<td>3.000</td>
<td>0.569</td>
<td>0.680</td>
<td>2.109</td>
<td>Yes</td>
</tr>
<tr>
<td>10.00</td>
<td>3</td>
<td>3.333</td>
<td>0.449</td>
<td>0.536</td>
<td>1.663</td>
<td>Yes</td>
</tr>
<tr>
<td>11.00</td>
<td>3</td>
<td>3.667</td>
<td>0.354</td>
<td>0.423</td>
<td>1.312</td>
<td>Yes</td>
</tr>
<tr>
<td>12.00</td>
<td>3</td>
<td>4.000</td>
<td>0.279</td>
<td>0.334</td>
<td>1.035</td>
<td>Yes</td>
</tr>
<tr>
<td>12.15</td>
<td>3</td>
<td>4.050</td>
<td>0.270</td>
<td>0.322</td>
<td>0.999</td>
<td>No</td>
</tr>
</tbody>
</table>
SPREAD FOOTING SCOUR: BRO-221-0554

1998
SPREAD FOOTING SCOUR: BRO-221-0554

2000
SPREAD FOOTING SCOUR: BRO-221-0554
SPREAD FOOTING SCOUR: BRO-221-0554

2007
SPREAD FOOTING SCOUR: BRO-221-0554

2009
SPREAD FOOTING SCOUR: BRO-221-0554

2013
SPREAD FOOTING SCOUR: BRO-221-0554

2019
SPREAD FOOTING SCOUR: BRO-221-0554

2019
SPREAD FOOTING SCOUR: BRO-221-0554
BRIDGE DESIGN MANUAL REVISIONS

- Section 305, Foundation Design
- Section 306, Retaining Walls
- Sections 600 and 700: Foundation and Wall Plan Notes
- Associated Special Provisions
305 Foundation Design

- 305.1 General Discussion
- 305.2 Spread Footings
- 305.3 Driven Piles
- 305.4 Drilled Shafts
- 305.5 Micropiles
- 305.6 Continuous Flight Auger (CFA) Piles
- 305.7 Field Verification of Nominal Resistance
306 Retaining Walls

- 306.1 General Discussion
- 306.2 Rigid Gravity and Semigravity Walls
- 306.3 Prefabricated Modular Walls
- 306.4 MSE Walls
- 306.5 Reinforced Soil Slopes
- 306.6 Drilled Shaft Walls
- 306.7 Steel Sheet Pile Walls
- 306.8 Anchored Walls
306 Retaining Walls

- 306.9 Soil Nail Walls
- 306.10 Temporary Walls
305.1 General Discussion
  305.1.1 Overall Stability
  305.1.2 Lateral Loading on Deep Foundations
  305.1.3 Vertical and Horizontal Movements
  305.1.4 Ground Improvements
  305.1.5 Seismic Design
  305.1.6 Scour
305.2 Spread Footings

- 305.2.1 General Discussion
  - 305.2.1.1 Settlement
  - 305.2.1.2 Minimum Depth and Scour Considerations
  - 305.2.1.3 Resistance to Horizontal Forces
  - 305.2.1.4 Reinforcing Steel
  - 305.2.1.5 Design Considerations
BRIDGE DESIGN MANUAL REVISIONS

- 305.2 Spread Footings
  - 305.2.2 Spread Footings on Cohesionless Soils
  - 305.2.3 Spread Footings on Cohesive Soils
  - 305.2.4 Spread Footings on Bedrock
305.3 Driven Piles

- 305.3.1 General Discussion
  - 305.3.1.1 Pile Types
  - 305.3.1.2 Pile Driving Hammers

- 305.3.2 Load Effects
  - 305.3.2.1 Scour
  - 305.3.2.2 Downdrag and Drag Load
  - 305.3.2.3 Uplift
  - 305.3.2.4 Setup
Research Update:

Pile Driving Setup for Ohio Soils

This is a study to quantify and predict pile setup for soils based on soil type and/or region within Ohio.
305.3 Driven Piles

- 305.3.3 Point Bearing Piles on Bedrock
- 305.3.4 Friction Piles
- 305.3.5 Design Considerations
  - 305.3.5.1 Minimum Pile Spacing, Clearance, and Embedment into Cap
  - 305.3.5.2 Estimated Pile Length
  - 305.3.5.3 Corrosion and Protection
  - 305.3.5.4 Vertical and Horizontal Movements
305.3 Driven Piles

- 305.3.5.5 Buckling and Lateral Stability
- 305.3.5.6 Pile Setup and Relaxation
- 305.3.5.7 Steel Pile Points or Shoes
- 305.3.5.8 Minimum Pile Penetration Requirements
- 305.3.5.9 Battered Piles

- 305.3.6 Vibration Monitoring

- 305.3.7 Embankment Construction Constraints
305.4 Drilled Shafts

- 305.4.1 General Discussion
- 305.4.2 Load Effects
  - 305.4.2.1 Scour
  - 305.4.2.2 Downdrag and Drag Load
  - 305.4.2.3 Uplift
- 305.4.3 Rock-Socketed Drilled Shafts
- 305.4.4 Friction Drilled Shafts
305.4 Drilled Shafts

305.4.5 Design Considerations

305.4.5.1 Drilled Shaft Spacing, Clearance, and Embedment into Cap

305.4.5.2 Drilled Shaft Size

305.4.5.3 Reinforcing Steel

305.4.5.4 Drilled Shaft Design Depth

305.4.5.5 Vertical and Horizontal Movements

305.4.5.6 Demonstration Drilled Shafts
305.4 Drilled Shafts
- 305.4.6 Integrity Testing of Drilled Shafts
- 305.4.7 Embankment Construction Constraints
305.5 Micropiles
   - 305.5.1 General Discussion

305.6 Continuous Flight Auger (CFA) Piles
   - 305.6.1 General Discussion
305.7 Field Verification of Nominal Resistance

- 305.7.1 Dynamic Testing
- 305.7.2 Static Load Test
- 305.7.3 Special Load Tests
306.1 General Discussion

- 306.1.1 Loading
- 306.1.2 Overall Stability
- 306.1.3 Resistance to Horizontal Forces
- 306.1.4 Limiting Eccentricity and Overturning Resistance
- 306.1.5 Bearing Resistance
- 306.1.6 Vertical and Horizontal Movements
- 306.1.7 Seismic Design
306.2 Rigid Gravity and Semigravity Walls

- 306.2.1 Rigid Gravity Walls
- 306.2.2 Cantilever Walls
- 306.2.3 Counterfort Walls
- 306.2.4 Precast Gravity and Semigravity Walls
306.3 Prefabricated Modular Walls

306.3.1 Modular Block Walls
306.3.2 Bin Walls
306.3.3 Crib Walls
306.3.4 Gabion Walls

See Supplemental Specification 870
306.4 MSE Walls
  306.4.1 Precast Concrete Panel Walls
  306.4.2 GRS-IBS Abutments

306.5 Reinforced Soil Slopes
306.6 Drilled Shaft Walls

306.6.1 Tangent Drilled Shaft Walls
306.6.2 Secant Drilled Shaft Walls
306.6.3 Soldier Pile Walls
306.6.4 Landslide Drilled Shafts
BRIDGE DESIGN MANUAL REVISIONS

- 306.7 Steel Sheet Pile Walls
  - 306.7.1 Cantilever Sheet Pile Walls
  - 306.7.2 Cellular Sheet Pile Walls

- 306.8 Anchored Walls

- 306.9 Soil Nail Walls
306.10 Temporary Walls
- 306.10.1 Wire Faced MSE Walls
- 306.10.2 Fabric Wrapped Walls
- 306.10.3 Temporary Support of Excavations
BRIDGE DESIGN MANUAL REVISIONS

- New Plan Notes:
  - 605.1 and 605.2 Pile Driving Constraints and Footing Construction Constraints: added optional waiting period to all notes
  - 605.6 Shaft Drilling Constraints
  - 605.5-2 Foundation Bearing Resistance (MSE Walls)
  - 606.3 Steel Pile Points or Shoes: for H-piles, CIP reinforced concrete pipe piles, or steel open-ended pipe piles
New Plan Notes:

- 606.6 Foundation Reference Monuments for Retaining Wall Footings
- 606.7 New Section: Pile Driving
  - 606.7-1 Pile Driving Hammer Minimum Rated Energy
  - 606.7-2 Vibration Monitoring
  - 606.7-3 Preconstruction Condition Survey
  - 606.7-4, 606.7-5, and 606.7-6 Pile Setup Notes
New Plan Notes:

- 606.8 Drilled Shafts:
  - 606.8-2 Friction Drilled Shafts
  - 606.8-3 Laterally Loaded Drilled Shafts
  - 606.8-4 Drilled Shafts Installed to Tip Elevation for Uplift
  - 606.8-5 Drilled Shaft Maximum Coarse Aggregate Size
  - 606.8-6 Demonstration Drilled Shaft
New Plan Notes:

- 606.8 Drilled Shafts:
  - 606.8-7 Thermal Integrity Profiler (T.I.P.) Wire Cable Testing of Drilled Shafts
  - 606.8-8 CSL Testing of Drilled Shafts
  - 606.8-9 High-Strain Dynamic Testing of Drilled Shafts
New Plan Notes:

- 606.8 Drilled Shafts:
  - 606.8-7, 606.8-8, and 606.8-9 reference Special Provisions, now available on OGE Website:
305 FOUNDATION DESIGN

305.1 General Discussion

305.1.3 Vertical and Horizontal Movements

Builds on existing guidance in LRFD 10.5.2.2, and sets definitive limits to bridge substructure differential settlement, and gives guidance for when to consider settlement force effects (SE) in the superstructure design. (1” for bridges spans S < 100’, and 0.000833 S for spans of 100’ or more).

305.1.5 Seismic Design

Sets Site Class D as the limit for Ohio, and sets valid ranges for seismic coefficients within the state of Ohio. Also states, “The site-specific procedure, per LRFD 3.10.2.2 is not required for Ohio.”

305.1.6 Scour

Defines the design flood as the 100-year flood event, and the check flood as the 500-year flood event.

305.2 Spread Footings

305.2.1.2 Minimum Depth and Scour Considerations

In addition to guidance stated above in the presentation, within the 500-yr flood plain, perform an Extreme Event II Limit State check with all resistance factors = 1.00. At the 100-yr flood scour condition, evaluate the foundations at the Strength I Limit State. Sets 4 feet as the minimum embedment for footings in soil, and 5 feet as the minimum embedment for footings on embankment fill.

305.2.2 Spread Footings on Cohesionless Soils

Directs consideration of settlement due to incremental loading during the construction sequence.

305.2.3 Spread Footings on Cohesive Soils

Sets a minimum $S_u = 2$ ksf for bridge spread footing foundations.

305.2.4 Spread Footings on Bedrock

The sliding resistance factor shall be taken as $\varphi_r = 0.9$ for pier footings founded on weak or very weak bedrock ($Q_u < 1500$ psi).

305.3 Driven Piles

305.3.2.2 Downdrag and Drag Load

Directs location of the neutral plane per the Goudreault and Fellenius (1994) method and analysis of downdrag and drag load per the Siegel et al. (2013) method, both as described in FHWA-NHI-16-009/010, Geotechnical Engineering Circular 12 (GEC 12) “Design and Construction of Driven Pile Foundations.”

305.3.2.4 Setup

Gives guidance on how to estimate pile setup for consideration in design, including recommended setup factors. Piles incorporating setup in design are driven to a specified EOID resistance and then restruck to verify UBV. Research update: Pile Driving Setup for Ohio Soils.
**BDM Revisions Highlights Notes**

**305.3.3 Point Bearing Piles on Bedrock**

The table specifying the factored structural resistance \( (P_r) \) for common H-pile sizes has been moved to the commentary, in recognition of different pile sizes and strengths being utilized in design, particularly in DB projects.

**305.3.4 Friction Piles**

The tables specifying the maximum UBV for common pile sizes have been moved to the commentary, in recognition of different pile sizes and strengths being utilized in design, particularly in DB projects.

**305.3.5.3 Corrosion and Protection**

Directs reference to Eurocode 3, Part 5, Section 4.4 for the environmental conditions at the site to determine the appropriate corrosion loss rate for carbon steel. For zinc coatings, the minimum coating thickness is 4 mils, and the corrosion loss rate is considered as \( \frac{1}{2} \) the respective loss rate for carbon steel.

**305.3.5.6 Pile Setup and Relaxation**

Gives direction on when to consider setup in the design, and three methods for incorporation of setup through plan notes. Potential relaxation is ignored in design.

**305.3.6 Vibration Monitoring**


**305.4 Drilled Shafts**

**305.4.2.2 Downdrag and Drag Load**


**305.4.5.2 Drilled Shaft Size**

Sets new limits on cover over longitudinal reinforcement as follows:

- 3.0 inches for shafts ≤ 3′-0" diameter
- 4.0 inches for > 3′-0" but < 5′-0" diameter
- 6.0 inches for shafts ≥ 5′-0" diameter

**305.4.5.6 Demonstration Drilled Shafts**

Gives conditions for specifying a demonstration drilled shaft. A plan note is provided.

**305.4.6 Integrity Testing of Drilled Shafts**

Gives conditions for specifying drilled shaft integrity testing. Thermal Integrity Profiling (TIP), is the preferred method. Plan notes are provided for TIP and CSL.
305.6 Continuous Flight Auger (CFA) Piles

305.6.1 General Discussion

CFA piles (auger-cast piles) are allowed for many applications, with the exception of deep foundation elements supporting bridge substructures. Design is referred to FHWA-HIF-07-039, Geotechnical Engineering Circular 8 (GEC 8) “Design and Construction of Continuous Flight Auger Piles.” A new AASHTO LRFD Section is under consideration, and may result in changes to this BDM Section.

305.7 Field Verification of Nominal Resistance

305.7.2 Static Load Test

Provides direction for specification of static load tests for all deep foundation types. Allows for alternate high strain dynamic testing of drilled shafts.

305.7.3 Special Load Tests

Allows specification of a drop weight test, Osterberg load cell test, lateral load test, or Statnamic test with consultation of the Office of Geotechnical Engineering.

306 RETAINING WALLS

306.1 General Discussion

Abutments are retaining walls! So is any structure with greater than 2 feet of differential height of soil from one side to the other.

306.1.6 Vertical and Horizontal Movements

Gives limits on differential settlement for various types of retaining walls.

306.2 Rigid Gravity and Semigravity Walls

Traffic barrier shapes supporting a differential height of earth on either side are considered rigid gravity walls.

306.2.4 Precast Gravity and Semigravity Walls

Allows use of precast footings with a leveling pad or sub-footing.

306.3 Prefabricated Modular Walls

See Supplemental Specification 870.

306.4 MSE Walls

In a permanent condition, do not use corners with interior angles of less than 90 degrees (acute corners). Do not use corners with interior angles of less than 45 degrees for temporary MSE walls utilized for maintenance of traffic. Lesser angles require a different kind of wall.

306.4.1 Precast Concrete Panel Walls

Allows use of a two-stage MSE wall, with permanent precast panels attached to a wire-faced MSE wall. References Supplemental Specification 867 for design of the wire-faced MSE wall.
BDM Revisions Highlights Notes

306.4.2 GRS-IBS Abutments

GRS-IBS shall not be used to support bridges on Interstate, U.S. Federal Route, or State Route highways. GRS-IBS shall not be constructed with dry-cast block wall facing elements.

306.6 Drilled Shaft Walls

306.6.3 Soldier Pile Walls

Provides requirements for reinforcement and concrete cover of concrete lagging panels and permanent cast-in-place facing.

306.7 Steel Sheet Pile Walls

306.7.2 Cellular Sheet Pile Walls

These are designed as modular gravity walls. Allows use of deeper elements for increased sliding resistance. Provides resistance factors for Connection Interlock Tension: $\phi_{\text{interlock}} = 0.75$ and Horizontal Pullout Resistance: $\phi_{\text{pullout}} = 1.00$.

306.10 Temporary Walls

306.10.1 Wire Faced MSE Walls

References Supplemental Specification 867 for design of wire-faced MSE walls.