Section 6

Bridge Foundations

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The foundations of a bridge are particularly critical because they must support the entire weight of the bridge and the traffic loads that it will carry.
View ODOT Video, Part 6/12

Introduction to Bridge Foundations

Common Foundation Types

- Spread Footing
- Piling
- Drilled Shafts
Type Of Excavation

“Dry” Excavation:
Generally stable with no waterway or de-stabilizing groundwater

“Wet” Excavation:
In or near water or significant groundwater

Spread Footings
Spread Footings

Settlement “d” < allowable settlement in project specifications.
Spread Footings

- Check the Foundation Report and Drill Logs to verify that the actual foundation material exposed below the footings matches what was anticipated.
- If there are any questions related to foundation material suitability contact the Geotechnical Engineer.

Concrete volume of a spread footing:

\[ V = L \times W \times H \]
Footing Concrete Volume Example

- Footing Size: 14 ft long x 10 ft wide x 5 ft high
- Volume = (14 ft)(10 ft)(5 ft) / (27 cf/cy)
- $V = 26$ cy

Footing Concrete Volume Exercise

Footing Size: 12 ft long x 9 ft wide x 6 ft high

Volume =
Spread Footings

Open-Pit Excavations

- Walls of excavation are sloped for safety.
- No shoring required.
- Wide enough for workers outside of footing.

Spread Footings

Open-pit excavations are permitted when:

- Not in or near water.
- The soil material is adequately stable to ensure worker safety.
- The soil can be maintained in a dry condition.
- There is no threat of compromising the stability of any nearby structure or the structure being built.
Spread Footings

Shored excavations

Shoring and cribbing: A series of horizontal and vertical members that resist the surrounding soil pressure.

Spread Footings

Shored Excavations must be used when:

- The excavation is greater than 4 feet deep.
- The soil is not stable enough to ensure worker safety.
- The presence of adjacent structures limits the allowable size of the excavation.
Spread Footings

Foundations on rock:
- Level
- Stepped
- Serrated
- Against solid rock
- For arches

Spread Footings

Unsuitable soils for spread footings:
If any evidence of problematic soils is discovered during footing construction, work should be stopped, and the Engineer should be contacted immediately.
Spread Footings

Items to inspect for with spread footings:

- Elevation
- Dimensions
- Reinforcement
- Soil stability

Spread Footings

Items to inspect for spread footings:

- Concrete cover. Dobies settle into base rock and may require larger size to maintain proper clearance.
- 3” clearance if pouring against natural ground
Unstable or Disturbed Materials

- Must be removed and replaced as directed.
- Structure fill must be placed in layers of not more than 6 inches. (00510.46(a))
- Each layer must be compacted to 95% of maximum density, or as specified. (00510.46(a))
- Any foundation must be approved by the Engineer before any concrete placement.

Foundation Location

Check correct position and preserve offset reference points.
Reference Points

Structure Excavation
Structure Excavation

Measuring Excavation / Backfill

- Cross-Section original ground before excavation begins.
- Normal volume bounded by vertical planes 1 foot outside the footing. (00510.80(b)(2)(c))

Structure Excavation

Measuring Excavation

- Volume of excavation is from bottom of footing to natural ground line.
- Volume to nearest 0.1 cy (00190.10 (e))
Structure Excavation

Measuring Backfill
Volume of backfill is from bottom of footing to finished construction line.

Structure Excavation Volume Example

Pier footing size is 20 ft x 10 ft
Average Depth of excavation is 5 ft

What is the volume of excavation that will be paid for?
Volume = L x W x H

Volume = \((22 \text{ ft}) (12 \text{ ft}) (5 \text{ ft}) / 27 \text{ cf/cy}\)
Volume = 48.9 cy
Structure Excavation Exercise

Pier footing size is 18 ft x 15 ft
Average Depth of excavation is 7 ft

What is the volume of excavation that will be paid for?

Volume =

Calculate Volume by Average End Area

- Measure end areas
- Average end areas
- Measure horizontal distance “d” between areas
- Multiply average end area by horizontal distance “d”
Average End Area Example

Left End of Excavation is 10 ft wide x 6 ft high
Right End of Excavation is 10 ft wide X 10 ft high

What is volume of excavation if it is 30 ft long:

Left End Area = (10 ft)(6 ft) = 60 sf
Right End Area = (10 ft)(10 ft) = 100 sf

Volume = ((60 sf + 100 sf) / 2)(30 ft) / 27 cf/cy
Volume = 88.9 cy

Average End Area Exercise

Left End of Excavation is 12 ft wide x 4 ft high
Right End of Excavation is 12 ft wide X 10 ft high

What is volume of excavation if it is 20 ft long:

Left End Area =
Right End Area =

Volume =
Foundation Exercise

From the Foundation Report (page 14), determine the type of bridge foundation to be used for Bridge #21162. From the Drill Log determine the anticipated type of material to be encountered.

Bridge foundation: ________________________
________________________
________________________

Anticipated material: ________________________
Geotechnical and Foundation Report

Dodge Canyon Creek Bridge, Bridge 21162, M.P. 20.95
Dodge Canyon Creek Bridge, Bridge 21163, M.P. 21.15
Calapooya Creek Bridge, Bridge 20861, M.P. 22.10

OR138W: Dodge Cr/Calapooya Cr Bridge Replacements
Elkton – Sutherlin Hwy (Hwy. 231, M.P. 20.74 – 22.22)
Douglas County

Published: August 2010
Bid Date: November 2010
EA PE001472-000
Key 16796 (old Keys 14813 and 15970)
event) of the soil samples appeared to have liquefaction potential. Given the disjointed nature of the alluvial stringers which have been deposited and re-cut by the creek, it is believed the samples indicating liquefaction potential are not continuous enough to suggest a layer of soil is subject to appreciable liquefaction risk.

6.0 FOUNDATION DESIGN RECOMMENDATIONS

In accordance with ODOT’s design practice, the foundation design was performed using AASHTO LRFD Bridge Design Specifications, 2007, 4th edition (with 2008 interims). Foundation design recommendations for the bridge are discussed below under the subsection following headings.

6.1 Dodge Creek Bridge 21162

It is recommended that the end bents (Bent 1 & 2) of the proposed single-span bridge be founded on HP14x89 driven H-pile with tip protection. Piles are considered the best option for the subsurface conditions encountered. The piling will derive their axial capacity, primarily through end bearing on and within the Tenmile Bedrock Formation.

The resistance factor for Bents 1 and 2 is 0.40 as determined from LRFD Table 10.5.5.2.3-1 for nominal resistance of a single pile in compression using static pile analysis with a combination of the Nordlund and Tomlinson methods and pile driving criteria determined by Wave Equation. Due to driving stress limitations induced during the driving process, the piles are recommended to be ASTM A572, Grade 50 (50 ksi yield strength). Due to driving stress limitations induced during the driving process, the recommended factored resistances are based on ASTM A36 (36 ksi yield strength) and are therefore less than the actual structural capacity of the pile. Table 1 provides detailed information for the piling recommended for Bents 1 and 2.
<table>
<thead>
<tr>
<th>Bent</th>
<th>Pile Type, Size, Material Specification &amp; Tip Treatment</th>
<th>Ultimate (Nominal) Capacity (kips)</th>
<th>Resistance Factor</th>
<th>Factored Resistance (kips)</th>
<th>Pile Driving Criteria</th>
<th>Estimated Average Cutoff Elevation (ft)</th>
<th>Estimated Length (ft)</th>
<th>Minimum Required Tip Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HP14x89, ASTM A572 Grade 50, Reinforced Tip</td>
<td>940</td>
<td>0.40</td>
<td>375</td>
<td>Wave Equation</td>
<td>434</td>
<td>30</td>
<td>415</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>434</td>
<td>35</td>
<td>412</td>
</tr>
</tbody>
</table>

**Table 1 – Dodge Creek Bridge 21162, Axial Pile Capacity Information**

The pile sizes provided in Table 1 are based on axial loading of the pile. If controlling loads other than the axial loads contemplated, are anticipated, then the pile should be evaluated for those loads and sized accordingly. The cutoff elevation was estimated by assuming 2 ft. embedment into the pile cap. If the cutoff elevation listed in Table 1 is revised by 2 ft. or more, the Geotechnical Engineer should be given the opportunity to revise the estimated pile lengths to be included in the Special Provisions for the project. The estimated pile length is based on the difference between the estimated cutoff elevation and the estimation that the pile will have a penetration of approximately 7 ft. into the moderately to slightly weathered Tenmile Bedrock Formation. The minimum required tip elevation for this bridge is based on the rock contact of the adjacent test holes.

For pile foundations designed in accordance with the above recommendations, settlement is estimated to be less than approximately 1 inch and to be elastic in nature, occurring as the load is applied.

**6.1.1 Lateral Pile Load Capacity**

The pile foundations will be subject to lateral loads resulting from live loads, wind and earthquake loading. The laterally loaded pile analysis may be performed with the aid of the “L-Pile” computer program, geotechnical input parameters for the L-Pile program are provided in Table 2. Ground water should be assumed at an elevation of 420 ft.
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Soil Type</th>
<th>Rock Type</th>
<th>Test Type</th>
<th>Drilling Method</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td>N1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>N2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td>N3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td>N4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Material Description**

- **SOIL**: Sandy CLAY with some silt trace gravel, CL; orange-brown to brown, low plasticity, damp, medium stiff, has subrounded to angular gravel. (Fill)
- **ROCK**: Sandy CLAY with some silt trace gravel, CL; orange-brown to brown, low plasticity, damp, medium stiff, has subrounded to angular gravel. (Fill)

**Unit Description**

- **Dodge Unit-1**: Sandy CLAY with some silt trace gravel, CL; orange-brown to brown, low plasticity, damp, medium stiff, has subrounded to angular gravel. (Fill)
- **Dodge Unit-2**: Sandy CLAY with some silt trace gravel to Clayey SAND with some silt, SC; orange-brown to brown, low plasticity, damp to moist, medium stiff and very loose, has subrounded gravel; (Alluvium)
- **Dodge Unit-3**: Silty Sandy GRAVEL, GM; brown, nonplastic, wet, medium dense, fine rounded gravel; (Alluvium)
- **Dodge Unit-4**: MUDSTONE, gray, fresh, soft, very close to moderately close jointing, laminated to
<table>
<thead>
<tr>
<th>Depth (ft)</th>
<th>Test Type, No.</th>
<th>Soil</th>
<th>Rock</th>
<th>Material Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>N5</td>
<td>50'2&quot;</td>
<td>RQD = 0</td>
<td>N-5 (25.0-25.2) MUDSTONE, gray, moderately to slightly weathered, very soft to soft. (Tenmile Formation)</td>
</tr>
<tr>
<td></td>
<td>C1</td>
<td>92</td>
<td>RQD = 88</td>
<td>C-1 (25.2-25.4) MUDSTONE, gray, fresh, soft, close to moderately close jointing. (Tenmile Formation)</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td>100</td>
<td>RQD = 78</td>
<td>C-2 (25.4-31.4) MUDSTONE, gray, fresh, soft, close to moderately close jointing. (Tenmile Formation)</td>
</tr>
<tr>
<td>30</td>
<td>C3</td>
<td>100</td>
<td>RQD = 26</td>
<td>C-3 (31.4-36.4) From (31.4'-33.0') MUDSTONE, gray, fresh, soft, close to moderately close jointing. (Tenmile Formation)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>From (33.0'-36.4') MUDSTONE, gray, fresh, soft, very close to close jointing, laminated to thin bedded dipping 20 deg, fissile along some laminations. Has clay seam 33.2'-33.4'. (Tenmile Formation)</td>
</tr>
<tr>
<td>35</td>
<td>C4</td>
<td>100</td>
<td>RQD = 28</td>
<td>C-4 (36.4-41.4) MUDSTONE, gray, fresh, soft, very close to close jointing, laminated to thin bedded dipping 20 deg, fissile along some laminations. Has clay seam 37.0'-37.2'. (Tenmile Formation)</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td>(41.4) Bottom of hole.</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td>Bottom of hole 41.4'</td>
</tr>
</tbody>
</table>

**Unit Description**

thin bedded dipping 20 deg, fissile along bedding; (Tenmile Formation)

Drilling method changed to HQ3-WL (25'-41.4')

WC gray

Backfilled with bentonite chips (41.4'-0')
Cofferdams

View ODOT, Part 8/12
Cofferdams

A water-tight enclosure that allows the construction of a bridge foundation in the dry.

Cofferdams

Used in or near water.
Cofferdams

A seal is used when sheet piling cannot be driven to sufficient depth to cut off water flow.
Construction Steps with Seal

- Drive sheet piles
- Cut vent holes
- Install bracing
- Excavate
- Drive foundation piles
- Placing concrete seal

Construction Steps with Seal (continued)

- De-water
- Construct footing and column in the dry
- Flood cofferdam
- Remove cofferdam
- Place riprap
Sheet Piles

- Check sheet piling size and grade.
- Deep-arch interlocking sheet piles are used.

Sheet Piling Is Often Driven Using a Temporary Guide Structure

All sheet piles must be plumb.
Vibratory Hammer

Sheet Piles

Drive sheet piling at a cofferdam corner first and then work your way around.
Sheet Piles

- Each sheet piling section is driven about 3 feet at a time.
- Sheet Piling sections are driven progressively around the cofferdam until the required depth is reached.

Vent Holes

- Cut vent holes at high water elevation
- Allows water to enter the cofferdam to prevent cofferdam failure
Bracing

Cofferdams require adequate bracing.
Underwater Exploration

- The inspector should take and record soundings to determine underwater elevations.
- Underwater inspection may be required by divers to determine proper excavation to the edges of the cofferdam, so that seals will hold.

Driving Foundation Pile

**Template is often used**

- As a guide for pile location.
- To establish elevation references.
Driving Foundation Pile

The inspector must:

- Monitor penetration and bearing.
- Take soundings after pile driving to check for soil displacement.

Placing Concrete Seal

- Keep water levels the same on both sides of the cofferdam to prevent flow through the seal.
- Place concrete under water by means of a tremie pipe.
- Use a suitable plug in the tremie pipe during the initial discharge of concrete to keep water out.
Placing Concrete Seal
00540.48(e)

- The concrete shall be placed continuously until seal is completed. Minimum of 50 cy/hr.
- Do not vibrate.
- Tops of seals should be kept nearly horizontal at all times.
- Take soundings of the surface of the seal.

Placing Concrete Seal
02001.20(c)

- Slump of 6”-10”
- Entrained Air not required
- 3,300 psi (Table 2001-1)
De-water Cofferdam
00540.48(e)

- After seal concrete reaches 2,200 psi
- Sump pump usually required to keep work area dry

Completing Construction

- Footing and pier constructed in the dry as in other situations.
- Cofferdam flooded.
- Natural streams bed lines and grades restored to avoid scour.
- Riprap placed as required.