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Chapter

16

16. Foundation Design for Signs Signals, Luminaires, Sound Walls and Buildings

16.1. General

This chapter covers the geotechnical design of traffic structures, soundwalls, and small buildings. Traffic structures include sign bridges, cantilevered signs, signal supports, strain poles, illumination and camera poles. Sound walls (also referred to as Sound Barriers, Noise Walls, and Noise Barriers) are walls that are used to mitigate traffic noise effects. Small buildings typically include single story structures such as those required for ODOT maintenance facilities, park and ride lots or rest areas.

AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals and *AASHTO Guide Specifications for Structural Design of Sound Barriers* both currently refer to *AASHTO Standard Specifications for Highway Bridges* (which uses Allowable Stress Design, and in some cases Load Factor Design). The design approach used for the foundation design must be consistent with the design approach used for the structure.

Standard drawings have been developed for most of the traffic structures and soundwalls and many (but not all) of these drawings include standard foundation designs as well. Either shallow spread footings or short drilled shafts are the typical foundation types used to support these structures. Each foundation design shown on a standard drawing is based on a certain set of foundation material properties, groundwater conditions and other factors which must be met in order to use the foundation design shown on the standard drawing. These foundation material properties, groundwater and other conditions are described on the standard drawings.

For standard foundation designs with assumed geotechnical conditions, the geotechnical designer will determine whether actual site conditions are consistent with the assumed conditions. Based upon the recommendations of the geotechnical designer, the structural designer will either specify the use of a standard foundation or will design a special (non-standard) foundation.

16.2. Site Reconnaissance

General procedures for site reconnaissance are presented in **Chapter 2**. Prior to the site reconnaissance, the location of the structures should be staked in the field, or an accurate and up-to-date set of site plans identifying the location of these structures should be available. An office review of all existing data pertinent to the site and the proposed foundations should also be conducted prior to the site reconnaissance. The geotechnical designer should have access to detailed plan views showing existing site features, utilities, proposed construction and right-of-way limits.

With this information, the geotechnical designer can review structure locations, making sure that survey information agrees reasonably well with observed topography.

During the site reconnaissance consider the following:

- Existing slopes (natural and cut) in the immediate vicinity of the structures should be inspected and their performance evaluated.
- Observation of existing slopes should include types of vegetation that may indicate wet or unstable soil. Equisetum (horsetail), cattails, blackberry and alder may be indicative of wet or possibly unstable soils.
- It is especially important to establish the presence of high ground water and any areas of soft soil, unstable ground or exposed bedrock.
- Potential geotechnical hazards such as landslides that could affect the structures should be identified.
- The identification and extent/condition (i.e., thickness) of existing man-made fills should be noted.
- Surface and subsurface conditions that could affect constructability of the foundations, such as the presence of utilities, shallow bedrock, or cobbles and boulders, should be identified.

Many of these structures have very shallow foundations and the investigation may only consist of general site reconnaissance with minimal subsurface investigation.

16.3. Field Investigation

All new soundwalls, traffic structures or buildings require some level of subsurface investigation. Considerable judgment is needed to determine which structures will need site-specific field investigations such as borings or test pits. If the available geotechnical data and information gathered from the site reconnaissance and/or office review is not adequate to make an accurate determination of subsurface conditions, then site specific subsurface data should be obtained through a more extensive subsurface investigation. Refer to **Chapter 3** for details regarding the investigation requirements for these types of structures.

16.4. Foundation Design

Standard foundation designs for these structures typically consist of spread footings (continuous or individual) or short drilled shafts. These standard drawings are typically used at sites where the soil conditions are relatively uniform with depth. Lateral loads such as wind and seismic usually govern the foundation designs for these structures. The foundation designs provided on the Standard Drawings have been developed over many years, using a variety of foundation design methods.

Therefore, the foundation design method used for each of the standard drawings is discussed separately in the following sections. The standard drawings can be obtained from the following ODOT web site:

http://egov.oregon.gov/ODOT/HWY/ENGSERVICES/standard_drawings_home.shtml

16.5. Traffic Structures

16.5.1. Traffic Structures Standard Drawings

Refer to the ODOT Roadway Engineering Services web site for a list of all the standard drawings for traffic structures. The traffic standard drawings that have standard foundation designs are summarized as follows:

- VMS Bridges;
  - TM611: Standard Truss Type VMS Bridge 50' to 167' Span Range; Foundation Type: Spread Footing.
- Sign Bridges;
  - TM619: Standard Truss Type Sign Bridge 50' to 167' Span Range; Foundation Type: Spread Footing.
- Cantilever Signs;
  - TM626: Standard Monotube Cantilever Sign Support, Foundation Type: Spread Footing.
- Luminaire Supports;
  - TM 630: Slip Base and Fixed Base Luminaire Supports; Foundation Type: Square or Round Footing/Shafts

Standard foundation designs for traffic signal supports (cantilever signal poles and strain pole foundations) are no longer on standard drawings. These are typically short drilled shafts and the shaft foundation diameters and depths are determined based on site specific designs.

High Mast Luminaire Supports are rarely used and therefore standards are now available only as a roadway detail drawing. These structures are typically supported on drilled shafts.

16.5.2. Foundation Design of Traffic Structures

Traffic structures are designed using the procedures described in the ***ODOT Traffic Structures Design Manual***. In addition to the *ODOT Traffic Structures Design Manual*, the design of mast arm signal poles, strain poles, monotube cantilever sign supports, sign and VMS truss bridges, luminaire poles, high mast luminaire supports and camera poles shall be performed in accordance with the most current version of the *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*.

The foundation conditions should be investigated in accordance with **Section 16.3**. Some additional considerations regarding the characterization of soil conditions are as follows:

Standard Foundation Designs

Use these drawings for sites with soils consistent with those described on the standard drawings. Consider the soil throughout the entire depth of the proposed foundation. Where the foundation soil is stratified, a weighted average SPT "N" value, ($\overline{N}$), should be used to design the foundation. An exception to this would be where soft or organic soils are encountered at the ground surface (or at depth), in which case the use of a weighted average is not appropriate and non-standard designs may be needed.

$\overline{N}$ can be calculated based on the following equation:

$$\overline{N} = \frac{\sum_{i-1}^{n} d_i}{\sum_{i-1}^{n} \frac{d_i}{N_i}}$$

N_i = standard penetration resistance as measured directly in the field, uncorrected blow count, of "ith" soil layer (not to exceed 100 blows per foot)

d_i = thickness of "ith" soil layer (ft.)

n = total number of distinctive soil layers within the depth of the shaft or within 2B below the bottom of footings (B = footing width)

i = any one of the layers between 1 and *n*

In general, sign, signal, and luminaire structure dead loads are relatively small, but wind loads on the structure can still lead to high vertical and lateral soil bearing pressures. Where soil bearing pressures could lead to unacceptable deflection or settlement of the structure or foundation, consideration should be given to a special foundation design.

Non-Standard Foundation Designs

Special foundation designs are required for sites where the site conditions do not meet the requirements of the standard drawings. These include sites with poor soils and any of the following:

- Soil, rock or groundwater conditions are present that are not suitable for using the standard foundations,
- Multiple soil layers within the foundation depth (or depth of influence) with extreme contrasting strength and soil characteristics (such that the weighted average SPT approach is not applicable),
- Slopes are too steep or other site conditions are marginally stable,
- Non-standard loads are applied.

If the foundation soil consists of very soft clays, silts, organic silts, or peat it may be possible to over-excavate the very soft compressible soils and replace with higher quality material if the soft layer is fairly shallow. If not, deeper and/or larger diameter foundations are typically required.

For foundations on rock, a special design is typically required. Fracturing and jointing in the rock, and its effect on the foundation resistance, must be evaluated carefully on a case-by-case basis.

For shafts in rock, lateral resistance should be estimated based on the procedures provided in **Chapter 8**. This means that for special lateral load designs of shaft foundations, the geotechnical designer will need to develop soil input data for developing P-y curves for modeling the bedrock condition.

For drilled shaft type foundations in soil, the Broms' Method as specified in the *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (AASHTO, 2001) or the procedures specified in **Chapter 8** for lateral load analysis of deep foundations (e.g., P-y or strain-wedge type analysis) should typically be used for these special cases unless otherwise noted in this chapter.

For spread footing design, the design methods referenced in **Chapter 8** to estimate nominal bearing resistance and settlement should be used. However, instead of the referenced load groups and resistance factors for AASHTO LRFD design, the *AASHTO Standard Specifications for Highway Bridges* (2002) combined with a minimum bearing capacity safety factor of 2.3 for Load Factor Design (LFD), or 3.0 for allowable stress or service load design (ASD) should be used for static conditions. A safety factor of 1.1 should be used for seismic conditions, if seismic conditions are applicable.

Note:
Note that in general, foundations for traffic structures are not designed for seismic loads nor mitigated for liquefaction.

Sloping Ground Conditions

The footing dimensions and shaft depths provided on the standard drawings typically assume relatively flat ground surface conditions or a certain setback distance back from a slope break. Most of the standard drawings for traffic structures require a minimum of 3 feet of cover over the top of the footing. Refer to the individual drawings for guidance on these restrictions.

Always evaluate whether or not the local geometry will affect the foundation design.

If sloping ground is present, or does not otherwise meet the requirements of the drawing, some special considerations in determining the foundation depth are needed. For spread footings constructed on slopes refer to *Article 4.4.7.1 of AASHTO* (2002). Consult with the traffic structure designer to determine the design requirements for these non-standard cases. When a non-standard foundation design is required, the geotechnical designer must identify the soil units, soil layer elevations and groundwater data and provide soil design properties for each soil unit for use in preparing the non-standard foundation design.

16.5.2.1 Mast Arm Signal and Strain Poles

The standard drawings for Mast Arm Signal Poles are TM650 through TM653. The Strain Pole standard drawings are TM660 and TM661. These structures generally consist of a single vertical metal pole member (mast arm pole or strain pole) of various heights. The cantilever signal poles support a horizontal signal (or mast) arm. Lights, signals and/or cameras will be suspended or supported from the mast arm. For strain poles, cables extend horizontally from the poles across the roadway and signals and/or lights are attached to the cables. Both types of poles may have luminaires attached to the top.

Foundation support for both the standard mast arm signal poles and strain poles are typically drilled shafts ranging in diameter from 36 to 42 inches. Typical shaft depths range from about 6'- 6" to 18'- 6" depending on the signal pole required (loading condition), the properties of the foundation materials and groundwater conditions.

The foundation conditions at the signal pole site should be investigated and characterized in terms of soil type, soil unit weight, and soil friction angle or undrained shear strength. The unit weight and internal friction angle (or undrained shear strength) may be determined by standard subsurface investigation techniques such as using the Standard Penetration Test (SPT) or other approved methods.

In addition to the soil conditions, the groundwater conditions also affect soil strength and the depth of shaft embedment. The groundwater depth at the site needs to be determined and provided in the Geotechnical Report. Groundwater monitoring using piezometers may be needed as appropriate to detect and record seasonally fluctuations in groundwater levels. Refer to *AASHTO* (1988) for guidance in groundwater monitoring. The highest groundwater depth expected at any time during the life of the structure should be reported in the Geotechnical Report and used in the analysis.

Approximate relationships between SPT 'N' values, unit weights, soil friction angles and undrained shear strength are provided in **Table 16-1** and **Table 16-2**. All field SPT 'N' values should be adjusted to a hammer energy of 60% (N_{60}). Only the 'N' values used in Table 16-1 are corrected (normalized) for overburden pressure (N'_{60}). For the majority of signal and strain pole projects these approximations, combined with engineering judgment, will suffice for classifying the foundation soils and determining the appropriate properties for foundation design. In soft cohesive materials, 'N' values are not reliable for determining engineering properties for design and field or laboratory testing is recommended.

For granular soils, Table 16.1 may be used to estimate soil properties for design. This table is based on data for relatively clean sands. Therefore, selected values of φ′ based on SPT 'N' values should be reduced by 5° for clayey sands and the value from the table should be increased by 5° for gravelly sands.

Table 16-1. Relationship of SPT 'N_{60}' value, internal friction angle and unit weight of cohesionless soils

Note:
The information in the table was modified after Meyerhof (1956), ODOT Soil & Rock Classification Manual (1987) and FHWA Soil & Foundation Workshop Manual (1993).

Description	SPT N'60* value (blows/ft.)	Approximate Angle of Internal Friction (Φ)**	Moist Unit Weight (pcf)	Field Approximation
Very Loose	0 – 4	< 30	70 – 100	Easily penetrated many inches (>12) with ½ inch rebar pushed by hand.
Loose	4 – 10	30 – 35	90 – 115	Easily penetrated several inches (>12) with ½ inch rebar pushed by hand.
Medium	10 – 30	35 – 40	110 – 130	Easily to moderately penetrated with ½ inch rebar driven by 5 lb. hammer.
Dense	30 – 50	40 – 45	120 – 140	Penetrated one foot with difficulty using ½ inch rebar driven by 5 lb. hammer.
Very Dense	> 50	> 45	130 – 150	Penetrated only a few inches with ½ inch rebar driven by 5 lb. hammer.

* N'_{60} is corrected for overburden pressure and energy

** Use the higher phi angles for granular material with 5% or less fine sand and silt.

For cohesive soils, the approximate undrained shear strength and soil unit weight may be estimated from **Table 16-2**, based on SPT "N" values or visual observations. Field tests such as the vane shear or pocket penetrometer should also be considered to aid in estimating the strength of cohesive soils. Note that SPT "N" values are typically unreliable for estimating soil shear strength, especially in soft soil conditions. The strength values obtained from Table 16-2 should only be used for approximate estimations for soil strength and additional field or laboratory testing, or other verification of soil strength, is required for final design.

Table 16-2. Relationship of SPT 'N_{60}' value and soil properties for cohesive soils

Note:
Modified from ODOT (1987), FHWA (1993) and AASHTO (1988).

Consistency	SPT N60 value (blows/ft.)	Approximate Undrained Shear Strength (psf)	Moist Unit Weight (pcf)	Field Approximation
Very Soft	< 2	< 250	100 – 120	Squeezes between fingers when fist is closed; easily penetrated several inches by fist.
Soft	2 – 4	250 – 500		Easily molded by fingers; easily penetrated several inches by thumb.
Medium Stiff	5 – 8	500 – 1000	110 – 130	Molded by strong pressure of fingers; can be penetrated several inches by thumb with moderate effort.
Stiff	9 – 15	1000 – 2000	120 – 140	Dented by strong pressure by fingers; readily indented by thumb but can be penetrated only with great effort.
Very Stiff	16 – 30	2000 – 4000	125 – 140	Readily indented by thumb nail.
Hard	31 – 60	4000 - 8000	130 – 140	Indented with difficulty by thumb nail
Very Hard	> 60	> 8000		

For shaft type foundations in soil, the Broms' Method as specified in the *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (AASHTO, 2001) is generally used to determine the foundation depth. The Rutledge Method described in the AASHTO specifications should not be used for the design of signal pole drilled shaft foundations. If site conditions are suitable for use of the Broms' method, refer to the *ODOT Traffic Structures Manual* for additional design guidance for designing mast arm and strain pole foundations using the soil properties and groundwater conditions identified at the site. Also, consult with and coordinate this work with the traffic structure designer in these cases.

The Broms' method is based on uniform soil and level ground conditions and should suffice for foundation design in the majority of cases. However, the geotechnical engineer should review the soils data and decide whether or not the foundation conditions are suitable for use with the Broms' method of analysis.

If the Broms' method does not apply, then the procedures specified in **Chapter 8** for lateral load analysis of deep foundations (e.g., P-y or strain-wedge type analysis) should be used for these special cases. For these special cases, the shaft design is based on a soil-structure analysis using either the LPile or DFSAP soil-structure interaction programs. A maximum lateral deflection of

0.50 in. is allowed at the top of the shaft (ground line) under service loads. Provide recommendations as necessary for the following special design cases:

- **Soft soils:** If the soils at the site are very soft (s_u < 600 psf or Φ < 25°) then a special design is required. If possible, consideration should be given to relocating the pole to a more favorable soil site where standard design methods could be used. If the soft soils at the site are relatively shallow, then sub-excavation and replacement with high quality, compacted granular soil should be considered. Otherwise, the geotechnical engineer should provide the soil properties necessary to develop a special foundation design.
- **Solid bedrock:** If solid bedrock is expected to be encountered within the depth of the shaft foundation, then the rock should be characterized in terms of its unconfined compressive strength (qu) and overall rock mass quality. In general, if the bedrock can be classified with a hardness of at least R1 (100 psi) and is unfractured with tight joints then a minimum shaft embedment depth of 5 feet can be used, as shown in Figure 16.1, for all mast arm pole types specified on TM650 through TM653, TM660 and TM661.

  Often bedrock is not encountered right at the ground surface but at some shallow depth below the surface. If the rock quality requirements are satisfied then the shaft must penetrate at least 5 feet into the rock, unless the required footing depth based on the properties of the soil above the rock, is reached first.

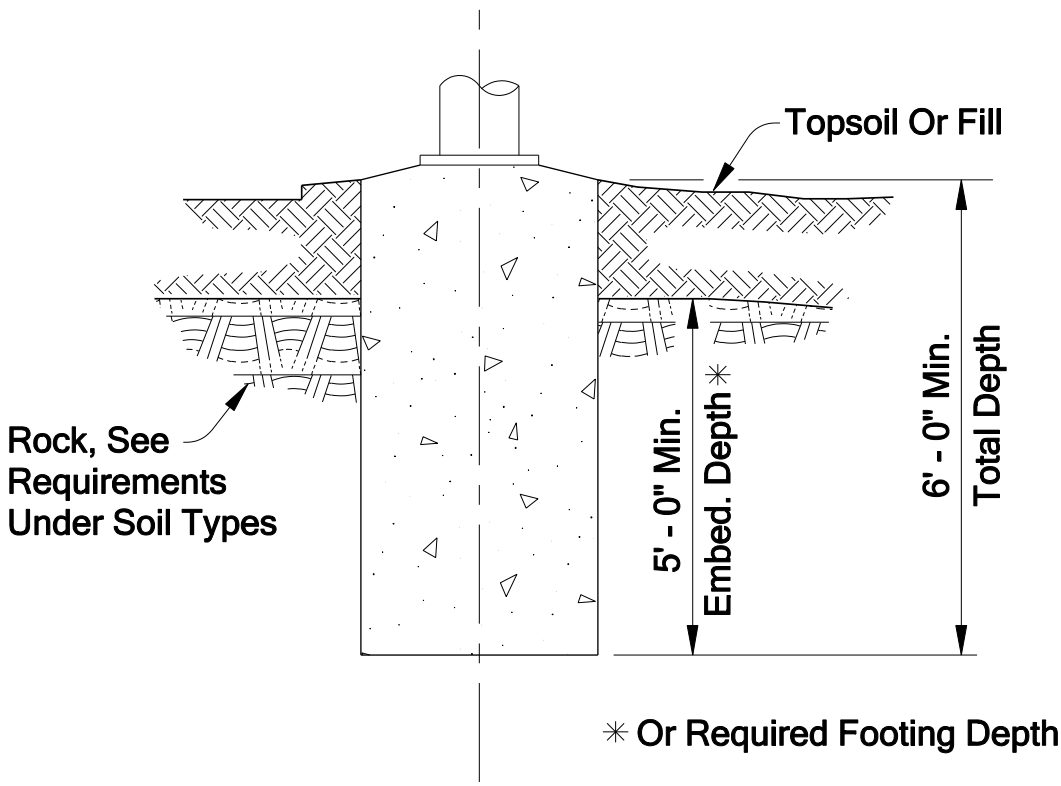

Figure 16-1. Rock Installation Requirements

If the rock is weaker than R1, moderately weathered or contains open fractures, then the properties of the rock mass should be more thoroughly investigated and a special foundation design should be performed based on the procedures specified in **Chapter 8**. For allowable stress design of drilled

shafts in rock use a minimum factor of safety of 2.5 (for both side shear and end bearing) in determining allowable axial capacity. Use the soil-structure interaction (P-y) methods described in *AASHTO 2004* for lateral load analysis of drilled shafts in rock.

16.5.2.2 Monotube Cantilever Sign Supports

Cantilever signs consist of large metal posts up to 31 feet in height supporting a cantilevered metal arm which carries various types and sizes of signs and luminaires. Standard Drawings TM622 – TM627 cover the entire standard for this type of traffic structure. There are currently 10 different structure designs based on arm length, post length, sign area and other factors.

The standard foundation used for supporting cantilever signs is a rectangular spread footing, as shown on Drawing TM626. The dimensions of the spread footings range from 7'- 6" by 15'- 0" up to 15'- 0" by 30'- 0". All footings are 2'- 3" thick with a minimum 3'-0" of cover over the top of the footing. Footing dimensions are based on the Structure Design Number (1 – 10) and whether the footing is constructed on non-buoyant (Type A) or buoyant (Type B) soil conditions. Drawing TM626 contains soil descriptions for these two soil types and other geotechnical design criteria as shown in Figure 16.2.

The Standard Monotube Cantilever Sign Support Spread Footing drawing contains two standardized designs, based on Type A or Type B assumed soil conditions. The assumed soil will be verified by the Engineer of Record before referencing Dwg.# TM626 on the Project Plans. Verification of assumed soil conditions will be based on a site-specific geotechnical study to be preformed by ODOT. The assumed allowable equivalent uniform bearing pressure is based on the methodology described in the references listed below. The assumed soil conditions are as follows:

Type A designs assume non-buoyant conditions for stability calculations (compacted soil density of soil over footing = 120 lb/ft^3, concrete density = 150 lb/ft^3). Type A designs assume allowable equivalent uniform bearing pressures of 1000 psf for Group I Loads, and 1333 psf for Group II and Group III Loads.

Type B designs assume buoyant conditions for stability calculations (compacted soil density of soil over footing = 48 lb/ft^3, concrete density = 88 lb/ft^3). Type B designs assume allowable equivalent uniform bearing pressures of 1000 psf for Group I Loads, and 1333 psf for Group II and Group III Loads.

Both Type A and Type B designs assume that permanent rotation of the footing will not exceed 0.1 degree, and uniform settlement of the footing will not exceed 2 inches.

Reference:

1. *Standard Specification for Highway Bridges*. 16th Ed.. AASHTO. 1996. Section 4.4.7.1.1.
2. Meyerhoff, G.G (1953), T*he Bearing Capacity of Foundations Under Eccentric and Inclined Loads, Proceeding of Third ICSMFE, vol. 1*, pp. 440-445.

Figure 16-2. Soil types and design criteria for Cantilever Sign Supports (from ODOT Drawing TM626

Both Type A and Type B soil conditions require an allowable equivalent uniform bearing pressure (capacity) of 1000 psf, for Group 1 loads, the footing dimensions shown on the drawing and the 3' - 0" minimum cover requirement. This is a relatively low bearing capacity which can usually be provided by the foundation soils except under very poor soil conditions. The difference between Type A and Type B soils is Type B soils assume the groundwater table can rise up above the top of the footing and fully saturate the minimum 3 foot soil cover depth overlying the footing. If so, this reduces the effective unit weight of the overlying soils and the uplift resistance of the footing. The footing dimensions then have to be increased to compensate for this effect.

The geotechnical engineer is required to check that the following conditions are met for each proposed cantilever sign support footing:

- The foundation soils will provide an allowable equivalent uniform bearing capacity of at least 1000 psf (1.0 ksf) for the proposed sign support design.
- Footing settlement under the 1.0 ksf uniform load will not exceed 2 inches of total settlement.
- The unit weight of the soil overlying the footing will be at least 120 pcf (Type A) or 48 pcf (Type B)

It can generally be assumed that if the allowable bearing capacity is at least 1000 psf then the foundation soils can also provide at least 1333 psf allowable bearing capacity under Group II & III (transient) loadings.

The soil designation (as either Type A or B), should be provided in the Geotechnical Report for each monotube cantilever sign support structure and shown on the plans at each sign location for bidding purposes.

16.5.2.3 Sign and VMS Truss Bridges

Standard sign and VMS bridges consist of two large end truss posts supporting a bridge truss system that spans over the roadway. The bridge truss then supports the signs and luminaires. Span lengths can reach up to 167 feet. Standard Drawings TM614 - TM620 cover the entire standard for this type of traffic structure. There are currently 6 different structure designs based on span length, sign area and other factors.

The standard foundations for sign bridges (TM619) and VMS bridges (TM611) are rectangular spread footings. The same foundation design requirements and procedures described in **Section 16.5.2.2** ("Monotube Cantilever Sign Supports") should be used for the design of sign and VMS bridge footings.

Spread footings for sign and VMS bridges are much larger than footings for cantilever sign supports. Footings range in size from 12'-6" by 25'-0" up to 20'-6" by 41'-0", depending on soil type and truss span length. Minimum embedment over the top of the footing is 3'-0". All footings are 2' -6" thick. Additional differential settlement criteria apply to these structures as noted on the drawings. Differential settlement between footings on opposite ends of the bridge should not exceed 2 inches. Footings are to be constructed on undisturbed soil or compacted granular structure backfill.

16.5.2.4 Luminaire Supports

Standard luminaire poles consist of metal poles typically 30' to 70' high with a luminaire mast arm attached at the top. Standard foundations for luminaire supports are shaft foundations. Shafts may be either drilled shafts or constructed with concrete forms, backfilled, and compacted. These footings are either 30" or 36" in diameter or width and range from 6 feet to 11.5 feet in depth. Drawing TM630 provides a table for footing width and depth as a function of Base to Luminaire height ("BL") and Luminaire Arm length ("LA"). This table is reproduced as **Table 16-3**.

Table 16-3. Footing width and depths for Standard Luminaire Supports
(from Drawing TM630)

FIXED BASE CHART (Single Luminaire Arm)										
Pole & Arm Dimensions		4 Anchor rods req'd per pole, each with 3 nuts, 2 washers & 1 anchor plate						Footing width	Footing Depth	
"BL"	"LA"	Anchor rod Diameter	"B"	Length	Thread Top	Proj. "E" max.	Anchor plate size		"LA"≤20' Round Ftg.	"LA">20' Square Ftg.
≤30' or less	40' or less	1½" A307	16½"	3'-6"	6"	5"	4" sq. x ⅝"	2'-6"	6'-0"	6'-0"
>30' Thru 40'	↓	1¾" A307	18"	↓	6½"	5¼"	4½" sq. x ¾"	2'-6"	6'-0"	7'-0"
>40' Thru 50'	↓	2" A307	19½"	↓	7"	5½"	5⅛" sq. x ⅞"	3'-0"	6'-6"	8'-0"
>50' Thru 60'	20' or less	2" A307	19½"	↓	7"	5½"	5⅛" sq. x ⅞"		8'-0"	_____
>50' Thru 60'	>20' thru 40'	2¼" A307	21"	↓	7½"	5¾"	5¾" sq. x 1"		_____	9'-6"
>60' Thru 70'	20' or less	2¼" A307	21"	↓	7½"	5¾"	5¾" sq. x 1"		9'-6"	_____
>60' Thru 70'	>20' thru 40'	2½" A307	22½"	↓	8"	6"	6⅜" sq. x 1"		_____	11'-6"
*50' or less	20' or less	1¼" (A449)	*15"	*	5½"	5"	4" sq. x 1"	*structure mount		

Drawing TM630 also indicates that footings may be round only if the luminaire arm "LA" is ≤ 20 feet. This means that some of the footings may be constructed as drilled shafts (round footings) and some have to be constructed by excavating, placing reinforcement and concrete (with or without forms), backfilling, and compacting the area (square footings).

The standard footing design shown on Drawing TM630 is based on a soil parameter S_1= 1500 psf. S_1 is termed the "allowable soil pressure" in Section 13.10 of the *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals*. It is equated to the "allowable average soil stress" term (also, S_1) shown in the nomograph in **Figure 16-3**, which was originally developed by Professor P. C. Rutledge.

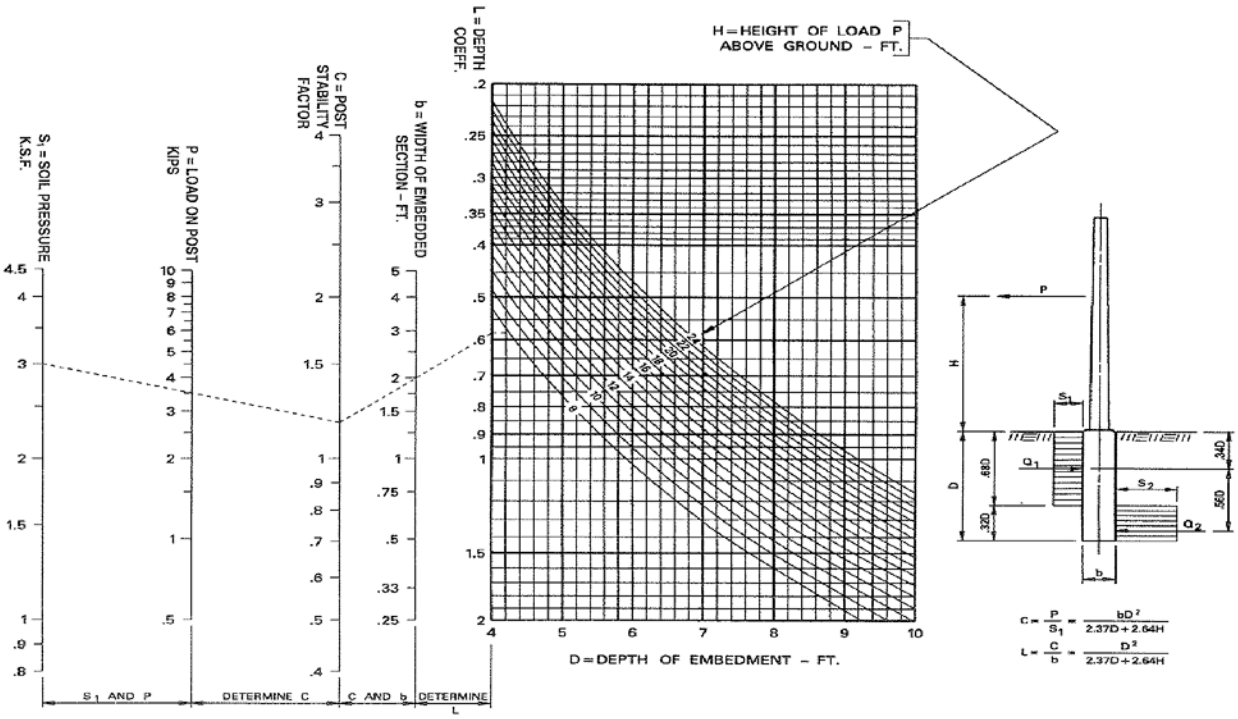

Figure 16-3. Rutledge Nomograph for Estimating Post Embedment under Lateral Loads (AASHTO, 2001)

The allowable average soil stress (S_1) is related to a series of field pullout tests using a 1½" diameter auger, installed to various depths in different soil types (Patterson, 1962 and Ivey 1966). The auger pullout force was related to the allowable average soil stress (S_1) and five general soil classifications, which range from "very soft" to "very hard". The required S_1 value of 1500 psf (1.5 ksf) for the standard drawing correlates to an average SPT 'N_{60}' value of about 10 for either noncohesive (granular) soil or cohesive soils. This 'N' value is not corrected for overburden pressure. If soils are present that do not meet the minimum strength requirements, special designs will be required

If bedrock is expected to be encountered at shallow depths then a special design should be considered. If the bedrock is relatively hard, difficult to excavate or drill through, and would greatly impact the time required to construct the foundation excavation then develop a special foundation design, taking into account the higher foundation material strengths.

Refer to **Chapter 8** for further design guidance for these cases. If the bedrock is relatively soft and can be excavated or drilled through with conventional equipment, such as to not significantly impact foundation construction time, then the standard drawing may still be appropriate.

16.5.2.5 High Mast Luminaire Support

High Mast Luminaire Supports are not regularly used on ODOT projects. If they are required, the foundations for these structures are typically drilled shafts ranging from 4.0- to 5.0 ft in diameter and ranging from about 6'-3" to 20'-4" in depth. If required, then the foundation design should be developed based on site specific soils investigation and a full soil-structure interaction analysis as described in **Chapter 8**. The traffic structures designer should be consulted for design loads and other special design requirements for these structures.

16.5.2.6 Camera Poles

Camera poles consist of metal poles that are typically 50 ft high with a short arm that supports a camera at the top. Foundation supports for camera poles are similar to luminaire supports and the general design guidelines from **Section 16.5.2.4** should be followed.

16.6. Soundwalls

16.6.1. Soundwall Standard Drawings

ODOT currently has three standard designs for soundwalls (see **ODOT Standard Drawings**):

- Standard Reinforced Concrete Masonry Soundwall; Drawing No. BR730
  - Foundation Type: Continuous Spread Footing
- Standard Precast Concrete Panel Soundwall; Drawing No. BR740
  - Foundation Type: 2- to 3-ft- diameter drilled shafts
- Standard Masonry Soundwall on Pile Footing; Drawings No. BR750 & BR751
  - Foundation Type: 2- to 3-ft-diameter drilled shafts

The size of the spread footings and lengths of the drilled shafts vary as a function of wall height, wind speed and soil type. Footing widths for the continuous spread footing design range from 2'-3" to 5'-6" and shaft lengths range from 4'-0" up to 8'-7".

The footings for Drawings BR 740 and BR 750 (drilled shafts) are designed by Load factor design. The footing (shaft) embedment lengths for these walls were design by AASHTO and the Rutledge Equation using S1 = RL/3, where "S1" is the Allowable Ultimate Lateral Soil Capacity. "R" equals the Ultimate Lateral Soil capacity obtained by the log-spiral method increased by a 1.5 isolation factor and includes a 0.90 soil strength reduction factor.

All of the standard drawings for soundwalls are based on the same set of foundation soil descriptions and designations. These are described as follows:

- **Good soil:** Compact, well graded sand or sand and gravel. Design $\phi = 35°$, density 120 pcf, well drained and not located where water will stand.
- **Average soil:** Compact fine sand, well drained sandy loam, loose coarse sand and gravel, hard or medium clay. Design $\phi = 25\phi$, density = 100 pcf. Soil should drain sufficiently so that water will not stand on the surface.
- **Poor soil:** (Soil investigation required) Soft clay, loams, poorly compacted sands. Contains large amounts of silt or organic material. Usually found in low lying areas that are subject to standing water.

The foundation soils at each soundwall site should be investigated and the soils classified into one of the above three designations. **Table 16-1** and **Table 16-2** may be used to estimate soil properties for use in classifying the foundation soils. For spread footings the soil classification should take into account the soil within a depth of 2.0 times the footing width below the bottom of the footing. For drilled shafts, the soils within the estimated depth of the shaft should be classified. If more than one soil type is present along the length of a soundwall, these areas should be clearly delineated either by stationing and offset or on a plan map. The soil category for each soundwall should be documented in the Geotechnical Report and shown on the contract plans.

16.6.2. Foundation Design of Soundwalls

A non-standard, or special, foundation design will be required if the site, soil, or loading conditions are not consistent with the conditions assumed for the standard foundation designs. This includes soils classified as "Poor", hard bedrock conditions and high groundwater conditions. The standard drawings were developed assuming "dry" (unsaturated) soil conditions (dry total unit weights). Therefore, if ground water is anticipated to be above the bottom of the design shaft tip elevation, or within 2B of the bottom of the footing, a special design is required.

If non-standard foundation designs are required, the geotechnical designer should provide the following information to the sound wall designer:

- Description of the soil units using the ODOT Soil & Rock Classification System.
- Ground elevation and elevations of soil/rock unit boundaries.
- Depth to the water table along the length of the wall.
- Soil design parameters. Soil unit strength parameters include effective unit weight, cohesion, φ, Ka, Kp.
- The allowable bearing capacity for spread footings and estimated wall settlement.
- Overall wall stability factor of safety.
- Any foundation constructability issues resulting from the soil/rock conditions.

The soundwall designer will use this information to develop a special foundation design for the soundwall.

Seismic Design

Sound walls are also designed for seismic loading conditions as described in the *AASHTO Guide Specifications for Structural Design of Sound Barriers*. The acceleration coefficient required for design should be obtained from the *2002 USGS Seismic Hazard Maps* for the 500-year return event and provided in the Geotechnical Report. No liquefaction analysis or mitigation of ground instability is required for sound walls.

Sloping Ground Conditions

The standard foundation designs used for the Standard Plan soundwalls are based on level ground conditions. Level ground conditions are defined as follows:

- **Good Soils:** 10H:1V max.
- **Average Soils:** 14H:1V max.

Soundwalls are often constructed on sloping ground or near the edge of a steep break in slope. When the ground slope exceeds the above limits, the foundation design must be modified to account for slope effects. For the continuous spread footing design (BR730), a special design is necessary since there is no standardized method of modifying the standard footing widths or depths shown on the standard drawing. For the standard drilled shaft foundations (BR740 and BR751), methods are shown on the drawings for adjusting the length of the shafts to account for slope effects. The maximum slope angle that shafts may be constructed on, using the standard drawings, are:

- **Good Soils:** 1½H:1V max.
- **Average Soils:** 2H:1V max.

For drilled shafts, the minimum horizontal setback distance is 3.0 ft from the panel face to the slope break. Refer to *AASHTO (2002)* for the minimum setback distance for spread footings which takes slope effects into account in determining the footing bearing capacity. The 6 in. of cover over the top of the shaft is ignored in the computation of lateral earth passive pressure.

Backfill Retention

All Standard Drawing soundwall structures have been designed to retain a minimal amount of soil that must be no more than 2 ft in height with a level back slope. The retained soil above the soundwall foundation is assumed to have a friction angle of 34° and a wall interface friction of 0.67φ, resulting in a Ka of 0.26 for the retained soil, and a unit weight of 125 pcf. All standard and non-standard soundwall foundation designs shall include the effects of any differential fill height between the front and back of the wall.

16.6.2.1 Spread Footings

Continuous spread footings are required for the Standard Reinforced Concrete Masonry Soundwall (Drawing No. BR730). The footing dimensions shown on this drawing are all based on the "Average" soil conditions even though a description of "Good" soil is provided. Soundwall footings shall be located relative to the final grade to have a minimum soil cover over the top of the footing of 1 ft.

For sites that require specific foundation design, such as sloping ground, high groundwater, "poor" soils or hard rock the design methods described in the *AASHTO Guide Specifications for Structural Design of Sound Barrier*s (1989) and the *AASHTO Standard Specifications for Highway Bridges* (2002) should be used for footing design. For static conditions, use a minimum bearing capacity safety factor of 2.3 for Load Factor Design (LFD) and 3.0 for Allowable Stress or Service Load Design (ASD). A safety factor of 1.1 should be used for seismic conditions, if seismic conditions are being considered.

The soundwall footing shall be designed to be stable for overturning and sliding. The methodology and safety factors provided in the *AASHTO Standard Specifications for Highway Bridges* (2002) applicable to gravity walls in general for overturning and sliding (FS of 2.0 and 1.5, respectively for static conditions, and 1.5 and 1.1 for seismic conditions), shall be used to assess soundwall stability for these two limit states, using service loads.

Settlement of soundwalls is usually not considered in design since the vertical loads associated with these structures are generally very low and settlement of previously constructed walls has never been as issue. However, if spread footings are used for foundation support and the foundation soils consist of very soft compressible material, settlement calculations may be necessary to confirm the required noise barrier height is maintained for the design life of the wall. The geotechnical designer will be responsible for estimating foundation settlement using the appropriate settlement theories and methods as outlined in **Chapter 8**. The estimated total and differential settlement should be provided in the Geotechnical Report. In these cases, the total allowable settlement and differential settlement of the soundwall should be obtained from the soundwall structure designer and checked against the estimated amount of wall settlement. If the allowable settlement criteria cannot be met, then sub-excavation and replacement of the compressible materials, or redesign of the foundation, may be necessary.

In addition to foundation design, an overall stability analysis of the soundwall should be performed when the wall is located on or at the crest of a cut or fill slope. The design slope model must include a surcharge load equal to the footing bearing stress. The minimum slope stability factor of safety of the structure and slope shall be 1.5 or greater for static conditions and 1.1 for seismic conditions.

16.6.2.2 Shaft Foundations

For special designs, such as for "poor" soil conditions, buoyant conditions, or hard rock the geotechnical designer needs to provide the soil properties necessary to perform the foundation design. Foundation designs for these conditions should be performed using the Broms' method as described in *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (Section 13.6)*.

16.7. Foundation Construction Considerations

Structures that require short round or square foundations could be easily formed in an open excavation. Following the removal of the concrete forms, backfill should be placed and compacted around the shaft footing to provide containment and lateral support. Footings constructed using forms and backfill should be backfilled using Granular Structure backfill material compacted to the requirements specified in Section 00510 of the *ODOT Standard Specifications*. The geotechnical designer should make sure the contract specifications clearly state the backfill and compaction requirements for the backfill material placed around the formed foundation and that the degree of compaction is verified in the field.

Drilled shafts supporting signal supports (cantilever signals or strain poles) are to be constructed in accordance with Section 00963 of the *ODOT Standard Specifications*. Drilled shafts for sign structures should be constructed in accordance with Section 00512. Refer to the *ODOT Traffic Structures Manual* for further details regarding specification requirements for traffic structures.

Shaft foundations greater than about 10 ft in length may require the use of temporary casing, drilling slurries or both. Generally in most cases, the temporary casing can be removed. The concrete in all shaft foundations has been designed to bear directly against the soils. Special foundation designs may require the use of permanent casing if recommended by the geotechnical designer, in which case, the concrete will not be in direct contact with the soils.

An example of this is where the foundation soils may be too soft and weak to allow for the removal of temporary casing. In this situation, the structural designer must be informed of this condition. The use of permanent casing alters the stiffness and strength of the shaft as well as the soil-shaft friction and torsional shaft capacity.

The presence of a high groundwater table could affect the construction of shaft foundations. The construction of soundwalls with shaft foundations would be especially vulnerable to caving if groundwater is encountered and there are loose clean sands or gravels present.

16.8. Buildings

16.8.1. Overview

The provisions of this section cover the design requirements for small building structures, such as required at ODOT rest areas or for maintenance buildings. It is assumed these buildings are not subject to scour or water pressure by wind or wave action. Typically, buildings may be supported on shallow spread footings or on pile or shaft foundations for conditions where soft compressible soils are present.

16.8.2. Design Requirement for Buildings

Foundations shall be designed in accordance with the provisions outlined in Chapter 18 of the *2003 International Building Code (IBC, 2002)*. This design code specifies that all foundations be designed

using allowable stress design methodology. Table 1804.2 from the IBC provides presumptive values for allowable foundation bearing pressure, lateral pressure for stem walls and earth pressure parameters to assess lateral sliding. Note that these presumptive values account for both shear failure of the soil and settlement or deformation, which has been limited to 1 in.

Table 16-4. Allowable Foundation and Lateral Pressure, (2003 IBC, Table 1804.2).

Materials	Allowable Foundation Pressure (psf)c	Lateral Bearing (psf/ft below natural grade)d	Coefficient of frictiona	Resistance (psf)b
1. Crystalline Bedrock	12,000	1200	0.70	-------
2. Sedimentary and foliated rock	4,000	400	0.35	-------
3. Sandy gravel and/or gravel (GW & GP)	3,000	200	0.35	-------
4. Sand, silty sand, clayey sand, silty gravel and clayey gravel (SW, SP, SM, SC, GM, and GC)	2,000	150	0.25	-------
5. Clay, sandy clay, silty clay, clayey silt, silt and sandy silt (CL, ML, MH and CH	1,500	100	-------	130

a. Coefficient to be multiplied by the dead load.

b. Lateral sliding resistance value to be multiplied by the contact area, as limited by Section 1804.3 of the 2003 IBC.

c. Where the building official determines that in-place soils with an allowable bearing capacity of less than 1,500 psf are likely to be present at the site, the allowable bearing capacity shall be determined by a soils investigation.

d. An increase of one-third is permitted when using the alternate load combinations in Section 16.3.2 of the 2003 IBC that include wind or earthquake loads.

In addition to using the 2003 IBC design code, the geotechnical designer should perform a foundation bearing capacity analyses (including settlement) using the methods outlined in **Chapter 8** to obtain nominal resistance values.

These design methods will result in ultimate (nominal) capacities. Normally, allowable stress design is conducted for foundations that support buildings and similar structures. Appropriate safety factors must be applied to determine allowable load transfer. Factors of safety to be used for allowable stress design of foundations shall be as follows:

Table 16-5. Minimum factors of safety for ASD foundation design.

Load Group	Method	*Minimum Geotechnical Factor of Safety, FS		
		Spread Footings	Shafts	Piles
ASD (unfactored DL+ LL, or service load level)	Static shear strength analysis from soil/rock properties, (compression)	3.0	2.5	2.5
	Static analysis from soil/rock properties, (uplift)		3.0	3.0
	Load test conducted (number of tests depends on uniformity of conditions)		2.0	2.0
	FHWA Gates Equation driving formula			3.0
	Wave Equation			2.5
	PDA with CAPWAP (min. one per pier and 2 to 5% of the piles			2.25

The results of the ASD foundation bearing capacity analyses, after reducing the foundation bearing capacity by the specified FS from **Table 16-5**, and further reduced to meet settlement criteria for the foundation (normally, no FS is applied for settlement analysis results), should be checked against the IBC design code, and the most conservative results used.

For allowable stress design, spread footings on dry sandy soils may alternatively be designed for bearing and settlement by using **Figure 16-4**. When using **Figure 16-4**, a FS from **Table 16-5** does not need to be applied, as the bearing stresses in the figure represent allowable bearing resistances. A factor of safety of 2.0 has already been applied. The design bearing resistance in **Figure 16-3** has been developed assuming no groundwater is present, no eccentricity in the footing and footing settlement will be limited to no more than 1 in. The N-values needed to estimate bearing resistance in the figure should be determined from SPT blow counts that have been corrected for both overburden pressure and hammer efficiency, and hence represent $N_{1(60)}$ values.

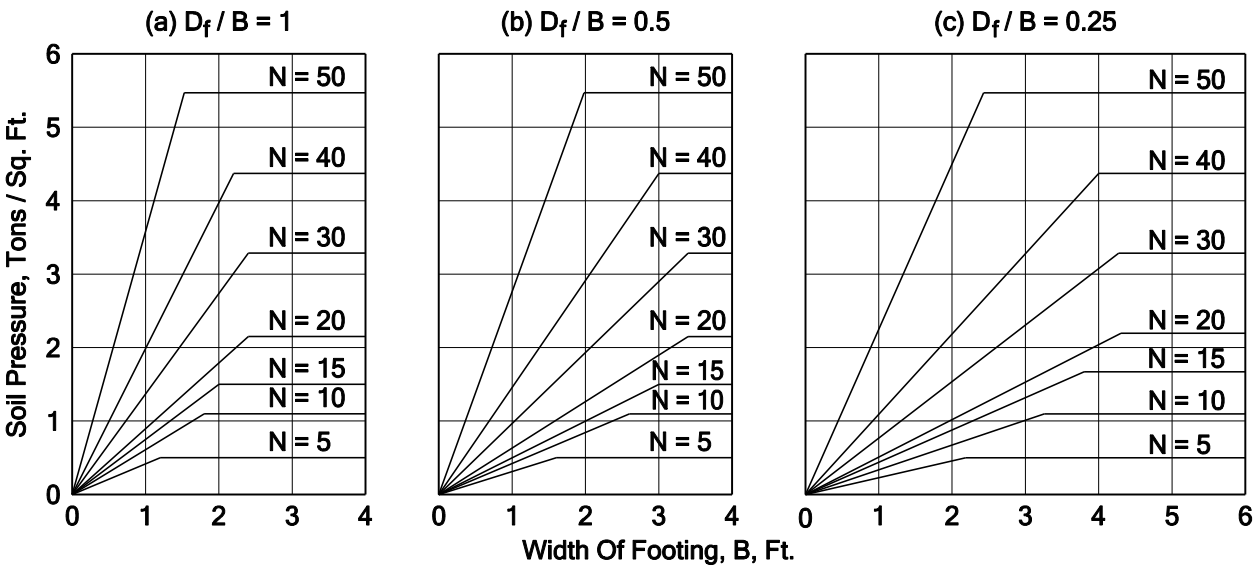

Figure 16-4. Design chart for proportioning shallow footings on dry sand (redrafted from Peck, et al., 1974)

Note that other issues may need to be addressed regarding the design of buildings and associated structures. For example, significant earthwork may be required including cut and fill design, stabilization of unstable ground, ground improvement or retaining walls. Refer to the relevant sections of this manual for design guidance on these types of work.

If septic drain field(s) are needed, local regulations will govern the geotechnical design, including who is qualified to perform the design (i.e., a special license may be required). In general, the permeability of the soil and the maximum seasonal ground water level will need to be assessed for septic system designs.

Note:
Note that in general, the foundations for the types of structures addressed in this chapter are not mitigated for liquefaction. However, for building foundations, liquefaction and other seismic hazards are at least assessed in terms of the potential impact to the proposed structures. Liquefaction and other seismic hazards are mitigated for building and other structures for which the International Building Code (IBC) governs and mitigation is required by the IBC.

16.9. References

AASHTO, 1988, *AASHTO Manual on Subsurface Investigations*.

AASHTO, 1989, ***AASHTO Guide Specifications for Structural Design of Sound Barriers*** *(including 1992 & 2002 interims)*.

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Patterson, D., 1962, *How to Design Pole-Type Buildings*, American Wood Preservers Institute, Chicago,Third Edition.

Peck, R. B., W. E. Hanson, and T. H. Thornburn, 1974. *Foundation Engineering*. Second Edition, John Wiley and Sons, Inc., New York, NY, p. 514.

Chapter

17

17. Culverts and Trenchless Technology Design

17.1. General

(This Chapter to be completed at a later date.)

18. Construction Recommendations and Report

18.1. General

Most construction recommendations should be included in the project Special Provisions or shown on the plans if they are to be contractually recognized. Construction recommendations can also be included in the final geotechnical report as appropriate and may include discussions or recommendations on the following items:

- Temporary shoring requirements
- Control of groundwater in excavations
- Temporary excavation slopes
- Difficult pile driving conditions
- Boulders or other obstructions expected in the area of foundation construction or excavations
- Existing foundations in the area of proposed foundations or excavations
- Monitoring of adjacent structures or facilities (preconstruction surveys)
- Underwater acoustic monitoring of pile driving or "bubble curtains"
- Monitoring of fill settlement and excess pore pressure
- Existing utilities, drainage pipes or other feature that may influence foundation construction

Other unique construction recommendations or quality control issues should be appropriately addressed.

18.2. Roadway Construction Support

The geotechnical designer and/or project geologist should read, and be familiar with, the ***ODOT Standard Specifications for Roadwork*** *(Section 00300)* and specifically *Section 00330, "Earthwork*". Also review all the *Standard Special Provisions for Section 00300*. Provide construction assistance for the following items as required:

- Review of material properties of proposed embankment,
- Review any embankment settlement monitoring data,
- Assist with assessment of unanticipated subgrade stabilization needs,
- Assist with solutions to drainage problems or other groundwater issues,

- Provide solutions and options for dealing with unstable cutslopes if they arise,
- Review of proposed blasting plans.

18.3. Bridge Construction Support

Provide review of contractor submittals and provide construction support as needed for the following general items related to bridge foundation construction:

- Review the stability of temporary excavation cutslopes and shoring submittals,
- Review of foundation designs for falsework,
- Review of foundations for temporary work bridges or detour bridges,
- Review cofferdam designs,
- Review and assist in approval of change orders regarding foundation related items such as changes to material specifications or foundation materials.

Refer to the ***ODOT Bridge Design and Drafting Manual (BDDM)*** for guidance and more details regarding specific design requirements for the above structures.

18.3.1. Spread Footing Construction

The geotechnical designer should be familiar with the *ODOT Standard Specifications for Structure Excavation and Backfill (Section 00510)*. Provide inspection services to the field as requested to verify that the foundation materials exposed at the footing foundation elevation are the same materials as assumed in design and suitable for foundation support. If the materials are not as assumed and are not suitable for footing construction, provide recommendations to the construction office regarding how to proceed with foundation construction. Consult with the structure designer and other project personnel, as necessary, if significant changes to footing elevations are required.

18.3.2. Driven Pile Construction

The geotechnical designer should be familiar with the *ODOT Standard Specifications for Driven Piles (Section 00520)* and the *Standard Special Provisions for Section 00520* which supplement the Standard Specifications. The final pile record books should be sent to the HQ Bridge Engineering Section office at the completion of the project. These records are scanned into a data base for further reference.

Construction support for pile foundation projects typically consists of the following review process and documentation:

- Review and approval of the *Pile & Driving Equipment Data Form*.
    - The contractor is required to submit a completed *Pile & Driving Equipment Data Form*. If the form is not complete or unclear, request a resubmital from the PM office. This review consists of verifying that the contractor's hammer meets the requirements of the standard specifications, which typically means the proposed hammer will provide sufficient field energy to drive the piles to the required minimum tip elevation and develop the required nominal resistance with a driving resistance within the allowable range of 3 to 15 blows per in.

- If the piles are driven to bearing based on the FHWA dynamic formula, simply check to see that, for the required nominal resistance, the estimated hammer field energy will result in a resistance between 3 and 15 blows per in. The maximum rated hammer energy should not be used in this evaluation since hammers rarely reach this level of performance.

- If the piles are accepted based on wave equation (WEAP) analysis, check the contractor's WEAP analysis to see that the correct input values were used, the analysis was performed properly and the predicted pile stresses are below the maximum stresses allowed. Also, check to see that the predicted resistance is between 3 and 15 blows per in.

- If swinging leads are proposed there should be a clear method of bracing, anchoring or fixing the bottom of the leads to maintain proper hammer-pile alignment throughout the pile installation.

- Provide final pile driving criteria to the field.

  - If the hammer does not meet the requirements of the specifications, provide a letter to the PM office rejecting the hammer and documenting the reasons for the rejection. Once the hammer is accepted, a letter stating so is sent to the project manager along with the final driving criteria.

The final pile driving criteria usually consists of an inspectors graph showing the required resistance in blows per inch as a function of hammer stroke (for open end diesel hammers) or field energy. An example is attached in **Appendix 18-A: Pile Inspector Graph**. A table showing the required resistance as a function of hammer stroke (for a fixed nominal resistance) may also be provided.

At this time in the pile hammer review and approval process, any important pile installation problems or issues that might arise should be communicated to the project manager and the pile inspector in the pile hammer approval letter. The following issues should be discussed as applicable:

- Pile freeze (setup) period, if required, and proper procedures to follow,
- Any anticipated difficult driving conditions and damage potential,
- Potential for piles running long and possible solutions,
- Preboring requirements,
- Vibration monitoring,
- Dynamic pile testing requirements and procedures.

An example of a pile hammer approval letter is shown in **Appendix 18-B: Hammer Approval Letter**.

For open-end diesel hammers, the hammer stroke must be determined during pile driving for use in determining bearing resistance. A saximeter is a small hand-held device that measures and records hammer stroke and other pile driving information during driving. These devices are available for loan to the field from the HQ Bridge Engineering Section for use in measuring and monitoring the field hammer stroke and other data. Saximeters are primarily recommended for monitoring stroke for open-end diesel hammers and are helpful in assessing overall hammer performance.

18.3.3. Drilled Shaft Construction

The geotechnical designer should be familiar with the *ODOT Standard Specifications for Drilled Shafts (Section 00512)* and the *Standard Special Provisions for Section 00512* which supplement the Standard Specifications. The project Special Provisions may contain several specifications pertaining to drilled shaft construction that are unique to a given project.

Proper inspection is a crucial element in the drilled shaft construction process. All drilled shaft inspectors should be certified in drilled shaft inspection procedures.

Construction support for drilled shaft projects typically consists of the following items:

- Review and approval of the drilled shaft installation plan and other submittals (see *Section 0512.40 of the Standard Specifications*). This review and approval should be coordinated closely with the structural designer. Shaft construction methods can affect both the structural and geotechnical capacity of drilled shafts and so both disciplines should be involved in this review.

- Attend drilled shaft preconstruction meetings with the drilled shaft subcontractor, prime contractor and construction staff,

- Review and approve crosshole sonic log test results. Coordinate the review and approval of CSL test results closely with the structural designer. See **Section 18.3.3.1** for details regarding the CSL testing and evaluation procedures.

- Review proposed drilled shaft repair plans (as needed).

- Provide construction support and advice to the construction office during shaft construction regarding any difficulties in shaft construction or to answer any questions the inspector may have. Help insure the proper inspection is taking place and the proper inspection forms are being completed.

Work with the inspector to make sure the shaft is being constructed in the foundation materials that were assumed in design. If changes to the estimated shaft tip elevations are necessary, work with the structural designer and project staff to determined acceptable revised shaft tip elevations.

18.3.3.1 Crosshole Sonic Log (CSL) Testing & Evaluation Procedures

CSL testing, in combination with a quality field inspection, are the primary methods used by ODOT for the quality control and acceptance of drilled shafts. CSL testing is not always a conclusive test and the results often require interpretation and further in-depth review. The CSL test results by themselves can sometimes be misleading. Therefore, all inspection records and forms should be provided to the CSL reviewer to use in combination with the CSL test results in determining shaft acceptance. It is highly recommended that the foundation and bridge designers both understand, and be familiar with, CSL testing procedures and have training in the use and interpretation of CSL test results.

The following procedures should be used when conducting CSL testing for quality control of drilled shafts on ODOT projects.

18.3.3.2 CSL Field Testing

- Contractor provides the CSL subcontractor to do the testing. This is included in the contract with bid items for mobilization of equipment and the number of tests per bridge.

- CSL testing is performed according to ASTM D6760-02.
- CSL testing is performed on the first shaft constructed and others as described in *Section 00512* of the special provisions.
- Additional shafts are tested if construction methods change or shaft construction results in questionable quality shafts. This is especially true for uncased shafts, excavated below the water level in soils.

18.3.3.3 CSL Test Results

- CSL test results should be forwarded to both the geotechnical engineer and the bridge designer for review, (regardless of what the CSL report says),
- Both engineers should concur that the shaft is acceptable or needs further investigation.
- Structural and/or geotechnical analysis may be necessary at this point to assess the load carrying capacity of the shaft based on interpretation of the CSL test results and inspection reports.

18.3.3.4 Further Testing/Inspection

If an anomaly or obvious defect is detected in the CSL testing, it may warrant further investigation to verify that it does indeed exist and to further quantify the extent and material properties of the material in the affected zone. If additional investigation appears necessary, review all the shaft inspection forms and confer immediately with the drilled shaft Inspector regarding all aspects of shaft construction to determine what could have happened at the depth of the anomaly.

Note:
This is a very important decision in that if, upon further investigation, there is no shaft defect found, ODOT may be responsible for paying the investigation costs along with additional compensation to the contractor for delaying drilled shaft construction due to the additional investigation work. If any defects are found, regardless of whether they are repaired or not, the full cost of the shaft investigation (coring and/or other work) is paid by the Contractor with no time extension.

If further investigation is deemed necessary, the following procedures should be considered to further quantify the affected zone:

- First, thoroughly review the inspection records of the drilled shaft in question and review the closest drill log to see if there is a correlation between the detected anomaly and something that occurred during the shaft construction process and/or related to the soils or groundwater conditions.
- Consider performing additional CSL testing after some period of time to see if the anomaly is the result of delayed concrete set or curing. Check concrete mix design to see if admixtures and retarders were used which could delay concrete set.
- If practical, excavate around the perimeter of the shaft to expose near-surface defects.
- Consider using CSL tomography (3D Imaging) at this time to try and better define the extent of the anomaly.
- If required, perform core drilling at the locations and depths of suspected defects.
- Insert downhole cameras (in drilled core holes) for visual examination of defects.

18.3.3.5 Core Drilling

If core drilling is necessary, the following procedures should be followed:

- The foundation or bridge designer should plan the number, location and depth of all core holes based on the CSL test results and inspection reports. Target the area(s) where the CSL results indicate possible defects. Do not allow the contractor to select core hole numbers, locations and depths.
- Use either double or triple tube coring equipment that will result in maximum recovery and minimal damage to the recovered concrete core.
- Carefully log all core holes using methods similar to those used for typical geotechnical bore holes, closely measuring depths, rate of advancement, any sudden drops in drill steel (indicating voids), percent recovery, concrete quality, breaks, fractures, inclusions and anything that does not indicate solid, good quality concrete.
- Core at least 3" away from any rebar, if possible, and do not core through any steel reinforcement without the clear, expressed approval of the structural designer.
- Take photos of the core recovery.
- Keep notes of any driller remarks regarding the nature and quality of the shaft concrete.
- Keep the contractor (or Drilled Shaft subcontractor) informed throughout this investigation. The core holes may be able to be used by the contractor for repairing any shaft defects.
- Cored holes could also be filled with water and used for additional CSL testing.
- If possible:
    - do core breaks (qu) on suspected core samples retrieved from defect area.
    - use down-hole cameras to help quantify the extent of defect area.

18.3.3.6 Shaft Defects and Repairs

Based on the results of the additional investigation work and an assessment of the shaft integrity, the bridge and foundation designers should confer and determine if a defect is present that requires repair. This determination should be based on an assessment of the effect the defect has on the shaft's ability to perform as designed (both for geotechnical and structural purposes).

Note:

If a shaft defect is determined to be present, it is the contractor's responsibility to submit a repair plan and repair the defect at no cost to ODOT.

All shaft repair proposals should be submitted to the foundation and bridge designers for review and approval. Shaft repair should not be allowed without written approval of the Engineer-of-Record. Grout repair of minor shaft voids may be allowed with approval of the Engineer-of-Record, if the CSL tubes are left open to verify shaft integrity after grouting. If shaft defects are severe enough to warrant complete shaft replacement or redesign, the contractor shall submit a plan for the redesign or replacement according to *Section 00512.41*.

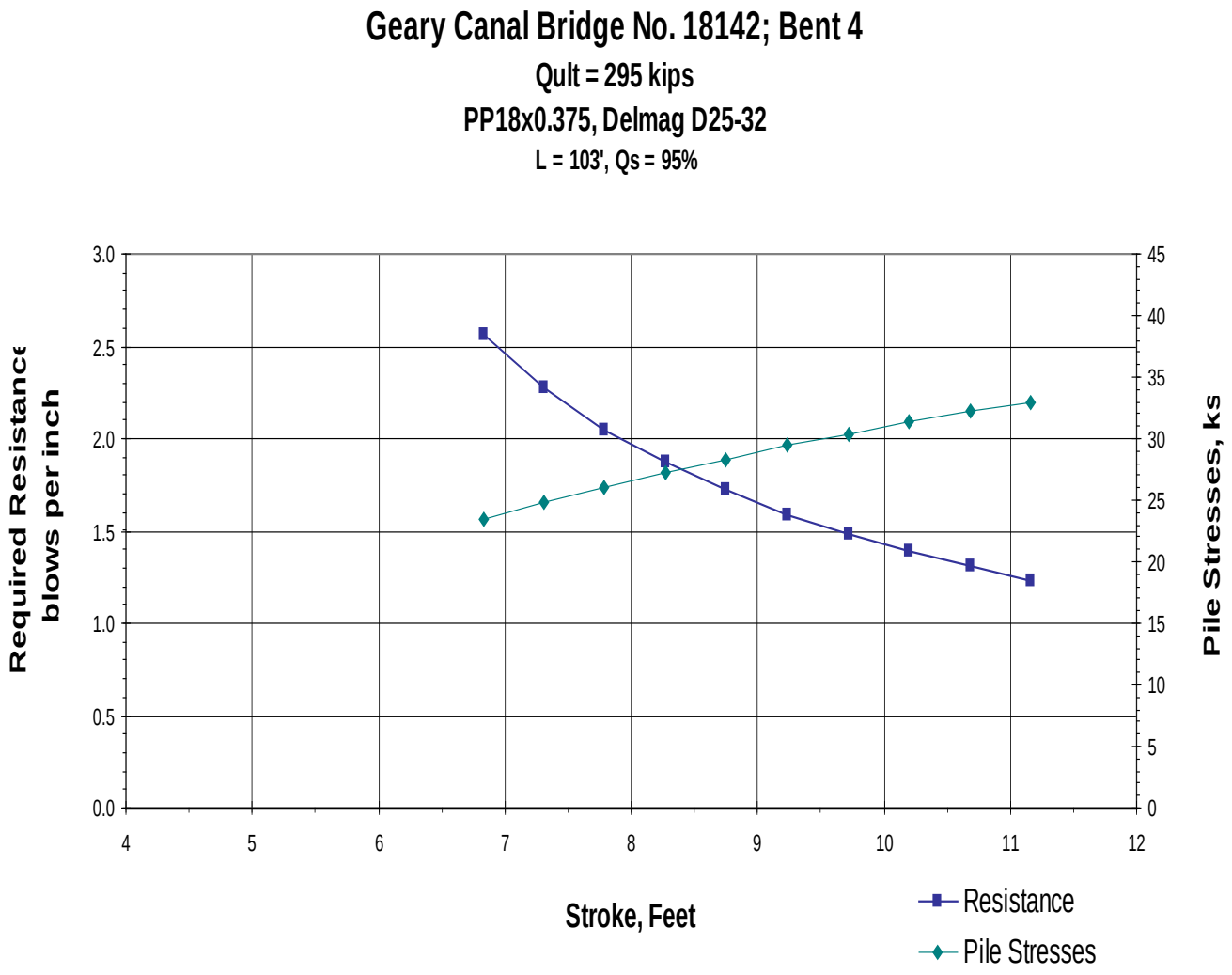
18.3.3.7 Remaining Shafts

The cause of any defects should be ascertained, if at all possibly, so the contractor can use modified shaft construction procedures and avoid repeating the same defects in the remaining drilled shafts on the project. A modified drilled shaft installation plan, showing these modifications to the installation procedures, should be submitted for approval.

18.4. References

This section blank intentionally.

Appendix 18-A: Pile Inspector Graph



Appendix 18-B: Hammer Approval Letter

INTEROFFICE MEMO

Bridge Section
Office Phone: 986-4200
Fax Phone: 986-3400

September 18, 2008

File Code:

TO: Joe Manager
Project Manager

FROM: Bob Geotech, P.E.
Geotechnical Engineer

SUBJECT: Fort Creek (Hwy 022) Bridge
OR62: Fort Creek Fish Passage
Bridge No. 20442
Crater Lake Hwy, M. P. 92.32
Klamath County
Contract C13454

The Pile and Driving Equipment Data Sheet submitted for use in installing the permanent piling on the Fort Creek Bridge has been reviewed and is conditionally approved for use. The data sheet submitted shows a Delmag Model D19-32 diesel hammer, which should be adequate for driving the PP12.75x0.375 piles for this project. All piles should be driven to a nominal resistance of 350 kips, with a minimum pile tip elevation of 4122 feet. Hammer approval is conditional due to the large size of the hammer relative to the required nominal bearing resistance. For the end-of-driving resistance to be within the specified range of 3 – 15 blows per inch (bpi) the hammer must be operating at a stroke height no greater than 8.5 feet (corresponding to 3 bpi). At stroke heights greater than 8.5 feet the required resistance is below the minimum value of 3 bpi. The hammer should be operated with a stroke range of between 6.0 and 8.5 feet when determining bearing resistance.

End of driving criteria was based on the FHWA Gates Equation presented in the 2008 Oregon Standard Specifications for Construction and is summarized in the table below.

STROKE (feet)	BLOWS/INCH
8.5	3
7.5	4
6.5	5
6.0	6

An inspector's graph showing the required resistance (blows per inch) as a function of field hammer stroke is attached. A saximeter should be obtained from the ODOT Bridge Section Headquarters office for use in measuring field hammer stroke. The Standard

Specifications state that the required blow count should be obtained for at least three consecutive inches unless "refusal" driving conditions occur (defined as 20 bpi or as determined by the Engineer).

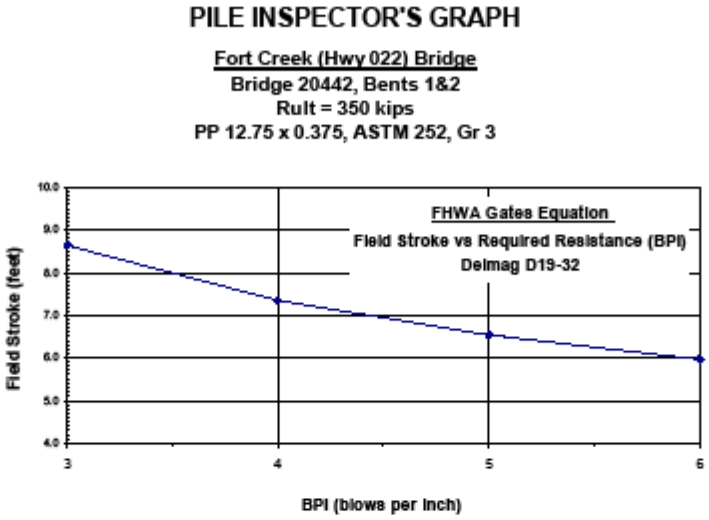
If the piles do not attain the required bearing resistance when driven to the specified length, the piles should be allowed to stand for a "set period" as described in Section 00520.42(d).

The pile material certifications should be checked to make sure the piles are certified as ASTM A252, Grade 3 (45 ksi yield strength). All piles should be closely observed during installation in order to stop driving at any signs of impending damage.

Please contact me at 541-555-1234 if you have any questions.

Attachment:
Pile Inspector's Graph

bc: Region X Geo/Bridge/Environmental Unit


PILE INSPECTOR'S GRAPH
Fort Creek (Hwy 022) Bridge
Bridge 20442, Bents 1&2
Rult = 350 kips
PP 12.75 x 0.375, ASTM 252, Gr 3
FHWA Gates Equation
Field Stroke vs Required Resistance (BPI)
Delmag D19-32
Field Stroke (feet)
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3
4
5
6
BPI (blows per inch)

Chapter

19

19. Unstable Slope Management

19.1. General

(This Chapter to be completed at a later date.)

Chapter

20

20. Material Source / Disposal Site Investigation and Report

20.1. General

This chapter discusses the purpose for Oregon Department of Transportation (ODOT) disposal site and material source exploration and design. Identification, design, development, and permitting of material sources and disposal sites require nearly all the same elements that go into a large transportation project. Material sources and disposal sites require identification, investigation, environmental review, mining and land use permitting, right-of-way acquisition and/or delineation, topographic survey, CAD design, and reclamation.

Time lines associated with various tasks that go into site and source exploration, development, and reclamation generally do not follow along with project time lines associated with similar tasks (e.g., surveying and environmental surveys). In general, many of these tasks need to be completed for sources and disposal sites, in advance of when they would be scheduled for the project that the source(s) or disposal site(s) will be associated with.

Disposal sites and material sources are investigated and designed in conjunction with construction and maintenance of the transportation facilities.

- **Material source investigation:** The purpose of a material source investigation is to identify and prove out sufficient quantities of material meeting the quality requirements for the intended use.
- **Design:** The purpose of the design is to graphically represent the proposed development of the material source or disposal site in the contract plan sheets taking into account the property limits, site conditions, permitting requirements, most efficient extraction, current need, and future use of the source and/or site. Detailed design and reclamation plans are also requirements for the permitting of material sources.

Throughout this chapter, various guidance documents and forms are identified and referenced. Document names will be shown in italicized font. Information that hyperlinks to other information such as tables, figures, other documents, forms, or URLs will be displayed underlined and in bold. In other sections, there are references made to available information. These specific documents and referenced material can be found at the following website:

Highway - Geo-Environmental Section Geology/Geotechnical

20.2. Material Source and Disposal Site Definitions

The following definitions and terms are used in this chapter.

ODOT Material Source - A unique parcel or combination of parcels of land that are ODOT owned or controlled, specifically identified as the location from which material can be removed for utilization in the construction of a highway project and the continued maintenance of the transportation facility. Material from an ODOT source may or may not require secondary processing prior to incorporation into a project.

ODOT Disposal Site - A unique parcel or combination of parcels of land that are ODOT owned or controlled, specifically identified as the location where excess clean fill from a highway construction project, or generated through routine or emergency maintenance activities, can be temporarily stockpiled for future beneficial use or permanently placed as a secondary beneficial use.

Note:

Placement of material without a beneficial use, equates to the creation of a landfill requiring permitting through DEQ.

Material - Material can either be in place naturally occurring earthen material (soil, cinder, hard rock, or gravel) or earthen material that has been transported to this location from another site or sites and stockpiled for future use. In some situations, the term "material" can be used to refer to recycled material such as pavement grindings.

Clean Fill - Rock, soil, concrete with or without rebar (provided the rebar is not exposed), brick, building block, tile, or asphalt paving (weathered and consolidated with no free oil) that does not contain contaminants that could adversely impact waters of the state or public health. Wood is not considered clean fill.

Quarry - A term generally used to refer to a hard rock source that commonly will require blasting techniques to be utilized prior to extraction of the native material. In Oregon, this term is commonly associated with quarry operations located in igneous flow deposits.

Pit - A term used to refer to a mine site that generally does not require blasting prior to extraction, and is commonly associated with gravel, cinder, or soil sources.

Source/Site Designer - In the context of this discussion, the Source/Site designer is defined as the Certified Engineering Geologist who ultimately will be the Professional of Record for the material source and/or disposal site design.

20.3. Material Source and Disposal Site Project Scoping

Project scoping is a key element of any project to assure a quality transportation solution and subsequently an efficient and economical design. Scoping related to material sources and disposal sites is critical at an early stage in the project development. As implied above, material sources and disposal site development should be viewed as small projects inside the larger transportation project. If the need for a source and/or disposal site and the subsequent identification of the site is not completed early in the process, there may be inadequate time and project funding to complete the required work tasks (especially if there is right-of-way acquisition or significant environmental requirements).

In the scoping phase of a project, it should be determined if there will be materials needed for the project. If the proposed project will need material, consider the following:

- **Estimate material quantity needed:** An estimated quantity of the various types of material should be developed.
- **Evaluate:** Evaluation of the project and the availability of the various material products needed should then be undertaken to determine what options are available to meet these project needs. It should be determined if the project needs can be met by utilizing material coming from the project or if material will need to be imported. If project quantities or quality are determined to be insufficient to meet the project needs, and material will be imported, it will need to be determined what the options are for meeting these needs: existing commercial suppliers, private sources, other ODOT projects, ODOT controlled material sources or a combination of these sources of material. ODOT has developed guidance documents to assist in determining the potential need for a material source and/or a disposal site titled ***Material Source Use Criteria, ODOT Material Source Management, Uses, and Associated Costs, Justification for Offering ODOT Material Sources, and Prospective versus Mandatory***.

The same process should be followed in regards to disposal sites for excess materials generated on a project. The potential need for a publicly controlled disposal site for placement of excess materials should be evaluated using the above mentioned guidance document.

PD-10, Project Delivery Leadership Team Operational Notice - 10, provides additional guidance as to when a publicly controlled disposal site may be needed for a project. The ***Geo-Environmental Bulletin GE08-04(B), Designating Construction Staging and Disposal Sites*** document also provides additional information on this issue.

20.4. Material Source and Disposal Site Project Reconnaissance

If it has been determined during the project scoping phase that a publicly controlled source of materials and/or a publicly controlled disposal site or both are needed, existing sources and properties will need to be evaluated. ODOT has developed guidance documents that generally outline the steps necessary for disposal site development and for source development titled, ***ODOT Material Source Checklist*, and *ODOT Disposal Site Checklist*.**

Evaluate existing database and file information to determine the existence of sources in the area and to identify those sites that may meet the project needs for both quantity and quality of material. Consider the following:

- **Additional information:** Information related to survey data, land use zoning, ownership, environmental clearances, visual restrictions, land use and permits should also be reviewed. If the project is in need of a publicly controlled material source and no existing sources appear able to meet the demand, it is at this point that new or alternative sources of material would be considered and additional reconnaissance be completed.

  When evaluating potential sources, a useful tool has been developed by ODOT to assist in gathering needed information. This tool is titled ***Material Source Field Inventory***.

- **Notifications:** If the proposed source or site is located near residential development or other potentially sensitive land use or environmental areas, it may be necessary to notify local property owners or groups of proposed activities in advance of on site work beginning. ODOT has developed a template that can be modified to fit the proposed

activities that can be completed and used to notify interested parties in an effort to inform them of what is being proposed and in an attempt to eliminate unrealistic fear and objections related to misunderstandings and misinformation. This template is titled ***Material Source Public Communication Document*.**

- **Other Agency information:** Valuable information on sources and source availability in the area of interest can be obtained by contacting the Department of Geology and Mineral Industries, the United States Forest Service, Bureau of Land Management as well as County Road/Public Works Departments.
- **Cost:** Once a site or sites have been identified, the estimated cost for development will need to be compared with the anticipated value of the site to the project and future projects to determine a cost benefit evaluation prior to moving forward with the source development. ODOT has developed an internal tool to assist in estimating the cost of source or site development titled ***Material Source Evaluation Form (on the second tab).*** In most cases, ODOT does not charge a royalty for material removed from their sources when the source is being offered for the project at the time of bidding. The cost of development and the value of the rock is realized in competitive bidding and long term material availability. The document ***Royalties & ODOT Sources*** provides additional information on this issue.

20.5. Right-of-Way Needs for Material and Disposal Sites

If it is determined that additional property is required at material sources or disposal sites to meet the proposed project, it is critical that this need is identified during the scoping phase. Right-of-way acquisition takes time and when dealing with material source properties, it generally will require an extended timeline. Once the agreements or permits of entry allowing additional work to be completed are in hand, a detailed evaluation and investigation can move forward. An ***Acquisition Guidance*** document has been prepared to explain the general process.

If the evaluation and investigation does not identify any fatal flaws, the right-of-way acquisition or lease negotiations can be finalized. The normal time lines associated with project right-of-way acquisitions do not generally allow for the right-of-way work associated with a material source or disposal site to move forward on the same schedule.

Note:
Right-of-way activities related to material sources and disposal sites generally need to start earlier than they would for the project to allow for adequate evaluation of sites and permitting.

Due to permitting requirements associated with the mining or disposal activity, the right-of-way purchase or other occupancy agreement must be completed prior to moving forward with the permit process that generally starts at the preliminary plan phase of a project. The investigation work associated with the evaluation of the site or sites in advance of finalizing what property is needed and the subsequent permitting work combine to lengthen the normal right-of-way process and also force an earlier than normal start to this effort for project right-of-way work.

20.6. Environmental Clearances for Material Sources and Disposal Sites

Material source and disposal site development, by nature of the activity, is a ground disturbing action. No source or disposal site development can take place without first obtaining all of the necessary environmental clearances required by state and federal law. ODOT projects must follow the federal

standards instead of state requirements when obtaining environmental clearances due to frequent federal participation in the project funding. Even if the currently proposed project is not federally funded, ODOT still tries to meet federal standards related to material sources and disposal sites since the sources are long term investments and will likely be used for federally funded projects in the future.

Investigation

The investigation work for sources and disposal sites is considered invasive enough to require environmental clearances prior to the implementation of the investigation plans. As a result, it likely will be necessary to obtain preliminary, if not all, clearances for the investigation work. If there is a high level of confidence that the source contains the necessary material quality and quantity, it is a better use of the resources to environmentally clear the entire site for all activities at one time prior to the implementation of the investigation plan. If there is uncertainty or inadequate time to complete the environmental surveys for the entire site prior to investigation, it may be necessary to complete only the minimum amount of clearances required to conduct the investigation. If only partial clearances are obtained in the early stages, and the source or site is pursued for use, follow up comprehensive environmental work to survey and clear the entire area will be required.

In addition to the common environmental concerns related to archeological, historic, wetland and Threatened and Endangered Species resources, the issue of noxious weeds, invasive plants and migratory birds will need to be evaluated and addressed in all source and/or site related activities.

20.7. Material Source and Disposal Site Investigation

Investigation techniques that are common to geologic and geotechnical investigations are also used for materials sources. Common methods include test pits, auger borings, and wire-line core sampling. Air track drill investigations are often used independently or in conjunction with core hole explorations.

Exploration methods: Test pits and auger hole explorations are the most common form of investigation in sources of common soil, cinder and gravel deposits. Air track drill and wire-line explorations are frequently used in investigating hard rock deposits. The selected method of investigation, and the number, location, and depth of holes or test pits planned and then completed will depend on the site and the existing information available on the site. When determining the method(s) to use in investigating the site, the proposed development strategy will also influence the method selected.

Investigating material source sites: When investigating material source sites, the investigation plan should be developed and carried out to identify the lateral and vertical extent of the deposit or deposits. Vertical and lateral variations in the deposits such as material type, gradation characteristics, coatings on the material, weathering, hardness, relative density, joint spacing, joint infilling, cementation, vesicularity, slaking, and other characteristics that may impact the development and or material quality are important and should be noted on the logs. Overburden thicknesses, flow contacts and existence of water are also critical elements that need to be noted.

Air track drill investigations: Air track drill investigations are ideal for gathering information rather inexpensively over a large area. This method of investigation can be useful in determining overburden depths, existence of rock and some basic rock characteristics, but should not be used as the sole source of information on most hard rock quarries. Air track drill information does not generally provide enough detail to fully understand potential material variations and does not provide samples sufficient for determining rock quality. In most cases air track drill investigations are used to obtain basic and preliminary information and to identify areas requiring more detailed wire line exploration.

Wire line explorations: Wire line explorations provide the investigator the details necessary to adequately characterize the material and the various source and material characteristics that will influence the source development.

The Engineering Geologist working on the source development must use experience and professional judgment in determining the level and type of investigation necessary for the proposed source development. As a guide, there are several "rules of thumb" associated with source investigations. These guidelines are:

- Sites with limited history and or complex geology will generally require a higher level of investigation.
- New sites will generally require a much more detailed and comprehensive effort than an existing site with a long history of use with no associated problems.
- In general, the larger the proposed operation the larger and more detailed the investigation will likely be.
- As mentioned earlier, if a site has rather simple geology or well defined geology and a long history of use and good information is available, the Engineering Geologist may decide not to complete additional subsurface investigation. If subsurface investigation is completed on a site, at least one if not more, of the exploration locations should be focused on and completed within the proposed excavation area for the upcoming project. Planned material source development should not exceed the extent or depth of the investigation.
- Investigations conducted for disposal sources are generally carried out to investigate for foundation stability concerns (see **Chapter 3** for details). Coordination between the engineering geologist and the geotechnical engineer will be critical in the site evaluation and development of the investigation plan, if required.
- In most situations, it will be necessary to have some form of land use agreement or permit and environmental clearances completed in advance of doing any investigation work.

20.8. Material Source and Disposal Site Sampling and Testing

The method of investigation and the sampling and testing program will be dependent on the site and proposed site use. For disposal sites if sampling and testing is needed it will be associated with subsurface samples and testing associated with site stability evaluation. For material sources the sampling and testing will be dependent on the site and the type of material that is needed for the project.

20.8.1. Sampling

Samples from the proposed source development area can be obtained from surface exposures for preliminary qualification information when completing initial site assessment, or when no subsequent investigation will be completed. When obtaining surface samples from an existing site that has not been worked for many years, the sampler should create a fresh face from which to obtain a representative sample. Existing stockpiled material can also be sampled and tested to obtain quality information. If follow up investigation is completed in the area or areas of proposed development, representative qualification samples should be obtained and tested. Sampling and testing differing units or zones of material becomes more important and critical as the quality requirements become more stringent. A source of material proposed for use on a paving project will require a more detailed investigation and sampling and testing program than a source proposed for use as common borrow.

Depending on the intended use of the material, it may be necessary to employ specific sampling techniques to determine if the material or various material units will meet the project requirements beyond simply the quality of the material. An example would be the need to sample a quarry site using coring equipment to determine the joint spacing of the material if the project needs are for rip rap of a specified size and the site has little to no history that would allow for adequate site characterization.

Sampling guidelines for produced aggregate material or existing stockpiles are provided in AASHTO T2 (**ASTM D 75**).

No matter what is being sampled, or where the sample is coming from, it is critical that the person collecting the sample collect a representative sample of the material at the site, not just selecting the best or worst material.

Required sample size can vary, but for surface samples or samples obtained from a subsurface investigation, the following is a general rule of thumb for sample size: six bags of quarry rock or nine bags of gravel (a 5 gallon bucket could substitute for one canvas bag) per sample/per site. The size of quarry rock should be 4- to 6 in. chunks, and material from a gravel pit should be the whole range of sizes with the maximum size a 6 in. cobble.

20.8.2. Testing

In the past, the ODOT lab would only test sources that were involved or proposed for use on an ODOT project, but now the ODOT lab will run source compliance tests for a source not currently being used for an ODOT project as long as an ODOT source number has been assigned to the source.

The results of these source compliance tests, no matter if run by the ODOT lab or a private lab, are viewed as: ***INFORMATIONAL ONLY***. These "Informational" test results are intended to assist ODOT, contractors, consultants, or material suppliers in evaluating the quality of the aggregate potentially available in a particular source. No matter the outcome of these tests, this testing will not eliminate or reduce the need to sample and test produced material to assure compliance with project specifications.

The tests run for source compliance are normally the following:

- T84 (Fine Bulk Gravity)
- T85 (Coarse Bulk Gravity)
- T96 (Abrasion)
- T104 (Sodium Sulfate)

- T113 (Lightweight Pieces)
- T176 (Sand Equivalent)
- TM 208 (Sodium Sulfate)

In addition to these tests, ODOT also runs the following tests for informational purposes when the material may be used for MSE wall or gabion backfill or pipe bedding material:

- AASHTO T288 (Resistivity)
- AASHTO T289 (pH)
- AASHTO T291 (Chlorides)
- AASHTO T290 (Sulfates)
- AASHTO T267 (Organic content)

For gravel sources, ODOT also runs AASHTO T27 (Sieve analysis) as part of the source compliance testing. This allows for a preliminary estimation of the percent of waste material that can be anticipated.

Material proposed for use on any ODOT project must meet the requirements laid out in the **Oregon Standards Specifications for Construction** as well as the Special Provisions for the intended use or uses unless modified by the Special Provisions.

20.9. Material Source and Disposal Site Exploration Logging

The proper technique and format for logging material source explorations is described in **Chapter 4**. ODOT utilizes gINT software for the production of exploration logs. Site and exploration photos should be taken in the field at the time of the investigation. Sample and core photos should also be taken. When logging material source explorations, it is very important to note variations in the material even if there is no change in material type or geologic unit.

In gravel and cinder sources, it should be noted where there is either a noticeable change in the size of the material or in the grading. In gravel sites, it is also important to note whether or not a coating exists on the gravel, and if so, what it consists of.

In quarries, where the overall material type may not change it is still important to note minor differences such as the percent of vesicles, RQD, joint spacing, whether or not the joints are open or closed, and what the in-filling material is if open jointed.

Unit weight changes can also be an important variation that should be noted.

Any groundwater encountered should be noted, and if possible, distinguished from core drill water through checks against draw down or slug tests.

All of these subtle, and in some cases seemingly minor, variations may impact the development of the site for the proposed material use, and will only be obtainable with the proper investigation and logging of the explorations.

Logging holes for proposed material source requires close attention to details.

Another element that differs between material sources and disposal site investigations versus the more common geotechnical hole logging procedures and processes is the locating of various explorations. It is common for material source exploration to take place in advance of any type of formal topographic or other site survey work at a source. In many sources, no identifiable features

exist from which to reference hole locations. As such, it is common practice to number each hole, place a survey stake at each location, and to obtain a GPS reading at each exploration hole at the time of exploration. This location information can be used later to assist the survey crew with locating or accurately placing the exploration locations on the overall site maps when surveyed with precise survey-grade equipment. With the recent availability of resource-grade GPS units such as a Trimble GeoXT or GeoXH, the locations of drill holes and other features can be obtained using these devices, as long as sub-meter accuracy is acceptable.

Note:

GPS receivers used in locating material sources, disposal sites, and exploration site locations should have the datum set to WGS 84 for latitude/longitude and elevation, and International feet for Northing and Easting. Coordinates should be displayed as decimal degrees (D.D°) or degrees/ minutes/seconds (D°M'S") only.

In addition to the GPS readings at every exploration location, a sketch map should be produced showing each hole location and dimensions and direction between holes, again to assist in the accurate placement of hole locations on the detailed site map.

20.10. Material Source and Disposal Site Mapping

Detailed and accurate surface characterization is just as important in material source and disposal site development as the accurate subsurface geologic characterization. Therefore, it is very important to have a high quality, three-dimensional topographic map that includes site features such as drainages, springs, existing roads, fences and property/permit boundaries, as well as the surface contours showing the general land form and any significant changes in slope gradient.

The survey will be based on the Local Datum Plane based on NAD83 and NAVD 88. At least one position, placed on site but out of any development area, will have 1983 Oregon State Plane Coordinates calculated and reported on the face of the map. This position will be a 5/8" x 30" iron rod or the equivalent. Accuracy shall be such as can be achieved by using the NGS OPUS positioning service. In addition, a narrative related to the survey needs to be included that details who did the survey work, exactly what was done, where and when it was completed, and how the work was performed. Included in this narrative should be information regarding which bench marks were used for elevation control, what was used to control the boundary work, and the scale factor between the latitude/longitude and the surveyed local datum plane. The narrative should be placed on the produced map in the area where the north arrow and scale bar is located.

Source design and development plans completed without this level of mapping (digitized features and topographic lines from USGS maps, topographic features collected with resource or recreational grade GPS units, and/or plans developed in GIS) will result in substandard work, and carry with it a much higher degree of risk with a greater potential for construction claims resulting from the inaccurate portrayal of the site features and topography.

In addition to topographic surveying, the site may need to have a boundary survey completed. Boundary work should be completed in accordance with the ODOT Geometronics ***Monumentation Policy***.

20.11. Design and Development of Material Sources and Disposal Sites

The investigation work, survey work, and environmental clearances come together in the design phase of the material source and disposal site development. A conceptual design should be formulated in advance of the investigation work, and then modified as needed based on the results of

the investigation and clearances. With this information in hand, a source can be strategically developed to meet both the short term project needs and planned future utilization of the resource. Designing a material source requires the detailed analysis of both surface and subsurface information for maximum utilization of the resource in the most efficient and economical manner. Designing a source entry one project at a time without looking at future and long term development and reclamation will lead to poor utilization of the resources and generally lead to much higher costs in the long term. To assure best utilization of a source property or disposal site, the design should be developed and reviewed consistent with the appropriate Region's Quality Control Plan.

Material source and disposal site designs must be stamped by a Certified Engineering Geologist (C.E.G.) as per DES 05-02, the ***ODOT Policy for Document Stamping Requirements for Registered Engineers, Land Surveyors, Geologist, and Landscape Architects***. The registrant who stamps the material source design is the Professional of Record for the material source design.

20.11.1. Material Sources and Disposal Sites Slope Design

Slopes are a major consideration in all source and site developments. Final slope requirements by the Department of Geology and Mineral Industries are 1.5H:1V maximum. Slopes in gravel pits, cinder pits and most borrow sites can be developed steeper as working faces but should be reconstructed to 2H:1V or flatter for final slopes.

The flatter slopes will provide for better long term stability and for higher quality reclamation.

The maximum slope requirements imposed by DOGAMI do not differentiate between quarries and other sources, but they may allow for steeper final slopes if steep slopes occur naturally in the area and the construction of steep slopes is approved in advance.

The development of rock slopes in quarries differs slightly from those detailed in **Chapter 12**. Chapter 12 addresses rock slope development in and along transportation facilities, whereas most material source design will take place off highway, and generally will not require certain aspects of slope construction described in **Chapter 12** such as controlled blasting. Occasionally, highway road cuts will be designated as sources of material. When this occurs, the direction and guidance contained in Chapter 12 takes precedent. In quarries, benches are often required, and multiple bench development scenarios are common. In quarries, the stability of the back slopes, as well as the height of the slopes, is an important consideration in the design of the development plan. In quarries, no working face should be designed steeper than 0.25H:1V in order to prevent overhanging faces. ODOT uses 12 m (40 ft) as a target maximum height. Actual slope height and slope angle will vary depending on the geology and topography of the sites and at what stage the development of the site is in. In hard rock quarries, a standard "rule of thumb" is to design for 30-ft-wide benches, 40-ft-high slopes between benches, and 0.25H:1V slopes that will produce an overall 1H:1V slope (top of high wall to outermost toe).

20.11.2. Material Sources and Disposal Sites Designed Safety Elements

Safety is a significant concern that needs to be factored into the development and reclamation scheme for every ODOT material source and disposal site. The key site specific safety elements are listed and addressed below.

Safety Berms : Axle high safety berms are a Mine Safety and Health Administration (MSHA) requirement along high walls and elevated roadways. The approved Special Provisions call for safety berms in ODOT sites to be constructed a minimum of 1 m (3 ft) high with side slopes of 2H:1V. The footprint of the safety berms need to be considered when identifying roadway widths or clear areas

for overburden storage and working faces. The requirement for safety berms serves several purposes. They are required by MSHA; but in addition, when the operations are completed, they help to reduce potential liability by leaving the site with these safety features in place.

Ingress and Egress : Another key element in the safety of ODOT sources and disposal sites is site entrance/exits and their construction. Related to entrance/exit construction, the main concerns are sight distance, roadway width, safety berm construction, roadway grade, and stormwater control. In quarry sites, access to benches should be designed to accommodate tracked vehicles, but prevent easy access to unauthorized rubber tired vehicles. Furthermore, entrance/exit closures should be considered after the operation is completed for the sake of public safety and reduced liability. This is to address the concern of unauthorized vehicle trespass. Restricting access is intended to reduce the possibility of accidents, theft, vandalism, and illegal dumping; therefore, reducing ODOT's liability. Construction of features to control unauthorized trespass including fences, gates and other forms of entrance/exit closures should be coordinated with the appropriate ODOT Maintenance personnel. If sites have a history or potential for illegal dumping problems, ingress/egress control should be addressed during site development. For example, if fences and gates exist, provisions should be made for their maintenance or improvement. If there are no existing gates or fencing, the possibility of adding these features should be considered during site development.

Benches: Benches in quarry sites should be developed as working platforms. The minimum bench width design standard for ODOT quarries should be 10 m (30 ft). Narrower benches have been used in the past with mixed results. Frequently in quarry development, precision blasting is not used and outer edges of the benches are unstable and tend to break and fall off. With narrower bench designs, the potential for bench degradation often leads to unworkable benches for future operations. Using the wider design width allows for the inevitable degradation of the outer edge, provides room for placement of a safety berm, and will provide a stable working platform for subsequent entries. If narrower benches are specified for some reason, it needs to be recognized that it is likely they will not be usable during future operations unless controlled blasting techniques are also implemented in the site development.

20.12. Drafting of Material Source and Disposal Site Development Plans

ODOT utilizes Microstation and Inroads computer programs to model and manipulate information gathered for material sources and disposal sites. Development plan maps are drawn in Microstation, while Inroads is used in cross-section development and for quantity calculations. Material source and disposal site drawings should follow the examples available in the **ODOT Contract Plans Development Guide, Volumes 1 and 2**.

20.13. Material Source and Disposal Site Operational Specifications

Boiler plate operational specifications have been developed for material sources and disposal sites and are included in Section 00235 of the **2008 Boiler Plate Special Provisions**. The boiler plate specifications will need to be modified by the source or site designer to address project specifics and permit requirements.

20.14. Material Source and Disposal Site Quantity Calculations

In developing either material sources or disposal sites, it is important to obtain estimated project quantities from the project designers. Keep in mind as projects progress through various stages of design the quantity of material needed or in excess will likely fluctuate. It is important for the source designer to keep in contact with the project designer, especially at the various project milestones, to be aware of the current project estimates. Quantity calculations and the design of a material source or disposal site are intended to assure the source designer that there is adequate material available in the source to meet the anticipated material needs of the project or adequate space in the disposal site to accommodate material from the project.

The construction contractors are ultimately responsible for excavating adequate material to meet the project needs, factoring in the equipment that will be used, the way the products will be produced and the timing of the production.

There are many factors that influence the final quantity of material needed or generated as described below:

Shrink/Swell factors: Common shrink/swell factors for various types of material are available in many different publications. Estimated shrink/swell of an excavated material may or may not influence the design of a material source or disposal site. Estimated shrink/swell factors may be a critical element when designing a disposal site design or attempting to utilize material from a highway road cut as a material source. If there is limited space or quantity, the shrink/swell factor of the material becomes more critical.

Project materials: Regarding the materials being produced for a project, some of the factors that will influence the overall project quantities are estimated construction loss, the type of material being produced, the narrowness of the allowed gradational bands, the cleanliness requirements of the produced material, the number of different sizes of material being produced, and the characteristics of the native material. In addition, contractors will influence overall quantities required based on the equipment they bring in and how they opt to produce the required materials. These factors will all influence the overall volume of native material needed to produce the final project requirements. In general, the shrink/swell factors of the material is not a significant design consideration when designing an off-highway material source where the contractors can, within reason, adjust the size of the excavation area based on material characteristics and the planned approach to meeting the project requirements.

Volume of material: There are several factors related to the native in-place material besides shrink/swell and construction loss that need to be taken into consideration when calculating the volume of material needed for the project and designing the planned excavation area. In general, gravel sources will produce larger volumes of waste material than quarries due to increased scalping and fracture requirements. As such, when calculating quantities in a gravel pit, it is critical to have a representative sieve analysis of the native material to determine the estimated percent of loss due to the size characteristics of the native material. These factors will need to be evaluated when determining a target quantity for the designed excavation area.

Quarry sites generally produce lower volumes of waste products than gravel sites due to the natural characteristics of the material, but there are still factors that may be encountered in a quarry site that need to be taken into consideration. In some quarry sites the material infilling the joints may be of low quality and may force a contractor to scalp on a larger screen size resulting in extra waste product.

There may be zones within a flow or between different flows that are of lower quality that can be reasonably sorted and removed. These areas would need to be taken into consideration when calculating the overall quantity and source design.

Quantity calculations: Quantity calculations for material sources and disposal sites should be based on high quality three dimensional site models coupled with computer generated excavation/embankment design surfaces. For the final development concept that is used in the contract plans, there should be an accompanying computer generated design surface and text report showing the calculated quantities and which surfaces were used to develop these quantities (all products of Microstation and InRoads).

In general, for both quarries and gravel pits, development plans should be designed for an additional 10 percent over the estimated material needs of the project. This extra 10 percent within the designed excavation area is intended to cover minor quantity variations in the project, as well as a minor amount of variations such as varying overburden depth, irregular rock contacts, or increased scalping requirements over and above what is anticipated based on test results, the subsurface investigation, and the observations of the source designer.

20.15. Reclamation of Material Sources and Disposal Sites

Reclamation of material sources and disposal sites should not be considered an afterthought in the design process, or be viewed as an activity that will only take place when the site is ultimately depleted. Reclamation of mined sites are required by Oregon state law **ORS 517**. Commonly, reclamation plans for a site are a requirement in both the Department of Geology and Mineral Industries (DOGAMI) and the local agency permitting process, and are required prior to site use. How the laws and regulations are implemented and reflected in the source's development is somewhat dependent on the ownership of the property, the long term and planned post mine beneficial use for the property, and the desire of the property owner. There are different requirements for federal lands versus those that are privately or publicly owned.

As with the design of the site, reclamation should be considered in both the short and long term source plan. Certain elements of the design should take into account elements of concurrent reclamation and planning for long term reclamation. Common elements of reclamation include the salvage of overburden and/or soils, re-vegetation plans for seeding and plantings, and planning for final slope configurations and drainage within property boundaries. The overall aesthetics of the reclaimed site should be considered when designing the development and reclamation scheme. In quarry sites, reclamation blasting, coupled with redistribution of soils and subsequent seeding, can be an effective technique for reclaiming slopes.

In designing the reclamation of a disposal site, the post beneficial use of the site is a significant concern. If the future use of the site will be for the placement of a building, proper placement of the material, construction in lifts, and uniform compaction become critical in the site development. If the disposal site is in a rural area and there are no plans for use of the site for a structure, it is more desirable to leave the upper and outer several feet of the material un-compacted, irregularly shaped, and blended into the surrounding topography. This shaping, blending, and lack of compaction on the surface will allow for better re-vegetation and a more natural appearance.

The uneven, roughened surface will also help to reduce erosion. Avoid building a flat topped, rectangular shaped stockpile of disposed of material with long uniform slopes.

20.16. Material Source Blasting

Blasting is a common and necessary practice in quarry sites, and used less frequently in the development of gravel sources and disposal sites. Commonly when blasting is planned, concerns are raised by permitting agencies and neighboring land owners. When designing a material source where blasting will be required, special attention needs to be paid to the site's surroundings. The standard blasting requirements contained in the operational specifications for the material sources should be adequate if no special concerns exist. If there are environmentally sensitive areas or sensitive uses in the vicinity of the blast site, such as nesting sites, wetlands, fish bearing streams, homes, wells, utilities, or other fly rock, vibration and/or noise sensitive facilities, special provisions may need to be added to the standard blasting specifications. Several guidance documents have been developed by ODOT related to blasting and specifically blasting in quarry sites that may provide additional and needed information that are available on the Geo-Environmental website. These documents are

20.17. Material Source and Disposal Site Erosion Control

Erosion control at material sources and disposal sites represent a significant concern at some locations due to the ground disturbing nature of the activity and the potential for erosion within and off of the source. With any source or disposal site development, there will generally be large areas of disturbed soil that has the potential to result in erosion and sediment transport off of the site. Erosion control is a design element that should be considered and incorporated into the development plan for any material source or disposal site when appropriate. Storm water control is a federally mandated requirement that in Oregon is delegated to the State Department of Environmental Quality (DEQ). When storm water is specifically associated with material sources, regulation and oversight has been delegated from DEQ to the Department of Geology and Mineral Industries (DOGAMI). Erosion control measures associated with the material source or disposal site should be shown on the development plan maps for the source or site rather than the project erosion control plan sheets.

It may be necessary for the source designer to coordinate with an erosion control designer on the project when developing the site specific erosion control elements.

20.18. Material Source and Disposal Site Permitting

Permitting of material sources is a critical element in the design, development, and use of material sources. With very few exceptions, the development and use of material sites will require permits. Ownership of the property, site characteristics, hours of operation, and the proposed extent and quantities of the operation will determine which permit(s) will be required. Permit requirements and/or conditions can influence the way a site is designed and developed. Permitting agencies such as DOGAMI, local public agencies, as well as federal agencies, will require property set backs and/or buffer zones around drainage and other specific site features that will need to be taken into consideration when laying out the site development. Set back requirements will vary depending on the location of the site, other concurrent uses, and adjacent property ownership issues. Concerns over visual and noise impacts may also influence the direction and depth of development or the placement of stockpiles and berms. Similarly, groundwater, surface water drainages, and erosion control may be concerns to permitting agencies and may influence various elements of the design such as the buffers around these features, depth of the mining, and storm water control features. These concerns make it critical for a successful design to account for the site characteristics, the limitations of the site, and the likely permit restrictions while still in the design phase. If concerns are not taken into consideration early in the process, there will likely be the need for re-work of the design

prior to obtaining final approval of the permits, which may lead to a delay in obtaining the permits and impact the project schedule.

Disposal sites may also need to be permitted due to added traffic, noise impacts, hours of operation or simply due to the current zoning and the proposed action. The source/site designer will need to verify what permits if any will be required for the proposed activity. ODOT planners and local agency planners can provide information on what permits are necessary for the proposed action and may assist in completing the applications and in obtaining the needed permits.

20.19. Material Source and Disposal Site Visual Concerns

In most situations, there will be no visual concerns to address, but in some areas, the overall visual impact of a material source or disposal site will become a critical element of the design and reclamation. If visuals are a significant concern due to the location of the site or the ability of the site to be viewed from a significant scenic corridor, the impacts or the requirements associated with the visuals will need to be factored into the design and reclamation of the source. In Oregon, there are numerous areas that have varying degrees of scenic value and restrictions (e.g., the Columbia River Gorge Scenic Area, wild and scenic rivers corridors, and the many scenic highway routes). In addition to these nationally and state recognized scenic areas, there are also local scenic designations that may impact a site development. When looking at a site for proposed development, the elements of potential visual restrictions should be evaluated early in the process.

20.20. Material Source and Disposal Site Narrative Reports

Material Source or Disposal Site Narrative reports have multiple purposes. This report, stamped by a Certified Engineering Geologist, provides an opportunity to summarize all of the information that was taken into consideration as part of the site design. In the narrative, the following types of information should be included:

- Location information
- Existing utilities both underground and overhead
- Topography
- Drainage conditions
- Vegetation
- Climate
- Development plan and cross section sheets from the Contract Plans
- Operating specifications
- Regional geology
- Site specific geology
- Exploration logs
- Core or test pit photos
- Site photos
- Currently available lab test results (preferably within last 5 years)

- Groundwater conditions, springs, well locations
- Stability
- Permits and permit conditions
- Source Use History

In addition, the narrative allows the source/site designer to describe both the plan for this particular operation as well as the long term development concept. Concerns related to material characteristics, operational history, past operational problems, design elements, restrictions, and reclamation strategies can all be explained in detail. The narrative provides detailed information as well as assumptions and concerns.

Narratives are part of the contract documentation and are a requirement outlined in the operational specifications for the sources and/or disposal site and are required to be sealed by a CEG stamp. Material source and disposal site narratives are intended to be distributed to all interested contractors who are potentially preparing their bids based on the use of these sites. Therefore, the narrative report should be factual and provide a presentation of data and design assumptions based on the information gathered and considered during site development. Speculative or non-supported assumptions should not be included in the narrative. Each proposed source of materials or disposal site shall have a separate narrative report.

At this time, ODOT has no formal policy that requires that the material source or disposal site narratives be reviewed by others prior to being sealed by the Professional of Record (POR). It is currently recommended that all narratives be reviewed by a competent peer or other registered professional prior to final signatures and affixing a CEG stamp.

An example of a narrative report is available on the ODOT website titled ***Material Source Narrative Report Example***.

Material Source Narratives and Disposal Site Narratives need to be prepared and given to the Construction Project Managers Office in advance of project advertisement. The narrative(s) will be distributed to all interested contractors by the Project Managers Office and a record of who requested the information, as well as when and how it was supplied to them, will be kept and become a part of the project records.

20.21. Material Sources and Disposal Sites and Construction

During construction, it is common for questions to arise regarding the source/site development. The Professional of Record (POR) should be available for source/site visits to review and decide upon proposed modifications to the design or to address other development issues.

During construction, at a minimum, the POR, or an alternate, should plan to be involved with the on-site Pre and Post work meetings. If blasting is required for source development, the POR or alternate would be required for the review of the blast plan and any subsequent modifications of the blast plan. It may also be necessary, depending on how source or site development progresses, for the POR or alternate to witness and document the loading and actual blast(s), and attend other on site meetings to address requested design changes.

The construction project manager should provide a written post construction source or site evaluation to the POR. Information contained within the evaluation should be quantities of material produced or disposed of. It should also include discussion of any problems encountered during site development and/or issues related to the materials produced. If changes were made to source or site development

due to conditions encountered, these changes and the reasons for the changes should be noted in the evaluation. A form is available on the website titled ***Material source Post-Construction Report for Public and Private Sources.***

20.22. Material Source Numbering

ODOT has an established numbering system for material source sites. This source numbering system provides each and every site that has been, or is currently, recognized as a potential source of materials for ODOT projects with a unique material source number regardless of material type, ownership, or location. Source numbers are used to match site specific information with material quality information. These source numbers are used by the ODOT Materials Laboratory in Salem for connecting material test results to the source where the material came from. Matching of test results and source numbers allow for the tracking of site history.

The numbering convention used by ODOT is as follows: **ODOT Source # OR - 07- 003 - 4**

> 1st two characters are letters that represent the state in which the site is located, for example OR for Oregon, CA for California, WA for Washington, ID for Idaho, and NV for Nevada.
>
> 2nd two characters are a numeric County code; a two digit county code has been issued for each county in each state that ODOT has recognized sources in.
>
> 3rd is a three character unique numeric identifier. This three character identifier is automatically assigned to the source when placing the information into the Aggregate Source Information System (ASIS) database.
>
> 4th character represents the ODOT region that the source exists in or the ODOT region that is closest to the neighboring state where the site is located.

For the example shown above, the number given indicates that the site is located in the State of Oregon (**OR)** and in Crook County (**07**) , with a unique source number of 003 (**003**) and is located in ODOT Region 4 (**4**).

Material Source numbers can only be issued by ODOT personnel who have been given computer privilege to do so. These permissions have been limited to those who work in the Geology Units assigned to each Region, and to the Statewide Material Source staff.

If a new Source Number is Needed

If a new site or an existing site that has not previously been issued a source number is identified, the process to get a number assigned to the site is rather simple. The appropriate Region geology staff should be contacted. They will provide a list of information that will need to be supplied in advance of the issuance of a source number. Once the site specific information is supplied to the Region geology staff, the information can be entered into the system and a source number assigned to the site.

20.23. Asset Management for Material Sources: Inventory, Evaluate and Record

Asset management has become a key focus for ODOT. Material sources and sites used for disposal have been recognized as extremely valuable assets in ODOT's inventory. ODOT owns or controls approximately 1500 material sources located along, or in close proximity, to the State's transportation system. Managing these resources is a multifaceted effort starting with the inventory and evaluation of these sites. Information gathered about the State's material sources is recorded into a database system, that represents the primary tool used in managing these assets.

The Aggregate Source Information System (ASIS) is a SQL Server database with a user friendly Intranet web based input front end. Each material source, based on their unique source number, is an individual record with approximately one hundred individual data fields available per record. Several data fields are identified as required in each record prior to the system allowing for the record to be saved. Most of the required fields are associated with ownership and location data. Other data fields in each record are optional and may not apply to each source.

Similar to the issuing of source numbers, data input and editing of the database information is restricted to a few personnel within ODOT, primarily region Geology Unit staff members and Statewide Material Source staff who have been given the responsibility for site evaluation, inventory and updating these records. Access to the information contained within the database is available for review and use by any and all ODOT employees. A link to the ASIS database is available on the ODOT Intranet Material Sources page.

Individual source records contained in ASIS are constantly being updated whenever additional information is obtained for a source. The ASIS database is also undergoing periodic upgrades with additional data fields and functionality.

An ODOT application for collecting physical features within material sources using ArcPad has been developed and is available from the ODOT GIS Unit. All data collected with this application for material sources is tied to the same unique source number contained within the ASIS database. The data collected in the field is downloaded and stored in the ODOT Enterprise Geodatabase and displayed in ArcMap.

With the development of the ArcPad application for materials sources, ODOT now has the GIS database for physical features found in material sources, tied to the ASIS database containing the non physical data for these sources. Coupled together, these two databases, and the information contained within them, are used to more effectively manage the ODOT Material Source assets.

Additional tools have been developed to assist ODOT staff in completing site evaluations. One such tool is the ***Significant Site Evaluation Form*.** Through the use of this tool and others, ODOT staff are able to evaluate an individual source or site for its' individual value and the value of this site within the framework of the ODOT Material Source Network. From these evaluations, ODOT staff can determine if a source or site requires permitting work to protect it for current or future use, or if the property is a candidate to be disposed of. In addition to these efforts, ODOT staff can effectively identify areas around the state where the network of sources/sites is either deficient of sources/sites, or deficient for specific needs, and take the proper steps to correct these deficiencies.

Through effective Asset Management and proper development and permitting of material sources and disposal sites, ODOT can assure the wisest and most efficient use of these resource properties to the benefit of the traveling public and the tax payers.

20.24. References

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Chapter

21

21. Geotechnical Reporting and Documentation

21.1. General

ODOT geotechnical engineers, engineering geologists and consultants working on ODOT projects, produce geotechnical reports, engineering geology reports and other various design memorandums, documents and products in support of project definition, project design, and final PS&E development. Also produced are project specific Special Provisions, plan details, boring logs, Geotechnical and Foundation Data Sheets and the final project geotechnical documentation. Information developed to support these geotechnical documents are retained in the regional Tech Center files. The information includes project site data, regional and site specific geologic data, exploration logs, field and laboratory test results, instrumentation and monitoring data, interpretive drawings, design calculations, and construction support documents. This chapter provides standards for the development, content and review of these documents and records, with the exception of borings logs, which are covered in **Chapter 4** and Materials Source Reports, which are covered in **Chapter 20**.

Project geotechnical documentation and records produced by ODOT staff, and consultants working on ODOT projects, shall meet, as applicable, the informational requirements listed in the following FHWA manual:

- *FHWA, 2003, Checklist and Guidelines for Review of Geotechnical Reports and Preliminary Plans and Specifications, Publication No. FHWA ED-88-053*, Updated edition.

A copy of this manual can be obtained and downloaded from the Geo-Environmental web site. The FHWA manual includes "Geotechnical Report Review Checklists", covering the main information and recommendations that should be addressed in project geotechnical reports. In addition to these FHWA checklists, the ODOT checklist provided in **Appendix 21-A Geotechnical Report Review Checklist** covers additional items that should be included in the review of all bridge foundation design projects. These checklists should be used as the basis for evaluating the completeness of the final geotechnical or engineering geology reports and products.

21.2. General Reporting Requirements

In general, all geotechnical design recommendations should be documented with either a hard copy to the project file or an email record. Verbal recommendations that influence contract plans or specifications or result in design changes should be followed up with a formal document. It is recognized that some geotechnical recommendations may involve very minor design or construction issues and therefore minimal review or documentation is required. The level of review and documentation depends on the type and complexity of the design or construction issue and the

experience and qualifications of the engineer performing the work. It is the responsibility of each Region Technical Center to establish the quality control procedures and protocol, and the levels of review and documentation required, for all geotechnical work produced by its office.

A geotechnical document (either a design memorandum or standard report) is required for most highway projects involving any significant geotechnical design elements such as earthwork, landslides or rock slopes, or structure foundations. When geotechnical design is required for a project, this work should be documented in the form of either technical memoranda or reports which summarize the work performed and the resulting design recommendations and products. For reports that cover individual project elements, a geotechnical design memorandum may suffice, with the exception of bridge reports and major unstable slope repair projects, in which case a formal geotechnical report should be issued.

E-mail may be used for geotechnical reporting and for providing recommendations in certain circumstances. E-mails may be used to transmit review of construction submittals or to transmit preliminary foundation or other preliminary geotechnical recommendations. In both cases, a print-out of the e-mail should be included in the project file. For time critical geotechnical designs sent by e-mail that are not preliminary, the e-mail should be followed up with a stamped memorandum or report as soon as possible. A copy of the e-mail should also be included in the project file.

21.3. Quality Control

Quality control of geotechnical design work should be an ongoing process occurring regularly throughout the entire design process. Each Region Tech Center is responsible for the quality control of the geotechnical products produced in its region. These products should adhere to the ODOT geotechnical standards of practice established and defined in the *ODOT Geotechnical Design Manual*.

21.3.1. Quality Control for Bridge Foundation Design

For most routine bridge foundation design projects, the subsurface investigation program, materials classification and testing, recommended foundation type, design calculations, design recommendations, special provisions, reports and foundation data sheets should all be thoroughly reviewed by an independent geotechnical engineer with intimate knowledge of the project. This review should be thorough enough to verify and confirm all design assumptions and calculations leading to the recommendations made in the report. Important geologic interpretations made for foundation design purposes should be reviewed and approved by a Certified Engineering Geologist (CEG), and noted so by stamping and sealing the final geotechnical report. All design memorandum and geotechnical reports should be stamped and sealed by the appropriate Professional of Record (POR), registered in the state of Oregon, whose area of expertise is in geotechnical engineering. Each of these documents shall also be signed by the reviewer.

Foundation Data Sheets may be stamped by either a registered engineer (PE) or a Certified Engineering Geologist (CEG). All Foundation Data sheets must be independently checked by a qualified geotechnical engineer or engineering geologist familiar with the project. If the Foundation Data sheet is stamped by a CEG, it must be reviewed (checked) by the project geotechnical engineer. It should be understood that the Foundation Data Sheet is an important contract document that is sometimes used in the resolution of contract claims submitted by contractors under the Differing Site Conditions clause (Section 00140.40). Therefore, the person stamping the Foundation Data Sheet should have a complete understanding of what is being constructed based on the data sheet and how the data sheet information can effect the foundation construction, contract bidding and claim potential.

21.4. Geotechnical Report Content Requirements

The geotechnical information and types of recommendations that should be provided in geotechnical reports or memorandum is provided in the sections that follow. Both preliminary (TS&L) reports and final reports are addressed.

21.4.1. Preliminary Geotechnical Reports

Preliminary geotechnical reports are typically used to provide geotechnical input for the following:

- Developing the project definition,
- Development of TS&L bridge plans,
- Conceptual geotechnical studies for environmental permit development activities,
- Reconnaissance level corridor studies,
- Development of EIS discipline studies, and
- Rapid assessment of emergency repair needs (e.g., landslides, rockfall, bridge foundation scour, etc.).

Preliminary geotechnical reports are often developed primarily based on an office review of existing geotechnical data for the site, and generally consist of feasibility assessment, identification of geologic hazards and preliminary recommendations. Geotechnical design for preliminary reports is typically based largely on engineering judgment and experience at the site, or similar sites, combined with whatever existing geologic and geotechnical information is available. At this stage (especially for bridge projects), a geological reconnaissance of the project site has usually been conducted and in some cases a subsurface exploration program is in progress and some preliminary geotechnical analysis can be performed to characterize key elements of the design, assess potential hazards, evaluate potential design alternatives and estimate preliminary costs.

These preliminary geotechnical reports should contain the following information as applicable to the project. Refer to **Section 21.4.1.1** for additional preliminary report requirements related to bridge foundations.

- A general description of the project, project elements, and project background.
- A brief summary of the regional and site geology. The amount of detail included here will depend on scope of the project. For example, a landslide repair project will require a more detailed discussion of the site and regional geology than a routine bridge replacement project.
- A summary of the available site data, including as-built information.
- A summary of the field exploration conducted, if applicable.
- A summary of the laboratory testing conducted, if applicable.
- A description of the project soil and rock conditions. The amount of detail included here will depend on the type of report. For projects in which new borings have been obtained, soil profiles for key project features (e.g., bridges, major walls, etc.) may need to be developed and tied to this description of project soil and rock conditions.
- A summary of geological hazards identified that may affect the project design (e.g., landslides, rockfall, debris flows, liquefaction, soft ground or otherwise unstable soils, seismic hazards, etc.), if any.

- A summary of the preliminary geotechnical recommendations.
- Appendices that include any boring logs and laboratory test data obtained (old or new), soil profiles developed, any field data obtained, and any photographs.

21.4.1.1 TS&L Geotechnical Reports for Bridge Foundation Projects

For bridge foundation design projects, a preliminary geotechnical report (TS&L Memo) should be provided to the bridge designer early on in the design process. Maintain close communication and coordination with the bridge designer to see when this information is required. As a general rule, the memo should be provided no later than two-thirds of the way through the TS&L design process. The purpose of this memo is to provide sufficient data for developing TS&L plans and cost estimates and for permitting purposes. The memo is generally provided before the subsurface investigation is completed but may contain some subsurface information, such as preliminary drilling results, performed up to that date. It provides a brief description of the proposed project, the anticipated subsurface conditions (based on existing geologic knowledge of the site, as-built plans and records and other existing information) and presents preliminary foundation design recommendations such as foundation types and preliminary resistances. The rational for selecting the recommended foundation type should be presented. T he potential for liquefaction and associated effects should also be discussed as well as any other geologic hazards that may affect design.

The document should be stamped by the geotechnical engineer (POR) and also the project engineering geologist if significant geologic interpretations or other geologic input were used in developing the recommendations. The memo may be distributed in the form of an email message or a full report depending on the size and scope of the project. If the memo is distributed by email a hard copy should also be printed out, sealed and dated by the engineer, and placed in the project file.

Note:

The TS&L memo does not meet the requirements of a final Geotechnical Report, which is required for all bridge projects involving foundation work.

21.4.2. Final Geotechnical Reports

In general, final geotechnical reports are developed based on an office review of existing geotechnical data for the site, a detailed geologic review of the site, and a complete subsurface investigation program, meeting AASHTO and FHWA standards. Design analysis are then conducted based on the results of the field investigation work, combined with any insitu or laboratory test data, and the resulting design recommendations are included in the geotechnical report along with construction recommendations and project special provisions as appropriate.

Geotechnical reports for bridge foundation design projects are used to communicate and document the site and subsurface conditions along with the foundation and construction recommendations to the structural designer, specifications writer, construction personnel and other appropriate parties. The importance of preparing a thorough and complete geotechnical report cannot be overemphasized. The information contained in the report is referred to during the design phase, the pre-bid phase, during construction, and occasionally in post-construction to assist in the resolution of contractor claims.

21.4.2.1 Minimum Information in Final Geotechnical Reports

The following reporting guidelines are provided for use in developing the final Geotechnical Report. Also refer to the Geotechnical Report Review Checklist in **Appendix 21-A Geotechnical Report Review Checklist** for guidance on the general format and information that should be contained in Geotechnical Reports specific to structure foundations. Include all items below that apply to the project.

- **Description:** A general description of the project scope, project elements, and project background.
- **Surface conditions**: Project site surface conditions and current use.
- **Regional and site geology:** This section should describe the site stress history and depositional/erosional history, bedrock and soil geologic units, etc.
- **Regional and site seismicity:** This section should identify the major seismic sources affecting the site including nearby active faults. This section is generally only included in reports addressing structural elements (e.g., bridges, walls, etc.) and major earthwork projects. For bridges the information listed under Item 16 should be provided. Refer to **Chapter 6** for additional seismic design criteria that may be required.
- **Summary of in-house data:** A summary of the in-house data collected on the site (office research), including final construction records for previous construction activity at the site, as-built bridge drawings or other structure layouts, pile records, boring or test pit logs or other subsurface information, geologic maps or previous or current geologic reconnaissance results.
- **Summary of field exploration:** A summary of the field exploration conducted, if applicable. Provide a description of the methods and standards used, as well as a summary of the number and types of explorations and field testing that were conducted. Include a plan map (or data sheet) in the appendix showing the locations of all explorations. Also include a description of any field instrumentation installed and its purpose, data and results. Provide exploration logs in the report appendices along with any other field test data such as cone penetrometer, pressuremeter), vane shear tests or shear wave velocity profiles.
- **Summary of Laboratory testing:** A summary of the laboratory testing conducted, if applicable. Provide a description of the methods and standards used as well as a summary of the number and types of tests that were conducted. Provide the detailed laboratory test results in the report appendices.
- **Soil and rock materials and subsurface conditions:** This section should include not only a description of the soil/rock units encountered, but also how the units are related at the site. The soil and rock units should also be discussed in terms of the relevance and influence the materials and conditions may have on the proposed construction. Groundwater conditions should be described in this section of the report, including the identification and discussion of any confined aquifers, artesian pressures, perched water tables, potential seasonal variations, if known, any influences on the groundwater levels observed, and direction and gradient of groundwater, if known. The groundwater elevation is a very important item and should be provided in the report. T he measured depth of groundwater levels, and dates measured, should be noted on the exploration logs and discussed in the report. It is important to distinguish between the groundwater

level and the level of any drilling fluid. Also, groundwater levels encountered during exploration may differ from design groundwater levels. Any artesian or unusual groundwater conditions should be noted as this often has important effects on foundation design and construction.

- **Rock information:** If rock slopes are present, discuss rock structure, including the results of any field structure mapping (use photographs as needed), joint condition, rock strength, potential for seepage, etc.

Subsurface Profiles

These descriptions of soil and rock conditions should always be illustrated with subsurface profiles (i.e., parallel to roadway centerline) and cross-sections (i.e., perpendicular to roadway centerline) of the key project features.

Note:

A subsurface profile or cross-section is defined as a graphical illustration that assists the reader of the geotechnical report to visualize the spatial distribution of the soil and rock units encountered in the borings for a given project feature (e.g., structure, cut, fill, landslide, etc.).

Cross sections and profiles along certain features, such as landslides, may be needed to fully convey the site conditions and subsurface model. These profiles and cross sections help to define a geologic model of the subsurface materials and conditions. As such, the profile or cross-section will contain the existing and proposed ground line, the structure profile or cross-section if one is present, the boring logs (including SPT values, soil/rock units, etc.), and the location of any water table(s). Interpretive information should be provided in these illustrations, as appropriate, to adequately and clearly describe and depict the subsurface geologic model. The potential for variability in any of the stratification shown should also be discussed in the report.

Geotechnical or Foundation Data Sheet

A Geotechnical or Foundation Data sheet should always be provided for bridges, retaining walls, tunnels, and other significant structures. For retaining walls, subsurface data sheets should always be provided for soil nail walls, anchored walls, and non-gravity cantilever walls, and all other walls in which there is more than one boring along the length of the wall. For other wall situations, judgment may be applied to decide whether or not a data sheet is needed. For cuts, fills, and landslides, soil profiles should be provided for features of significant length, where multiple borings along the length of the feature are present. Subsurface cross-sections must always be provided for landslides, and for cuts and fills that are large enough in cross-section to warrant multiple borings to define the subsurface cross-section.

Provide a summary of geological hazards identified and their impact on the project design (e.g., landslides, rockfall, debris flows, liquefaction, soft ground or otherwise unstable soils, seismic hazards, etc.), if any. Describe the location and extent of the geologic hazard.

For analysis of unstable slopes (including existing settlement areas), cuts and fills, provide the following:

- Analysis approach,
- Assessment of failure mechanisms,
- Determination of design parameters, and
- Any agreements within ODOT or with other customers regarding the definition of acceptable level of risk.

Included in this section, would be a description of any back-analyses conducted, the results of those analyses, comparison of those results to any laboratory test data obtained, and the conclusions made regarding the parameters that should be used for final design.

Geotechnical Recommendations for Earthwork

Provide a summary of geotechnical recommendations for earthwork (embankment design, cutslope design, drainage design, use of on-site materials as fill). This section should provide the following recommendations as applicable to the project:

- Embankment design recommendations, such as the maximum embankment slopes, allowed for stability and any measures that need to be taken to provide a stable embankment (e.g., geosynthetic reinforcement, wick drains, staged embankment construction, surcharge, light weight materials, etc.).
- Estimated embankment settlement and settlement rate, along with any recommendations for mitigating excess post construction settlement. Include any recommendations for foundation improvement (subexcavation) such as the need for removal of any unsuitable materials beneath the proposed fills and the extent of these areas.
- Cutslope design recommendations, including the maximum cut slopes allowed to maintain the required stability. Recommendations for control of seepage or piping, erosion control measures and any other special measures (such as horizontal drains) required to provide a stable slope should be provided.
- Regarding the use of on-site materials, on-site soil units should be identified as to their feasibility for use as embankment material, discussing the type of material for which the on-site soils are feasible, the need for aeration, the effect of weather conditions on their usability, and identification of on-site materials that should definitely not be used in embankment construction. The degradation potential of rock materials should be identified and discussed, as appropriate.

Geotechnical Recommendations for Rock Slopes and Rock Excavation

Provide geotechnical recommendations for rock slopes and rock excavation. Such recommendations should include, but are not limited to the following:

- Recommended rock slope design and fallout area (if appropriate),
- Rock scaling,
- Rock bolting/dowelling, and other stabilization requirements (if appropriate), including recommendations to prevent erosion/undermining of intact blocks of rock,
- Internal and external slope drainage requirements,
- Feasible methods of rock removal such as blasting or ripping.
- Detailed plans and cross sections as needed to clearly depict the areas requiring rock slope stabilization and the methods and designs recommended.

Geotechnical Recommendations for Stabilization of Unstable Slopes

Provide geotechnical recommendations for stabilization of unstable slopes (e.g., landslides, rockfall areas, debris flows, etc.). This section should provide the following information and recommendations as appropriate:

- A discussion of the mitigation options available,
- Detailed recommendations regarding the most feasible options for mitigating the unstable slope,
- A discussion of the advantages, disadvantages, and risks associated with each feasible option,
- Cost estimates for each option should also be included, as appropriate.

Geotechnical Recommendations for Bridges, Tunnels and Structures

Provide geotechnical recommendations for bridges, tunnels, hydraulic structures, and other structures. See **Section 21.7** for additional information required for bridge foundation designs. This section should provide the following minimum information:

- Discussion of foundation options considered,
- Recommended foundation options, and the reason(s) for the selection of the recommended option(s),
- Foundation design recommendations:
- For strength limit state – nominal and factored bearing resistance, lateral and uplift resistances,
- For service limit state - settlement limited bearing, and any special design requirements,
- For extreme event limit state – nominal bearing, uplift, and lateral resistance, and soil spring values,

Seismic Design Parameters and Recommendations

Provide the following for seismic design parameters and recommendations:

- Peak Horizontal Ground Acceleration (PGA), 0.20 and 1.0 second spectral accelerations for the bridge site from the 2002 USGS seismic hazard maps fro the 500 and 1000-year events
- Site Class and Soil Coefficients (F_{pga}, F_a, F_v)
- Design Response Spectrum (from General Procedure or Ground Response Analysis)

Summary of Liquefaction Analysis

Provide a summary of liquefaction analysis. If liquefaction is predicted, provide:

- Estimates of embankment deformations including predicted settlement and lateral displacements,
- An assessment of potential bridge damage and approach fill performance for both the 500 and 1000 year events,
- Estimates of seismic-induced downdrag loads (if applicable),
- Soil properties for both the liquefied and non-liquefied soil conditions, for use in the lateral load analysis of deep foundations,
- Reduced foundation resistances,

- Liquefaction mitigation design recommendations (if necessary),
- Results of ground response analysis (SHAKE) and site-specific response spectra (if applicable)
- Design recommendations for scour, when applicable,
- Earth pressures on abutments and walls in buried structures

Geotechnical Recommendations for Retaining Walls and Reinforced Slopes

Provide geotechnical recommendations for retaining walls and reinforced slopes. This section should provide a discussion of:

- Wall/reinforced slope options and the reason(s) for the selection of the recommended option(s),
- Foundation type and design requirements:
  - For strength limit state - ultimate bearing resistance, lateral and uplift resistance if deep foundations selected,
  - For service limit state - settlement limited bearing, and any special design requirements,
  - Seismic design parameters and recommendations (e.g., design acceleration coefficient, extreme event limit state bearing, uplift and lateral resistance if deep foundations selected) for all walls except for ODOT Standard Retaining Walls,
  - Design considerations for scour when applicable,
  - Lateral earth pressure parameters (provide full earth pressure diagram for non-gravity cantilever walls and anchored walls).

Non-Proprietary Walls and Reinforced Slopes

For non-proprietary walls/reinforced slopes requiring internal stability design (e.g., geosynthetic walls, soil nail walls, all reinforced slopes), provide the following:

- Minimum width for external and overall stability,
- Embedment depth,
- Bearing resistance,
- Settlement estimates,
- Soil/rock adhesion values,
- Soil reinforcement spacing, strength, and length requirements in addition to dimensions to meet external stability requirements,
- For anchored walls, provide achievable anchor capacity, no load zone dimensions, and design earth pressure distribution.

Proprietary Walls

For proprietary walls, provide the following:

- Minimum width for overall stability,
- Embedment depth,

- Bearing resistance,
- Settlement estimates,
- Design parameters for determining earth pressures.

Geotechnical Recommendations for Traffic Structures, Soundwalls and Buildings

Provide geotechnical recommendations for traffic structures, soundwalls and buildings. This section should provide the following minimum information:

Provide the following foundation information:

- Discussion of foundation options considered
- Recommended foundation options, and the reason(s) for the selection of the recommended option(s),
- Foundation design recommendations.

For mast arm signal and strain poles provide soils information required for the Broms method. This includes soil type (cohesive or cohesionless), unit weight, soil friction angle or undrained shear strength and groundwater level. Provide the highest groundwater level anticipated at any time during the life of the structure.

Sites Conditions that Do Not Use Broms Method

If site conditions do not allow the use of the Broms method, provide soils information required for the LPile or strain-wedge analysis methods as appropriate,

- For structures that have standard foundation design drawings, provide the site-specific soil designation (i.e. “Good”, “Average” or Type “A” or “B”, etc.) for use with the standard drawing. Also provide recommendations on whether or not the foundation soils and site conditions meet all requirements shown on the standard drawing, such as slope limits and settlement criteria. If soil or site conditions are variable along the length or under the foundation, clearly delineate these areas on a plan map and provide recommendations for each delineated area.

Conditions that Do Not Meet Requirements for Using Standard Drawings

If the foundation materials or site conditions do not meet the requirements for using the standard drawings, such as conditions of hard rock or very soft, “Poor” soils, provide soil unit descriptions, soil properties, groundwater information and other design recommendations as required for design of the foundation to support the proposed structure. This includes the following information as a minimum:

- Description of the soil units using the ODOT Soil & Rock Classification System.
- Ground elevation and elevations of soil/rock unit boundaries.
- Depth to the water table.
- Soil design parameters, including effective unit weight(s), cohesion, φ, K_a, K_p, and/or P-y curve or strain-wedge data as appropriate.
- The allowable bearing capacity for spread footings and estimated wall or footing settlement (and differential settlement) as appropriate.
- Overall stability factor of safety.

- Any foundation constructability issues resulting from the soil/rock or groundwater conditions.

Special Provisions that May Be Required for Non-Standard Foundation Designs

Provide information relating to construction recommendations and any special provisions that may be required for non-standard foundation designs. This may include things such as sub-excavation, backfill and compaction requirements, blasting specifications or the use of temporary casing for drilled shafts. Provide the following information:

For buildings provide the following as appropriate:

- Nominal or ultimate bearing capacities and associated resistance factors or factors of safety as appropriate.
- Settlement calculations and the amount of total allowable and differential settlement described for the structure.

Provide recommendations regarding permanent cut and fill slopes, temporary slopes, stabilization of unstable ground, ground improvement and retaining wall recommendations including:

- Any foundation constructability issues resulting from the soil/rock or groundwater conditions.
- Earthwork recommendations, including recommendations for fill or cut slopes, material requirements, compaction, ground stabilization or improvements and provisions for drainage as applicable.

Long-Term or Construction Monitoring Needs

In this section, provide recommendations on the types of instrumentation needed to evaluate long-term performance or to control construction, the reading schedule required, length of monitoring period, how the data should be used to control construction or to evaluate long-term performance, and the zone of influence for each instrument.

In relation to construction considerations, address issues of construction staging, shoring needs and potential installation difficulties, temporary slopes, potential foundation installation problems, earthwork constructability issues, dewatering, etc.

Appendices

Typical appendices include all exploration logs of borings, test pits and any other subsurface explorations (including older exploration logs), Geotechnical and/or Foundation Data Sheets, design charts for foundation bearing and uplift, P-y curve input data, design detail figures, layouts showing boring locations relative to the project features and stationing, subsurface profiles and typical cross-sections that illustrate subsurface stratigraphy at key locations, laboratory test results, instrumentation measurement results, and special provisions needed.

Note:
The detail contained in each of these sections will depend on the size and complexity of the project or project elements and the subsurface conditions. In some cases, design memoranda that do not contain all of the elements described above may be developed prior to developing a final geotechnical report for the project.

21.5. Bridge Foundation Data Sheets

A Foundation Data Sheet is typically required for each bridge project that involves foundation construction. The Foundation Data Sheet should provide an accurate and detailed presentation of the subsurface conditions at the project site. The data sheet represents a compilation and condensation of the information contained on the project exploration logs and is included in the contract documents, usually as the second sheet in the bridge plans, behind the Plan and Elevation sheet for the structure. All subsurface information that would significantly affect foundation construction should be clearly shown on the data sheet. This may include important subsurface information known to exist at the site but not necessarily encountered or identified in any of the subsurface borings for the project. However, since these are contract documents, the information presented on Foundation Data sheets should remain factual in nature. Interpretive information, assumptions or extrapolation of geologic data should generally not be shown.

Include rock compressive strength test results in the table of rock core for each boring, if available. If pressuremeter or cone penetrometer tests were performed, show the locations of these tests on the data sheet and provide a reference for obtaining the test data. Make a note of any non-standard tests such as oversized SPT samples. A Foundation Data sheet should be provided in the Final Geotechnical Report for all bridges and for retaining walls attached to bridges (bridge abutment walls). Refer to the *Bridge Design and Drafting Manual (Section II)* for drafting guidelines for the data sheet.

21.6. Project Special Provisions

The final geotechnical report should also include all applicable special provisions for the project related to the geotechnical work. Coordinate with bridge, roadway and other designers as appropriate to make sure all necessary special provisions related to the geotechnical aspects of the project are supplied. Consult with the "owner" of the special provisions if any major changes are to be made. Supply additional information in the project special provisions as necessary that further describes specific geotechnical conditions that may affect the contractor's work and bid. Sections typically requiring input from the geotechnical engineer include 00300, 00510, 00512, 00520, and 00596.

Some unique geotechnical special provisions can be obtained (internal to ODOT) at the following location:

scdata\geosite\G-H Geotech Common\GEO-SPECIFICATIONS

These are project-specific specifications that are not often used but are available for use as templates or examples for developing specifications for unique geo-applications.

21.7. Additional Reporting Requirements for Structure Foundations

The geotechnical designer should provide the following additional information to the structural designer for Load and Resistance Factor Design (LRFD) of structure foundations:

21.7.1. Spread Footings

If spread footings are recommended, provide the following information in the geotechnical report:

- For Footing Elevations, the elevations of the proposed footings should be provided along with a clear description of the foundation materials the footings are to be constructed on and minimum cover requirements.

- Specify whether or not the footings are to be keyed into rock. Check with the bridge designer to see if a "fixity" condition is required in rock. On sloping rock surfaces, work with the structural designer to determine the best "bottom-of-footing" elevations.
- Provide the unfactored nominal bearing resistance available for the strength and extreme event limit states,
- Provide the settlement limited nominal bearing resistance for the specified settlement (typically 1 inch) for various effective footing widths likely to be used for the service limit state, and
- Provide resistance factors for each limit state.

  The allowable footing/wall settlement is a function of the structure type and performance criteria and the structural designer should be consulted to establish allowable structure settlement criteria.

Calculations

The calculations should assume that the nominal resistance for the strength and extreme limit state (q_n) and the nominal resistance at the service limit state (q_{serv}) resist uniform loads applied over effective footing dimensions B' and L' (i.e., effective footing width and length [(B or L) - 2e] as determined using the Meyerhof method for soil). For footings on rock, the calculations should assume that q_n and q_{serv} resist the peak footing stress resulting from a triangular or trapezoidal pressure distribution rather than uniform distribution. Minimum footing setback on slopes and embedment depths should be provided in the report

To evaluate sliding stability and eccentricity, the geotechnical designer provides resistance factors for both the strength and extreme event limit states for calculating the shear and passive resistance in sliding. Also the soil parameters φ, K_p, γ, K_a, and K_{ae} are provided for calculating the passive and active resistances in front of and behind the footing.

To evaluate soil response and development of forces in foundations for the extreme event limit state, the geotechnical designer provides the foundation soil/rock shear modulus values and Poisson's ratio (G and μ). These values should typically be determined for shear strain levels of 0.02 to 0.2%, which span the strain levels for typical large magnitude earthquakes.

The geotechnical designer evaluates overall stability and provides the maximum (unfactored) footing load which can be applied to the design slope and still maintain an acceptable safety factor (typically 1.5 for the strength and 1.1 for the extreme event limit states, which is the inverse of the resistance factor). A uniform bearing stress, as calculated by the Meyerhof method, should be assumed for this analysis. Example presentations of the LRFD footing design recommendations to be provided by the geotechnical designer are shown in **Table 21-1**, **Table 21-2**, and **Table 21-3** and **Figure 21-1**.

Table 21-1. Example presentation of soil design parameters for sliding and eccentricity calculations.

Parameter	Abutment Piers	Interior Piers
Soil Unit Weight, γ (soil above footing base level)	x	x
Soil Friction Angle, Φ (soil above footing base level)	x	x
Active Earth Pressure Coefficient, K_a	x	x
Passive Earth Pressure Coefficient, K_p	x	x
Seismic Earth Pressure Coefficient, K_{ae}	x	
Soil Unit Weight, γ (soil above footing base level)	x	x

Table 21-2. Example presentation of resistance factors for footing design

Resistance Factor, φ			
Limit State	**Bearing**	**Shear Resistance to Sliding**	**Passive Pressure Resistance to Sliding**
Strength	x	x	x
Service	x	x	x
Extreme Event	x	x	x

21.7.2. Pile Foundations

21.7.2.1 Bearing Resistance

The geotechnical designer provides information regarding pile resistance using one of the following two approaches:

A plot of the unfactored nominal bearing resistance (R_n) as a function of depth for various pile types and sizes (for strength and extreme event limit states). This design data would be used to determine the feasible ultimate pile resistance and the estimated depth for pile quantity determination. See **Figure 21-2** for an example of this pile data presentation.

Given a required R_n, the estimated depth at which it could be obtained is provided for one or more selected pile types and sizes. See **Table 21-5** for an example.

Resistance factors for bearing resistance for all limit states will also be provided (see **Table 21-4** for an example).

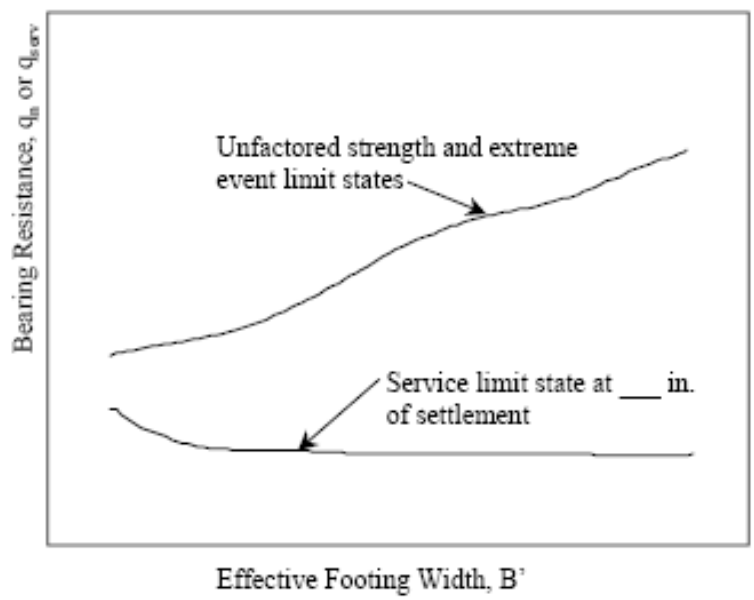


Figure 21-1. Example presentation of bearing resistance recommendations.

Table 21-3. Example presentation of bearing resistance recommendations.

Bent	Footing Size	Footing Elev.	R_n	ϕ	ϕR_n

Table 21-4. Example presentation of resistance factors for pile design.

Resistance Factor, φ		
Limit State	**Bearing Resistance**	**Uplift**
Strength	x	x
Service	x	x
Extreme Event	x	x

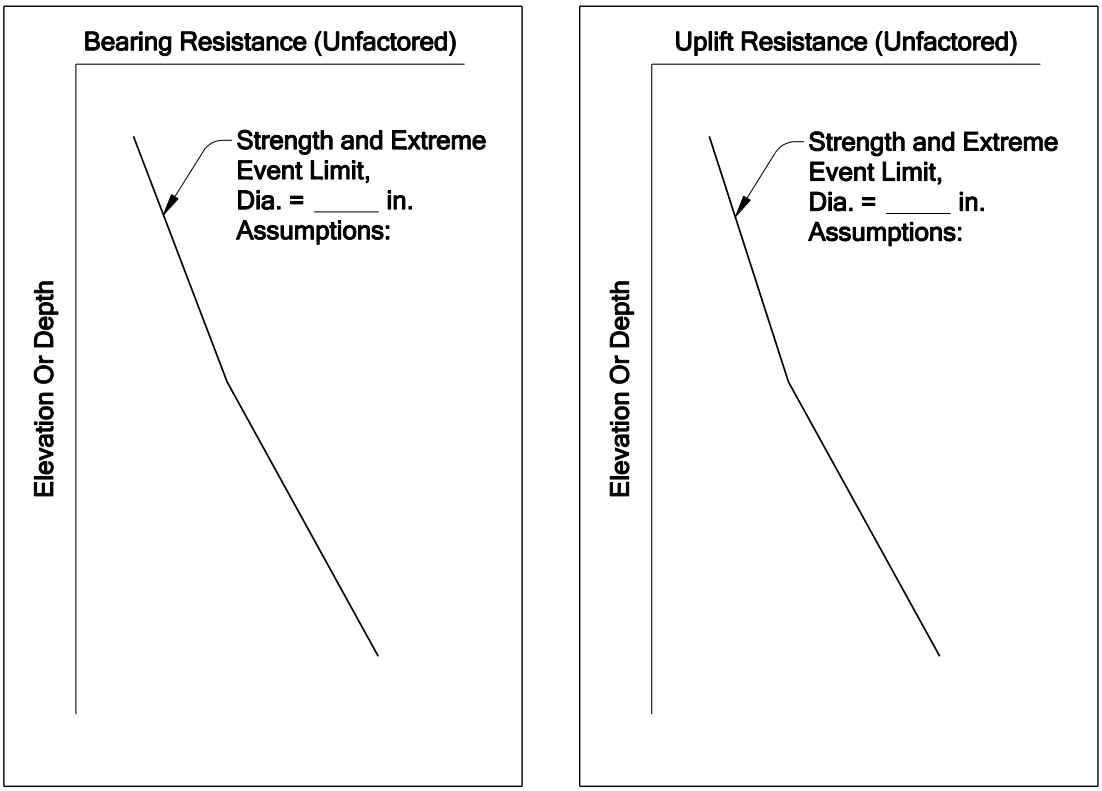


Figure 21-2. Example presentation of pile bearing resistance and uplift.

Once R_n is known (or the total driving resistance, R_{ndr}, if applicable) and the cutoff elevation of the piles is obtained from the bridge designer, then the "Engineers Estimated Length" can be determined for steel piles. The Engineer's Estimated Lengths are required in the project special provisions for each bridge bent. The table format below is as example of how this information should be presented.

The table should be modified as necessary to account for reduced capacities due to scour, liquefaction, downdrag or other conditions.

Table 21-5. Pile Resistances & Estimated Lengths (Br. 12345)
Pile Type: PP16x0.50"

Bent	Rn (kips)	φRn (kips)	C.O. Elev. (ft.)	Est. Tip Elev. (ft.)	Engr's Est. Length, (ft.)	Req'd. Tip Elev. (ft.)
1	450	180	210	130	80	150
	350	140	210	145	65	150
2	450	180	170	120	50	135
	350	140	170	130	40	135
3	450	180	200	125	75	140
	350	140	200	135	65	140

Legend & Table Notes:

R_n = Nominal pile bearing resistance

φR_n = Factored pile bearing resistance

C.O. = Pile cutoff elevation

21.7.2.2 Downdrag

If downdrag loads are estimated, the following should be provided:

- Ultimate downdrag load, DD,
- Depth of the downdrag zone, or thickness of the downdrag layer,
- Downdrag load factor,
- Cause of the downdrag (settlement due to vertical stress increase, liquefaction, etc.).
- Also the total driving resistance, R_{ndr}, (the required nominal resistance), taking into account the downdrag loads should be provided.

21.7.2.3 Scour

If scour is predicted, the depth of scour and the skin friction lost due to scour, R_{scour}, should be provided. The total driving resistance, R_{ndr}, (the required nominal resistance), taking the loss of friction due to scour into account, should be provided.

21.7.2.4 Uplift Resistance

For evaluating uplift, the geotechnical designer should provide the following:

- As a function of depth, the nominal (unfactored) uplift resistance, R_n. This should be provided as a function of depth, or as a single value for a given minimum tip elevation, depending on the project needs.
- The skin friction lost due to scour or liquefaction to be applied to the uplift resistance curves should also be provided (separately, in tabular form).

- Resistance factors should also be provided for strength and extreme event limit states.

The geotechnical designer should also provide group reduction factors for bearing resistance and uplift if necessary, as well as the associated resistance factors, but these will be rarely needed.

21.7.2.5 Lateral Resistance

The geotechnical designer should provide the soil parameters necessary to develop P-y curves and perform the lateral load analysis. The P-y curve soil input data should be provided as a function of depth. Resistance factors for lateral load analysis do not need to be provided, as the lateral load resistance factors will typically be 1.0.

The P-y soil/rock parameters provided should be in a format for easy insertion into the LPile or COM624 programs. The parameters required are typically those required for the LPile proprietary computer program. The *LPile Manual* or the manual titled *Laterally Loaded Pile Analysis Program for the Microcomputer; FHWA-SA-91-048 (COM624P)* should be referenced for more information. It is important that the geotechnical designer maintain good communication with the structural designer to determine the kind of soil parameters necessary for the lateral load analysis of the structure. If liquefaction of foundation soils is predicted, soil parameters should be provided for both the liquefied and non-liquefied soil conditions. **Table 21-6** is an example format for presenting the required data for a non-liquefied soil condition.

Table 21-6. Soil Parameters for Lateral Load Analysis (non-liquefied soil condition).

Bents 1 & 3

ELEVATION (ft.) From	To	KSOIL*	K (lbs/in^3)	SOIL PARAMETERS γ,(pci)	c,(psi)	e_{50}	φ	SOIL DESCRIPTION
63.5	55.0	3	500	0.06	3.5	.007	--	Sandy Clayey Silt to Silty Clay (fill)
55.0	30.0	2	1000	0.07	13	.005	--	Silt w/ trace sand & clay to Clayey Silt, low plasticity
30.0	10.0	2	2000	0.072	20	.004	--	Clay to Silty Clay, med.-high plasticity, very stiff

* KSOIL is a COM624P term referenced to soil types. For the LPile program provide the appropriate soil type from the default types listed in LPile or provide custom P-y curves if necessary.

If lateral loads imposed by special soil loading conditions such as landslide forces are present, the ultimate lateral soil force or stress distribution, and the load factors to be applied to that force or stress, should be provided.

21.7.2.6 Required Pile Tip Elevation for Minimum Penetration

Provide a required pile tip elevation for piles at each bent. The required tip elevation represents the highest acceptable tip elevation that will still provide the required resistances and performance under all loading conditions. The required tip elevation (sometimes referred to as “Minimum Tip Elevation”) is typically based on one or more of the following conditions:

- Pile tip reaching the required bearing layer or depth,
- Providing required uplift resistance,

- Providing required embedment for lateral support,
- Satisfying settlement and/or downdrag criteria,
- Providing sufficient embedment below scour depths or liquefiable layers.

The required pile tip elevations provided in the Geotechnical Report may need to be adjusted depending on the results of the lateral load or uplift load evaluation performed by the structural designer. If adjustments in the required tip elevations are necessary, or if changes in the pile diameter are necessary, the geotechnical designer should be informed so that pile drivability and resistance recommendations can be re-evaluated. The required tip elevation may require driving into, or through, very dense soil layers resulting in potentially high driving stresses. Under these conditions a wave equation driveability analysis is necessary to make sure the piles can be driven to the required embedment depth (tip elevation) without damage.

21.7.2.7 Pile Tip Reinforcement

Specify steel pile tip reinforcement if piles are to be driven through very dense granular soils containing cobbles and boulders or for penetration into weak rock. Pile points (H-piles) or shoes (pipe piles) are typically specified. In pipe pile driving conditions where difficult driving through dense sand and gravel is anticipated before reaching the required tip elevation, inside-fit pipe pile shoes are sometimes used to help retard the formation of a soil plug at the pile tip. *Section 02520 of the Standard Special Provisions* must be included in the project specifications for specifying the proper steel grade for pile tip reinforcement and other requirements. Also note that outside-fit pile tip reinforcement (points or shoes) can reduce the friction resistance and this effect should be taken into account in design before specifying outside fit tips or shoes.

21.7.2.8 Pile Splices

Provide the number of anticipated pile splices that might be needed due to variability of the subsurface conditions. This number of splices should be included as a bid item in the contract documents. ODOT pays for splices when piles have to be driven a certain length over the Engineer's Estimated Length. Refer to *ODOT Standard Specification 00520.87* and *00520.91* for the criteria used to determine measurement and payment for pile splices.

21.7.2.9 Pile Driving Criteria and Acceptance

The method of construction control and pile acceptance must be specified in the report for each project. All piles should be accepted based on field measured pile driving resistances, established by the FHWA dynamic formula, wave equation analysis, PDA/signal matching methods or static load test criteria.

Note:
ODOT typically uses the dynamic formula or wave equation method for most projects.

The pile driving analyzer (PDA) with signal matching (CAPWAP) is also sometimes used on projects where it is economically justified. Full scale static load tests are rarely performed but are recommended for large projects where there is potential for substantial savings in foundation costs. If necessary, use the following tests:

FHWA Gates Equation: For LRFD design the default dynamic formula used to establish pile driving criteria is the FHWA Gates Equation. When using this equation a resistance factor of 0.40 is applied to the nominal bearing resistance to determine the factored resistance.

Wave Equation Analysis Program (WEAP): Wave Equation driving criteria is generally used for the following situations:

- Nominal pile resistances greater than of 600 kips.
- Where driving stresses are a concern (e.g., short end-bearing piles or required penetration through very dense strata).
- Very long friction piles in granular soils

A resistance factor of 0.40 is applied to the nominal bearing resistance to determine the factored resistance. When the wave equation method is specified, the contractor is required to perform a wave equation analysis of the proposed hammer and driving system and submit the analysis as part of the hammer approval process. The soils input criteria necessary for the contractor to perform the WEAP analysis needs to be supplied in a table in Section 00520 of the contract special provisions. An example of a completed table that would be provided in the geotechnical report (and special provisions) is shown below.

Table 21-7. Example of a completed table.

Bridge 12345; Bents 1 & 2

Pile Type	Pile Length (ft.)	Quake (in.)		Damping (in./sec.)		Friction Distribution (ITYS)	IPRCS (Note 2)	R_n (kips)
		Skin	Toe	Skin	Toe			
PP16 x 0.50	85.0	0.10	0.15	0.20	0.20	Note 1	95	620

Note:

Use a rectangular distribution of skin resistance over the portion of the pile under ground.

IPRCS is the percent skin friction (percent of R_n that is skin friction in the WEAP analysis).

Refer to the *Standard Special Provisions for Section 00520* for additional specification requirements. Provide WEAP input data for the highest (worst-case) driving stress condition, which may not always be for the pile at the estimated tip elevation.

Pile Driving Analyzer (PDA): Large pile driving projects may warrant the use of dynamic pile testing using a pile driving analyzer for additional construction quality control and to save on pile lengths. Generally the most beneficial use of PDA testing is on projects with large numbers of very long, friction piles driven to high resistance. However, there may be other reasons for PDA testing such as high pile driving stress conditions, testing new pile hammers, questionable hammer performance or to better determine the pile skin friction available for uplift resistance. A resistance factor of 0.65 can be applied to the nominal bearing resistance determined by PDA if an adequate number of production piles are tested. *AASHTO Article 10.5.5.2.3* should be referenced for the procedures to use for PDA/CAPWAP pile acceptance. A signal matching (CAPWAP) analysis of the dynamic test data should always be performed to determine the axial capacity and to calibrate the PDA resistance prediction methods. Case methods may be used for determining the nominal bearing resistance providing it is calibrated with the dynamic test signal matching analysis. The piles should be tested after a waiting period if pile setup or relaxation is anticipated.

Special provisions for past PDA/CAPWAP projects are available on the ODOT "GEOSITE" on the scdata2 server (internal to ODOT only) at the following address:

scdata2\Geosite\G-H Geotech Common\GEO-SPECIFICATIONS

21.7.3. Drilled Shafts

To evaluate bearing resistance, the geotechnical designer provides, as a function of depth and for various shaft diameters, the unfactored nominal (ultimate) bearing resistance for end bearing, R_p, and side friction, R_s, used to calculate R_n, for strength and extreme event limit state calculations (see example figures below). For the service limit state, the unfactored bearing resistance at a specified settlement, typically 0.5 or 1.0 inch (mobilized end bearing and mobilized side friction) should be provided as a function of depth and shaft diameter. See **Figure 21-3** for an example of the shaft bearing resistance information that should be provided. Resistance factors for bearing resistance for all limit states should also be provided.

Downdrag

If downdrag loads are estimated, the following should be provided:

- The depth of the downdrag zone, or thickness of the downdrag layer,
- The ultimate downdrag load, DD, as a function of shaft diameter,
- The downdrag load factor,
- The loss of skin friction due to downdrag,
- The cause of the downdrag (settlement due to vertical stress increase, liquefaction, etc.).

21.7.3.1 Scour

If scour is predicted, the depth of scour and the skin friction lost due to scour, Rscour, should be provided.

21.7.3.2 Uplift Resistance

For evaluating uplift, the geotechnical designer provides, as a function of depth, the nominal uplift resistance. The skin friction lost due to scour or liquefaction to be applied to the uplift resistance curves should be provided (separately, in tabular form). Resistance factors should also be provided. The geotechnical designer also provides group reduction factors for bearing resistance and uplift if necessary, as well as the associated resistance factors.

21.7.3.3 Lateral Resistance

Provide soil input values for the LPile or COM624P program as described in **Section 21.7.2.5**. Resistance factors for lateral load analysis generally do not need to be provided, as the lateral load resistance factors will typically be 1.0.

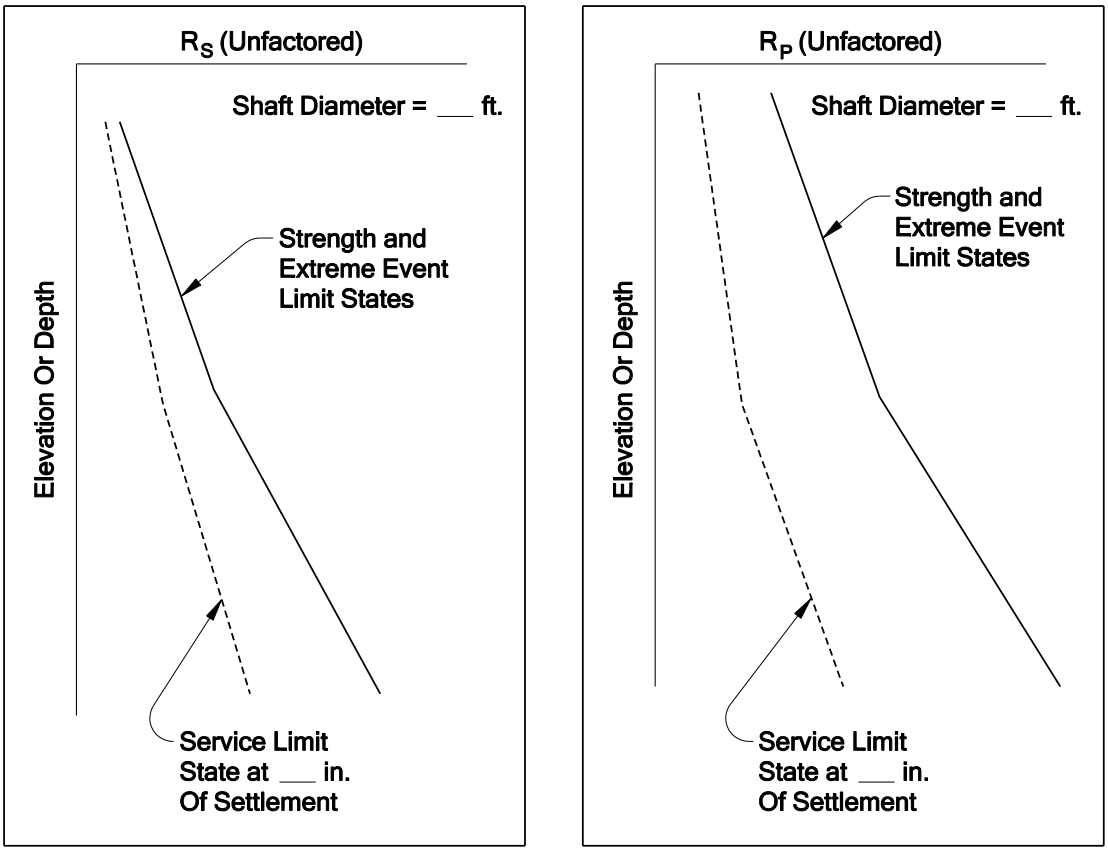


Figure 21-3. Typical shaft bearing resistance plots (all limit states).

21.7.3.4 Crosshole Sonic Log Testing

Access tubes for crosshole sonic log (CSL) testing are typically provided in all drilled shafts unless otherwise recommended by the geotechnical designer. Typically, one tube is provided per foot of shaft diameter with a minimum of 3 tubes provided per shaft.

The amount of CSL testing needs to be determined for each project and should be provided in the special provisions (Section 00512.42). Specify the minimum number of CSL tests to be conducted and the location of these tests. The actual number of tests can be increased, if necessary, during construction depending on the contractor's work performance. The amount of testing that should be performed depends on the subsurface conditions, the redundancy of the foundation system and the contractor's work performance. The first shaft constructed is always tested to confirm the contractor's construction procedures and workmanship. Subsequent tests should be based on the following guidelines and good engineering judgment:

- Test every single-shaft bent
- Minimum of 1 CSL test per bent (or shaft group) or 1/10 shafts

Also consider:

- Redundancy in the substructure/foundation
- Soil conditions (potential construction difficulties like caving soils, ground swelling, and boulders)
- Groundwater conditions (wet holes, artesian conditions)

See **Chapter 18**.

21.7.3.5 Shaft Reinforcement Lengths in Rock Socket Applications

As described in **Chapter 8**, provide the following in the Geotechnical Report:

- The additional length(s) of shaft reinforcement needed to account for the uncertainty in the top of the bearing layer for rock socket applications.
- Also, include these additional reinforcement lengths in Section 00512 of the project Special Provisions.
- Drilled shaft equipment must also be provided that is capable of drilling the full extra shaft length. This requirement must also be included in the project Special Provisions. Refer to the *ODOT Standard Special Provisions for Section 00512* for further guidance and details.

21.7.4. Geotechnical Report Checklist for Bridge Foundations

The Geotechnical Report Review Checklist in **Appendix 21-A Geotechnical Report Review Checklist** should be used to check the content and completeness of geotechnical reports prepared for bridge foundation projects. The checklist should be completed by the Professional-of-Record for the project. The checklist questions should be completed by referring to the contents of the geotechnical report. For each question, a yes, no, or not applicable (N/A) response should be provided. A response of "I don't know" to any applicable section on the checklist is not to be shown with a check in the "Not Applicable" (N/A) column. All checklist questions answered with “NO” should be fully explained.

A copy of the completed checklist, and all comments and explanations, should be included with the geotechnical report when submitted for review to ODOT.

21.7.5. Geotechnical Report Distribution

Geotechnical reports for bridges or other structure foundations should be distributed to the following personnel:

- Structure Designer
- Roadway Designer
- Specification Writer
- Project Leader
- Project Manager (more copies if requested for contractors)
- Hydraulic Engineer (if appropriate)
- Project Geologist
- HQ Bridge Engineering Section

Note:
For large projects, or projects with unusual or especially difficult foundation construction issues, consider putting the complete geotechnical report, including exploration logs, laboratory data, foundation data sheets and rock core photos, on an ODOT web page for easy access for contractors.

21.7.6. Retaining Walls

To evaluate bearing resistance for footing-supported gravity walls, the geotechnical designer provides q_n, the unfactored nominal (ultimate) bearing resistance available, and q_{serv}, the settlement limited bearing resistance for the specified settlement for various effective footing widths (i.e., reinforcement length plus facing width for MSE walls) likely to be used (see **Figure 21-4**). Resistance factors for each limit state are also provided. The amount of settlement on which q_{serv} is based shall be stated. The calculations should assume that q_n and q_{serv} will resist uniform loads applied over effective footing dimension B' (i.e., effective footing width (B - 2e)) as determined using the Meyerhof method for soil). For footings on rock, the calculations should assume that q_n and q_{serv} will resist peak loads and that the stress distribution is triangular or trapezoidal rather than uniform. The geotechnical designer also provides wall base embedment depth requirements or footing elevations to obtain the recommended bearing resistance.

To evaluate sliding stability, bearing, and eccentricity of gravity walls, the geotechnical designer provides:

- Resistance factors for both the strength and extreme event limit states for calculating the shear and passive resistance in sliding,
- Soil parameters φ, K_p, γ and depth of soil in front of footing to ignore when calculating passive resistance,
- Soil parameters φ, K_a, and γ used to calculate active force behind the wall,
- Coefficient of sliding, $\tan\varphi$,
- Seismic earth pressure coefficient K_{ae} and the peak ground acceleration (PGA) used to calculate seismic earth pressures and,
- Separate earth pressure diagrams for strength and extreme event (seismic) limit state calculations that include all applicable earth pressures, with the exception of traffic barrier impact loads (traffic barrier impact loads are developed by the structural designer).

The geotechnical designer should evaluate overall stability. If overall stability controls the required wall width, the designer should provide the minimum footing or reinforcement length required to maintain an acceptable safety factor (typically 1.5 for the strength and 1.1 for the extreme event limit states, which is the inverse of the resistance factor, i.e., 0.65 and 0.9, respectively). A uniform bearing stress as calculated by the Meyerhof method should be assumed for this analysis.

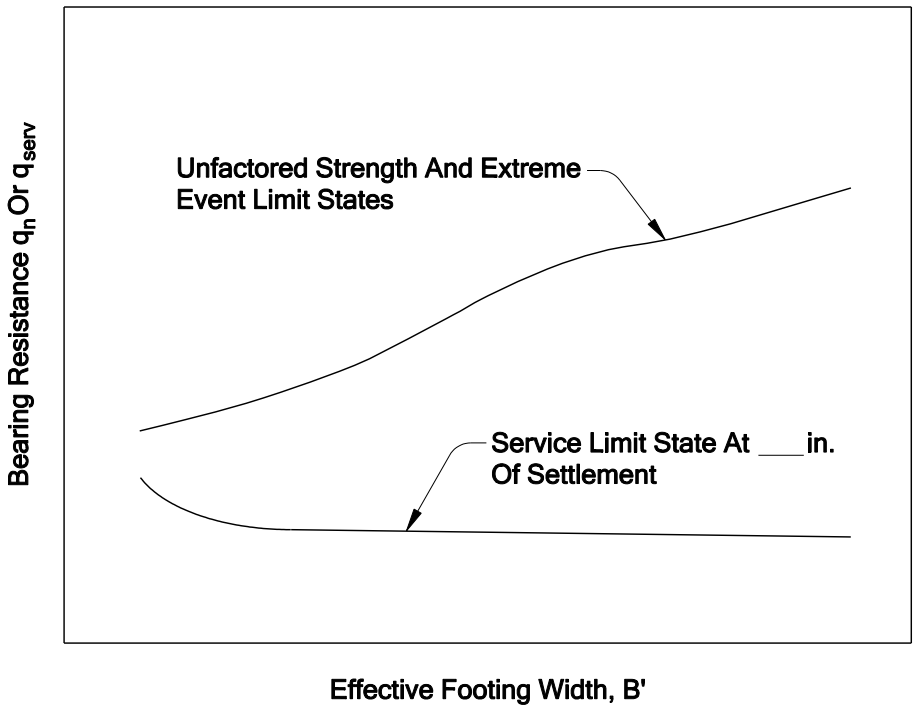


Figure 21-4. Example of bearing resistance recommendations for gravity walls

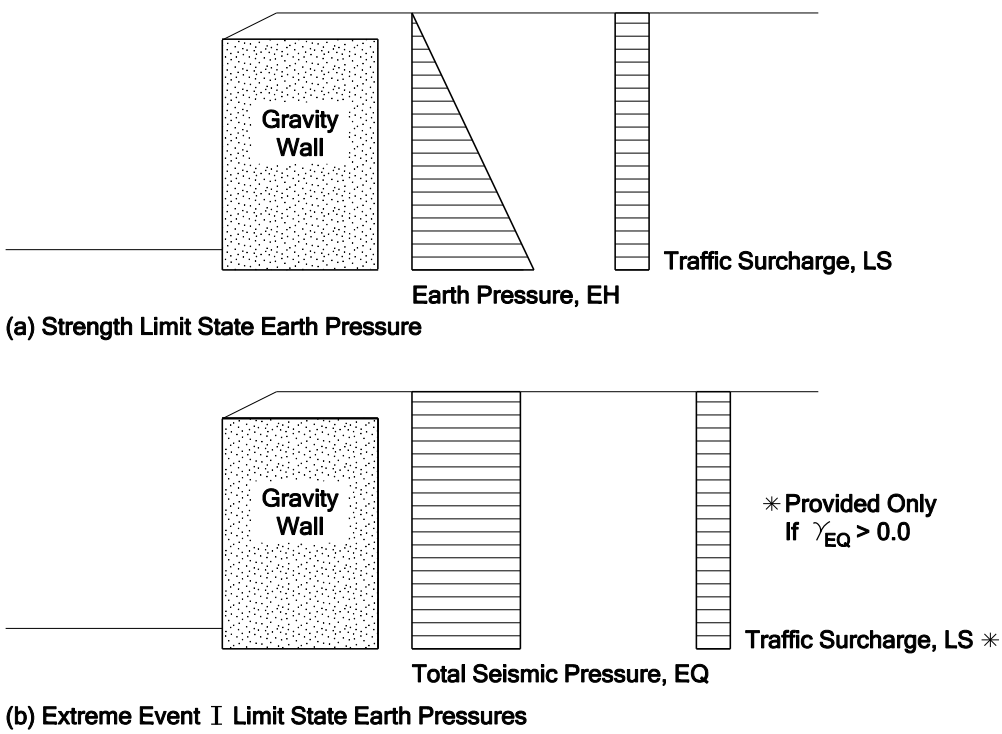


Figure 21-5. Example of lateral earth pressures for gravity wall design

For non-proprietary MSE walls, the spacing, strength, and length of soil reinforcement should also be provided, as well as the applicable resistance factors. MSE reinforcement properties should be specified in the special provisions for *Section 02320*. Spacing and length requirements may also be best illustrated using typical cross sections.

For non-gravity cantilever walls and anchored walls, the following should be provided:

- Ultimate bearing resistance of the soldier piles or drilled shafts as a function of depth (see **Figure 21-3**),
- Lateral earth pressure distribution (active and passive),
- Minimum embedment depth required for overall stability,
- No load zone dimensions,
- Ultimate anchor resistance for anchored walls, and the associated resistance factors.

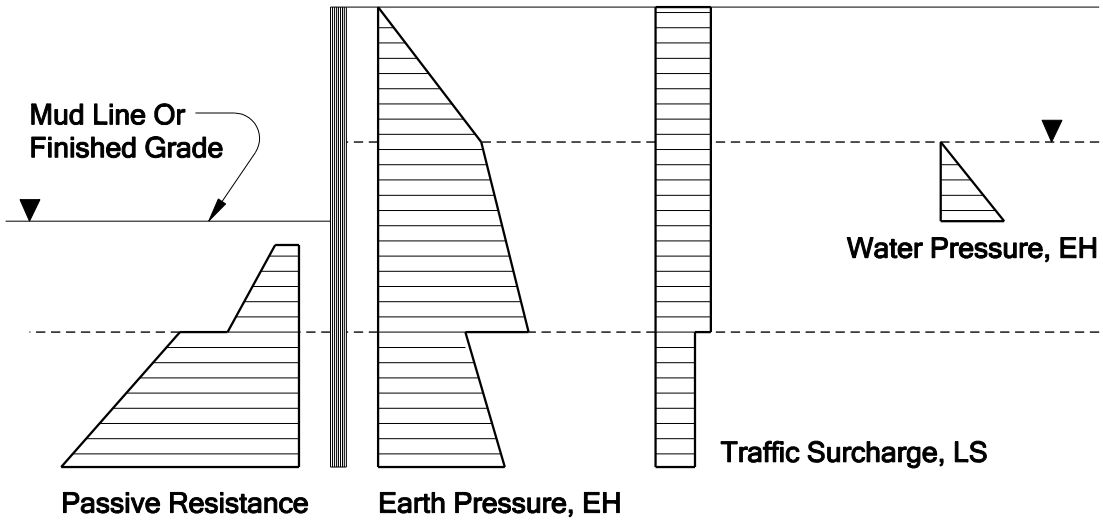
Table 21-8 and **Figure 21-6** provide an example presentation of soil design parameters and earth pressure diagrams for non-gravity cantilever and anchored walls to be provided by the geotechnical designer.

Table 21-8. Example presentation of soil design parameters for design of non-gravity cantilever walls and anchored walls.

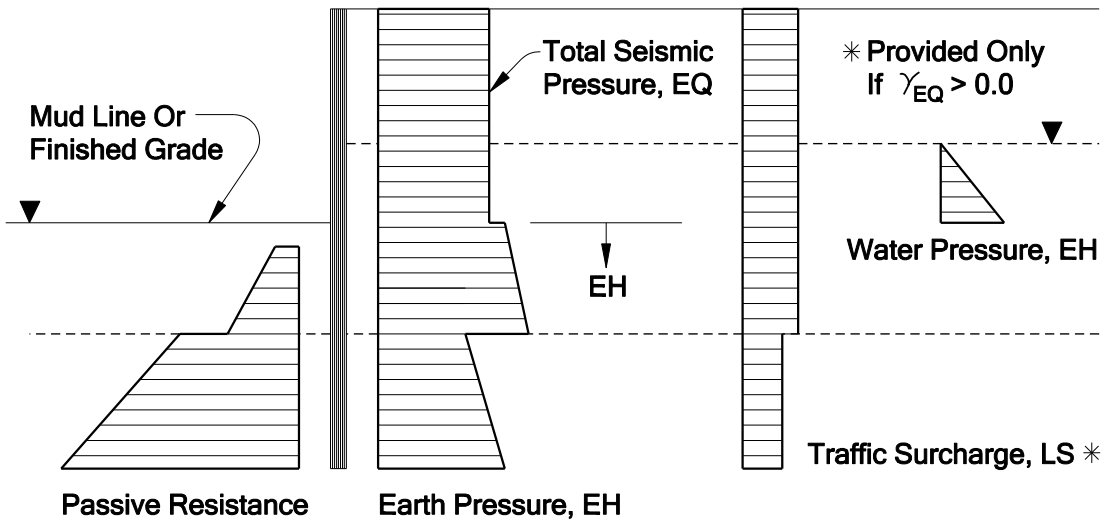
Parameter	Value
Soil Unit Weight, γ (all applicable strata)	x
Soil Friction Angle, Φ (all applicable strata)	x
Active Earth Pressure Coefficient, K_a	x
Passive Earth Pressure Coefficient, K_p	x
Seismic Earth Pressure Coefficient, K_{ae}	x
Averaged γ used to determine K_{ae}	x
Averaged Φ used to determine K_{ae}	x

21.8. Geotechnical Design File Information

Documentation that provides details of the basis of recommendations made in the geotechnical report or memorandum is critical not only for review by senior staff, but also for addressing future questions that may come up regarding the basis of the design, to address changes that may occur after the design is completed, to address questions regarding the design during construction, to address problems or claims, and for important information for developing future projects in the same location, such as bridge or fill widenings. Since the engineer who does the original design may not necessarily be the one who deals with any of these future activities, the documentation must be clear and concise, and easy and logical to follow. Anyone who must look at the calculations and related documentation should not have to go to the original designer to understand what was done.



(a) Strength Limit State Earth Pressures



(b) Extreme Event I Limit State Earth Pressures

Figure 21-6. Example presentation of lateral earth pressures for non-gravity cantilever and anchored wall design.

The project documentation should be consistent with FHWA guidelines and as set forth in this chapter. Details regarding what this project documentation should contain are provided in the following sections.

21.8.1. Documentation for Preliminary Geotechnical Design

Document sources of information (including the date) used for the preliminary evaluation. T ypical sources include as-built bridge or other structure drawings, as-constructed roadway drawings, existing test hole logs, geologic maps, previous or current geologic reconnaissance results or previous site investigation work and instrumentation data. Also document the following:

- If a geologic reconnaissance was conducted, the details of that site visit, including any photos taken, should be included in this documentation.
- For structures, provide a description of the foundation support used for the existing structure, including design bearing capacity, if known, and any foundation capacity records such as pile driving logs, load test results, etc.
- From the contract or maintenance records, summarize any known construction or maintenance problems encountered during construction or throughout the life of the structure. Examples from the construction records include over-excavation depth and extent, and why it was needed, seepage observed in cuts and excavations, dewatering problems, difficult digging, including obstructions encountered during excavation, obstructions encountered during foundation installation (e.g., for piles or shafts), slope instability during construction, changed conditions or change orders involving the geotechnical features of the project, and anything else that would affect the geotechnical aspects of the project.
- For any geotechnical recommendations made, summarize the logic and justification for those recommendations. If the recommendations are based on geotechnical engineering experience and judgment, describe what specific information led to the recommendation(s) made.

21.8.2. Documentation for Final Geotechnical Design

In addition to the information described above in **Section 21.7.1**, the following information should be documented in the project geotechnical file:

1. List or describe all given information and assumptions used, as well as the source of that information. For all calculations, an idealized design cross-section that shows the design element (e.g., wall, footing, pile foundation, buttress, rock slope, etc.) located in context to the existing and proposed ground lines, and the foundation soil/rock should be provided. T his idealized cross-section should show the soil/rock properties used for design, the soil/rock layer descriptions and thicknesses, the water table location, the existing and proposed ground line, and any other pertinent information. For slope stability, the soil/rock properties used for the design should be shown (neatly handwritten, if necessary) on the computer generated output cross-section.
2. Additional information and/or a narrative should also be provided which describes the basis for the design soil/rock properties used. If the properties are from laboratory tests, state where the test results, and the analysis of those test results, can be found. If using correlations to SPT or cone data, state which correlations were used and any corrections to the data made.
3. Identify what is to be determined from these calculations (i.e. what is the objective?). For example, objectives could include foundation bearing resistance, foundation or fill settlement (differential and total), time rate of settlement, the maximum cut or fill slope allowed, the size of a stabilizing buttress or berm required, etc.

4. The design method(s) used must also be clearly identified for each set of calculations, including any assumptions used to simplify the calculations, if that was done, or to determine input values for variables in the design equation. Write down equation(s) used and the meaning of the terms used in equation(s), or reference where equation(s) used and/or meaning of terms were obtained. Attach a copy of all curves or tables used in making the calculations and their source, or appropriately reference those tables or figures. Write down or summarize all steps needed to solve the equations and to obtain the desired solution.
5. If using computer spreadsheets, provide detailed calculations for one example to demonstrate the basis of the spreadsheet and that the spreadsheet is providing accurate results. Hand calculations are not required for well proven, well documented programs such as XSTABL, SLOPE/W, SHAKE2000 or GRLWEAP. Detailed example calculations that illustrate the basis of the spreadsheet are important for engineering review purposes and for future reference if someone needs to get into the calculations at some time in the future. A computer spreadsheet in itself is not a substitute for that information.
6. Highlight the solutions that form the basis of the engineering recommendations to be found in the project geotechnical report so that they are easy to find. Be sure to write down which locations or piers where the calculations and their results are applicable.
7. Provide a results summary, including a sketch of the final design, if appropriate.

Each set of calculations (for each structure) should be sealed and dated by the professional-of-record. If the designer is not registered, the reviewer should seal and date the calculations. Consecutive page numbers should be provided for each set of calculations and each page should be initialed by the reviewer.

A copy of the appropriate portion of the FHWA checklist for geotechnical reports (i.e., appropriate to the project) should be included with the calculations and filled out as appropriate. This checklist will aid the reviewer regarding what was considered in the design and to help demonstrate consistency with the FHWA guidelines.

21.8.3. Geotechnical File Contents

The geotechnical project file(s) should contain the information necessary for future users of the file to understand the historical geotechnical data available and all the geotechnical work that was performed as part of this project. This would include the scope of the project, the dimensions and locations of the project features, the geotechnical investigation plan, field and laboratory testing and results, the geotechnical design work performed and design recommendations.

Two types of project files should be maintained: 1) the geotechnical design file(s), and 2) the construction support file(s).

The geotechnical design file should specifically contain the following information:

- Historical project geotechnical;
- As-built data and historical geotechnical information related to, the project;
- Geotechnical investigation plan development documents;
- Geologic reconnaissance results;

- Cross-sections, structure layouts, etc., that demonstrate the scope of the project and project feature geometry as understood at the time of the final design, if such data is not contained in the geotechnical report;
- Information that illustrates design constraints, such as right-of-way location, location of critical utilities, wetlands and location and type of adjacent facilities that could be affected by the design;
- Boring log field notes;
- Boring logs;
- Field test results, (CPT, pressuremeter, vane shear, shear wave measurements);
- Laboratory test results, including rock core photos and records;
- Field instrumentation measurements;
- Final calculations only, unless preliminary calculations are needed to show design development;
- Final wave equation runs for pile foundation constructability evaluation;
- Key photos (must be identified as to the subject and locations), including CD with photo files;
- Key correspondence (including e-mail) that tracks the development of the project and contains information regarding design changes or geotechnical recommendations. This does not include general correspondence that is focused on project coordination activities.

The geotechnical construction file should contain the following information (as applicable):

- Pile hammer approval letter with driving criteria including wave equation analysis;
- Construction submittal reviews (retain temporarily only, until it is clear that there will be no construction claims);
- PDA/CAPWAP results;
- Embankment or other instrumentation monitoring data;
- Change order correspondence and calculations;
- Documentation of any changes to the original geotechnical design or specifications;
- Claims-related correspondence and data;
- Photos (must be identified as to the subject and locations), including CD with photo files;
- CSL reports and any correspondence concerning shaft defects, repair work and the approval of drilled shafts.

21.8.3.1 Consultant Geotechnical Reports and Documents Produced For ODOT

Geotechnical reports and documents produced by geotechnical consultants shall be subject to the same reporting and documentation requirements as those produced by ODOT staff, as described in **Sections 21.3** and **Section 21.7**. The detailed analyses and/or calculations produced by the consultant in support of the geotechnical report development shall be provided to ODOT.

21.9. References

Section intentionally blank.

Appendix 21-A Geotechnical Report Review Checklist

(Structure Foundations Supplement)

YES	NO	N/A	
			1 Title/Cover Page
			1.1 Heading "Geotechnical Report" in larger letters
			1.2 Bridge Name
			1.3 Bridge Number
			1.4 Section Name
			1.5 Highway & Milepoint
			1.6 County
			1.7 Key Number
			1.8 Date
			2 Table of Contents
			3 Detailed Vicinity Map
			4 Body of Report
			4.1 Introduction
			4.1.1. Is project scope and purpose summarized?
			4.1.2 Is a concise description given for the general geologic setting and topography of the area?
			4.2 Office Research
			4.2.1 Summary of all pertinent records and other information that relate to foundation design and construction.
			4.3 Subsurface Explorations and Conditions
			4.3.1 Is a summary of the field explorations, locations, and testing given?
			4.3.2 Is a description of general subsurface soil and rock conditions given?
			4.3.3 Is the groundwater condition given?
			4.4 Laboratory Data
			4.4.1 Are laboratory test results (e.g., natural moisture, Atterberg Limits, consolidation,
			shear strengths, etc.) discussed and summarized in the report?
			4.5 Summarize Hydraulics Information that affects foundation recommendations
			4.5.1 Bridge options providing required waterway
			4.5.2. 100 and 500-year scour depths and elevations
			4.5.3. Riprap protection; class, depth, and extent
			4.6 Seismic Analysis and Evaluation
			4.6.1 Bedrock acceleration coefficients (500 & 1000-yr) and AASHTO soil profile type
			4.6.2 Liquefaction analysis and bridge access & performance assessment (settlement, stability, lateral deformation)
			4.6.3 Liquefaction Mitigation recommended?
			4.6.3.1. Mitigation design, specifications and cost estimates supplied?
			4.7 Foundation Analyses and Design Recommendations
			4.7.1 Foundation Options and Discussion
			4.7.2 Pile Foundations
			4.7.2.1. Type (steel pipe, H-pile, concrete, displacement/friction or end-bearing)
			4.7.2.2. Material specification (e.g., ASTM & steel grade), size (e.g.,O.D. and thickness)
			4.7.2.3. Tip treatment; open or closed-ended, tip protection required
			4.7.2.4. Ultimate nominal resistance, estimated cutoff elevation, estimated tip elevation. "estimated" or "order" length and
			minimum required tip elevation.
			4.7.2.5. Axial factored resistance and resistance factor
			4.7.2.6. Nominal and factored uplift resistances
			4.7.2.7. Lateral resistance
			4.7.2.6.1. Soil parameters for LPILE or COM624P analysis (e.g., p-y data, liquefied & nonliquefied soil conditions)
			4.7.2.8. Pile group settlement addressed?
			4.7.2.9. Downdrag potential addressed?
			4.7.2.8.1. Provide downdrag loads, load factors and discussion of how downdrag loads are accounted for or mitigated?
			4.7.2.10. Reduced pile resistances (axial, uplift, lateral, etc) as a result of liquefaction, scour or downdrag
			4.7.2.11. Driving Criteria and Driveability Analysis
			4.7.2.10.1. Dynamic equation where driveability or driving stress problems are not expected
			4.7.2.10.2. Wave Equation for nominal resistances greater than 540 kips or expected driving stress problems.
			4.7.2.12. Static or dynamic load testing
			4.7.2.11.1 Are specifications provided describing how the tests are conducted and clearly defining all responsiblities?
			4.7.3. Drilled Shafts
			4.7.3.1. Shaft type (i.e., end-bearing, friction or combination)
			4.7.3.2. Nominal axial resistance provided for various diameters and lengths (depths or tip elevs.)
			4.7.3.3. Rock socket lengths specified (and/or shaft tip elevations)
			4.7.3.4. Estimates of shaft settlement with depth under unfactored (service) load conditions.
			4.7.3.5. Resistance factors and factored resistances.
			4.7.3.6. Shaft group effects addressed?
			4.7.3.7 Lateral capacity addressed?
			4.7.3.7.1. Soil parameters for COM624P or LPILE analysis provided (e.g., p-y data, liquefied & nonliquefied soil conditions)
			4.7.3.8 Static or dynamic load testing required?
			4.7.3.8.1 Are specifications provided describing how the tests are conducted and clearly defining all responsiblities?
			4.7.4. Spread Footings
			4.7.4.1. Description and properties of the anticipated foundation soil or rock
			4.7.4.2. Nominal bearing resistance as function of effective footing width
			4.7.4.3. Nominal bearing resistance for a given settlement (service limit state)
			4.7.4.4 Resistance factors and factored bearing resistance for strength and extreme limit states
			4.7.4.5. Recommended maximum elevation for base of footing
			4.7.4.6. Soil parameters for sliding and eccentricity provided?
			4.7.4.7. Overall stability checked?

YES	NO	N/A	
			4.7.5. Retaining Walls
			4.7.5.1. Description and properties of the anticipated foundation soil
			4.7.5.2. Nominal bearing resistance as function of effective footing width
			4.7.5.3 Nominal bearing resistance for a given settlement (service limit state)
			4.7.5.4. Resistance factors and factored bearing resistance for strength and extreme limit states
			4.7.5.5. Recommended maximum elevation for base of footing
			4.7.5.6. Overall stability, sliding, overturning.
			4.7.5.7 Earth pressure recommendations and diagrams
			4.7.5.8 Wall type options
			4.7.6. Engineered Fills
			4.7.6.1. Are materials, gradation, placement and compaction requirements provided for the engineered fill?
			4.7.6.2. Are the dimensions of the Engineered Fill clearly shown (in plan & cross section)
			4.7.7. Are foundation recommendations provided for Temporary and/or Detour Structures?
			4.8 Construction Issues and Recommendations
			4.8.1. Pile Foundations
			4.8.1.1. Have potential obstructions (e.g., boulders, riprap, existing foundations, utilities, etc.) been identified?
			4.8.1.2. Any limited head room or other clearance issues?
			4.8.1.3. Have the effects of pile driving vibrations on adjacent structures been evaluated?
			4.8.1.3.1 Is a preconstruction survey recommended to document existing conditions?
			4.8.2. Drilled Shafts
			4.8.2.1. Shaft stabilization issues discussed and evaluated (e.g., temporary or permanent casing, slurry)
			4.8.2.2. Adequate discription of any boulders, obstructions or other difficult conditions expected to be encountered provided?
			4.8.2.3. Discussion of expected groundwater conditons
			4.8.3. Spread Footings
			4.8.3.1. Anticipated foundation material adequately described
			4.8.3.2. Shoring required?
			4.8.4. Retaining Walls
			4.8.4.1. Anticipated foundation material adequately described
			4.8.4.2. Shoring required?
			4.8.4.3. Backfill and drainage requirements identified
			4.8.5. Temporary Excavations
			4.8.5.1. Discussion of any shoring and bracing
			4.8.5.2. Cofferdams
			4.8.5.3. Groundwater mitigation method
			4.9. Special Provisions
			4.9.1. Pile Foundations (Section 00520)
			4.9.1.1. Soil input parameters for Wave Equation Analysis
			4.9.1.2. Set period and redriving (freeze) addressed?
			4.9.1.3. Preboring required?
			4.9.1.4. Jetting permitted?
			4.9.1.5. Is tip protection required?
			4.9.1.6. Number of pile splices provided
			4.9.1.7. Specs for PDA, CAPWAP or other load testing provided?
			4.9.2. Drilled Shafts
			4.9.2.1. Crosshole Sonic Log Tests described? (number, locations, etc.); Section 00512.42.
			4.9.3. Spread Footings
			4.9.3.1. Any special excavation or foundation preparation specs required? (Section 00510)
			4.9.4. Retaining Walls
			4.9.4.1. Bearing resistance equation provided for MSE walls.
			4.9.4.2. Geotextile/geogrid material properties required? (Section 02320)
			4.9.5. Are unique special provisions provided (e.g. liquefaction mitigation)?
			4.9.6. Are special notes to the Contractor regarding subsurface materials or conditions required and if so, are they provided?
			4.10. Limitations
			4.11. General
			4.11.1. Has the report been independently reviewed by a qualified geotechnical engineer?
			4.11.2. Is the report stamped, dated, and signed by a registered PE licensed to practice in Oregon?
			5 Appendices
			5.1. Foundation Data Sheet (see example)
			5.1.1. Plan View
			5.1.1.1. Are the locations of the proposed, existing, detour structure (if applicable) and other important features shown?
			5.1.1.2. Are the locations of all explorations clearly shown (by station and offset)?
			5.1.2. Profile View
			5.1.2.1. Is the groundline profile(s) shown (centerline and/or 3 line profile)?
			5.1.2.2. Are the explorations plotted on the profile at the correct elevation and location?
			5.1.2.3. Is an identification number and the completion date shown for each exploration?
			5.1.2.4. Are the subsurface materials and conditions depicted with soil and rock descriptions in conformance with the ODOT Soil and Rock Classification Manual? Are the appropriate graphic symbols (see attached) used?
			5.1.2.5. Are the insitu tests and sample types (typically SPT or undisturbed samples) shown on the boring profile at the correct depth?
			5.1.2.6. Are the SPT results (uncorrected "N" values) shown on the profile?
			5.1.2.7. Are the highest measured groundwater levels, and the date measured, shown on the profile?
			5.1.2.8. Are percent rock core recovery, rock hardness, RQD and unconfined compressive strength (if available) values shown in a summary table?
			5.1.3. General
			5.1.3.1. Is the presentation of the subsurface information adequately shown on the Foundation Data Sheet (i.e. proper scaling and font size)?
			5.1.3.2. Has the Foundation Data Sheet been independently reviewed?
			5.1.3.3. Is the Foundation Data Sheet stamped, dated, and signed by a registered PE or CEG licensed to practice in Oregon?
			5.2. Exploration Logs
			5.3. Plan and Elevation of existing structure (if applicable)
			5.4. In situ test data and results
			5.5. Laboratory test data and results
			5.6. Photographs
			5.7. Other references as needed
			6 Foundation Analyses and Design Calculations Attached

May, 2006

Chapter

22

22. Noise Barriers

22.1. General

The primary purpose of noise barriers is to mitigate the effects of highway noise on people. Design of noise barriers includes acoustic design, structural design, and geotechnical design. This chapter contains design standards for noise barriers. The terms “noise barrier” and “sound wall” are interchangeable in this manual.

Load and Resistance Factor Design (LRFD) methods are not currently available in *AASHTO Guide Specifications for Structural Design of Sound Barriers*. Existing ODOT Standard Drawings were also developed using Load Factor Design (LFD) and Allowable Stress Design (ASD), rather than LRFD. Until LRFD ODOT Standard Drawings and LRFD AASHTO Guide Specifications are available, use LFD for structural design of sound barriers, and use ASD for geotechnical design of sound barriers.

Where a sound barrier is required, use the following ODOT Standard Drawings wherever possible:

- BR730 – Standard Reinforced Concrete Masonry Soundwall
- BR740 - Standard Precast Concrete Panel Soundwall
- BR750, BR751 - Standard Masonry Soundwall on Pile Footing

Construct noise barriers according to the Oregon Standard Specifications for Construction.

22.2. Acoustic Design of Noise Barriers

Guidance regarding acoustic design of noise barriers is located in the *ODOT Noise Manual*, which is available online at the Air Quality, Acoustics & Energy Program web site:

http://www.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/air_noise.shtml

22.3. Structural Design of Noise Barriers

Perform structural design of noise barriers according to the following publications:

- *ODOT BDDM* (*Section 1.4.2*)
- *AASHTO Guide Specifications for Structural Design of Sound Barriers*
- *AASHTO Standard Specifications for Highway Bridge*s

In the case of conflict or discrepancy between manuals, the following hierarchy shall be used: Those manuals listed first shall supercede those listed below in the list.

22.4. Foundations for Noise Barriers

Perform foundation design of noise barriers according to the following publications:

- *ODOT Geotechnical Design Manual (GDM*), ***Chapter 16***
- *ODOT Bridge Design and Drafting Manual (BDDM) Section 1.4.2.*
- *AASHTO Guide Specifications for Structural Design of Sound Barriers*
- *AASHTO Standard Specifications for Highway Bridges*

In the case of conflict or discrepancy between manuals, the following hierarchy shall be used: Those manuals listed first shall supercede those listed below in the list.

22.5. References

Bridge Design and Drafting Manual, *Section 1*; Oregon Department of Transportation Bridge Section; 2003.

Standard Specifications for Highway Bridges, American Association of State Highway and Transportation Officials (AASHTO), 2002, 17th Edition, Washington, D.C., USA.

Oregon Standard Specifications for Construction, Oregon Department of Transportation (ODOT), 2002 Edition and related Special Provisions.

Oregon Standard Drawings

Guide Specifications for Structural Design of Sound Barriers, American Association of State Highway and Transportation Officials (AASHTO), 1989, with 1992 and 2002 interims, Washington, D.C., USA.