Chapter

16

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

16.1 General

This chapter covers the geotechnical design of traffic structures, sound walls, 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 sound walls 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.

Depending on the type of standard foundation design, the geotechnical designer shall either: 1) verify that the soil conditions at the site meet or exceed the soil conditions assumed in the development of the standard drawing, or 2) provide site-specific soil properties and groundwater conditions for the structure designer's use in developing the final foundation design. 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 sound walls, 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.

Foundation Data sheets for traffic structures, sound walls, and buildings are recommended for cases where borings, or other subsurface explorations, have been conducted and the designs include:

- Large (≥30”) drilled shafts, such as those required for sign bridges and large cantilever sign structures,
- Special (non-standard) foundation designs in unusual or difficult ground conditions,
- Adverse subsurface conditions (such as high groundwater and unstable overburden soils) where foundation construction will require specialized construction techniques, materials, equipment, and expertise.

Foundation data sheets are part of the contract document. These are useful in depicting the subsurface conditions to be expected during construction, and document these conditions for easy future reference.

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.

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 provided on the standard drawings for these structures. The foundation design for these structures is 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 where the soil conditions can provide the bearing capacity and meet the settlement requirements shown on the standard plans. Non-standard foundation designs are required at sites where soil conditions are not suitable for standard drawing applications. Refer to the standard drawings listed in 16.5.1 for details of foundation design requirements.

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 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.

Foundations for traffic structures are typically not designed for seismic loads, nor mitigated for liquefaction. If seismic conditions are applicable, a safety factor of 1.1 should be used.

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 un-drained shear strength. This information should be provided for each signal or strain pole site in the Geotechnical Report. The unit weight and internal friction angle (or un-drained shear strength) may be determined by standard subsurface investigation techniques such as using the Standard Penetration Test (SPT) or other approved methods.

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 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, along with the recommended soil design properties. Groundwater monitoring using piezometers may be needed as appropriate to detect and record seasonal 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 un-drained shear strength are provided in Table 16-1: Relationship of SPT 'N60' value, Internal Friction Angle and Unit Weight of Cohesion less Soils and Table 16-2.

All field SPT 'N' values should be adjusted to hammer energy of 60% (N_{60}). Only the 'N' values used in Table 16-1 (cohesionless soils) 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: Relationship of SPT 'N60' value, Internal Friction Angle and Unit Weight of Cohesion less Soils 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 Cohesion less Soils

Note:
The information in the table was modified after Meyerhof (1956), ODOT Soil & Rock Classification Manual (1987), and Cheney R.S. and Chassie R.G., (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 penetrate 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 16-1, 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), Cheney R.S. and Chassie R.G., (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 thumbnail.
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 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.

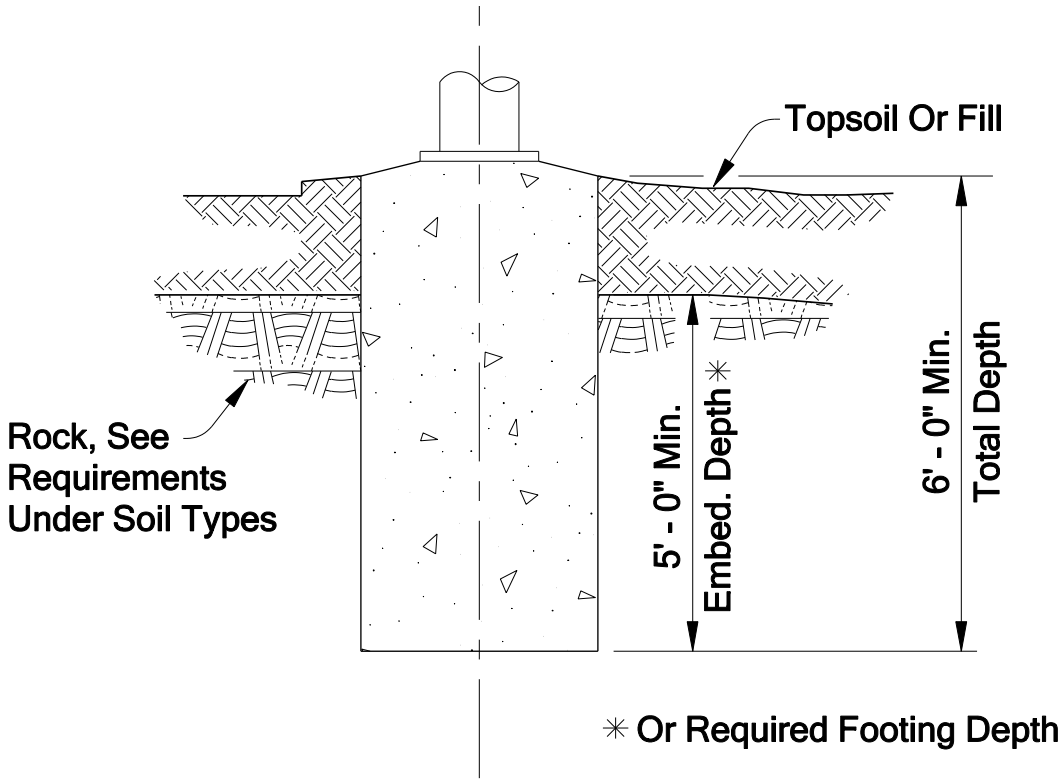

Figure 16-1. Rock Installation Requirements

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 "LRFD Bridge Design Specifications,"* 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 properties and required allowable bearing capacities for these two soil conditions as presented 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.

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 by Professor P. C. Rutledge.

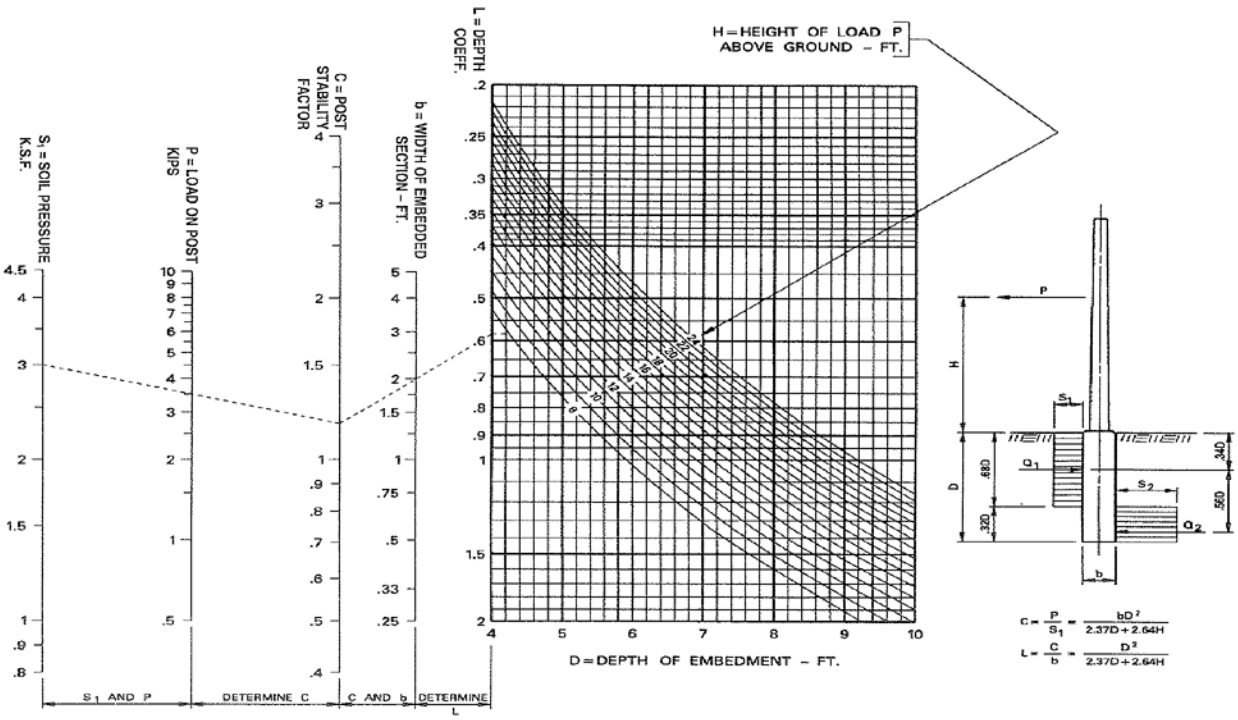

Figure 16-3. Rutledge Nomograph for Estimating Post Embedment under Lateral Loads (AASHTO, 2001)

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 and cost, 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 sound walls (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 sound walls 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 $\phi = 25$, 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 sound wall site should be investigated and the soils classified into one of the above three designations. Table 16-1: Relationship of SPT 'N60' value, Internal Friction Angle and Unit Weight of Cohesion less Soils 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 sound wall, these areas should be clearly delineated either by stationing and offset or on a plan map. The soil category for each sound wall 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 sound wall designer will use this information to develop a special foundation design for the sound wall.

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 sound walls 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 considers slope effects 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 sound wall 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 sound wall 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 sound wall 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 sound wall 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 sound wall stability for these two limit states, using service loads.

Settlement of sound walls 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 sound wall should be obtained from the sound wall 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 sound wall 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 00921. 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 sound walls 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 "*2012 International Building Code," (IBC, 2012)*. This design code specifies that all foundations be designed using allowable stress design methodology. 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.

In addition to using the 2012 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 16-4: Minimum factors of safety for ASD foundation design.

Load Group	Method	*Minimum Geotechnical Factor of Safety, FS		
		Spread Footings	Shafts	Piles
ASD (un-factored 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 ultimate foundation bearing capacity by the specified FS from Table 16-4: Minimum factors of safety for ASD foundation design 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: Design chart for proportioning shallow footings on dry sand (redrafted from Peck, et al., 1974). When using Figure 16-4, a FS from Figure 16-4 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 16-4 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.

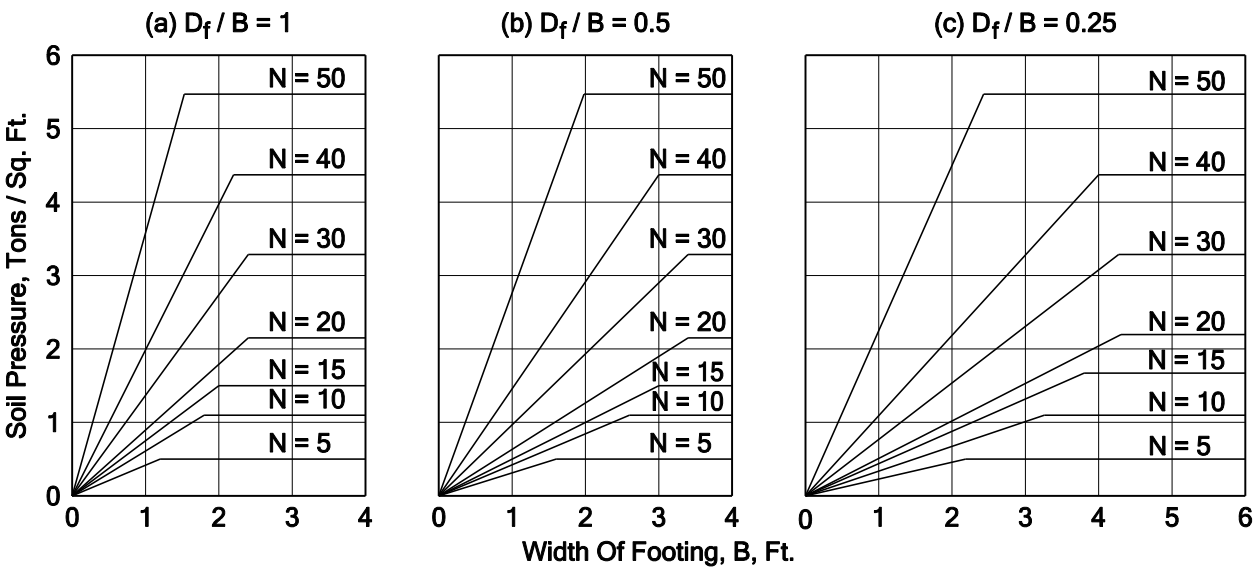

Figure 16-4: Design chart for proportioning shallow footings on dry sand (redrafted from Peck, et al., 1974)

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.

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 buildings and other structures for which the International Building Code (IBC) governs and mitigation is required by the IBC.

16.9 References

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