CHAPTER 19

FOUNDATION DESIGN FOR SIGNS, SIGNALS, NOISE BARRIERS, CULVERTS, AND BUILDINGS
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19.1 GENERAL

19.1.1 Overview

This chapter covers the geotechnical design of lightly loaded structures which include: sign span structures, cantilevered signs and signals, noise barriers, luminaires, culverts not supported on foundation elements, and small buildings. Small buildings typically include single story structures such as structures in park and ride lots, rest areas, or NYSDOT maintenance facilities. The structural design of these facilities is addressed in the NYSDOT Bridge Manual and NYSDOT Highway Design Manual.

19.1.2 Site Reconnaissance

General procedures for site reconnaissance are presented in NYSDOT GDM 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 (see NYSDOT GDM Chapter 2) should also be conducted prior to the site reconnaissance.

During the site reconnaissance, observations of the condition of existing slopes (natural and cut) in the immediate vicinity of the structures should be inspected for performance. It is especially important to establish the presence of high ground water and any areas of soft soil. Many of these structures have very shallow foundations and the investigation may only consist of general site reconnaissance with minimal subsurface investigation. The Departmental Geotechnical Engineer should have access to detailed plan views showing existing site features, utilities, proposed construction and right-of-way limits. With this information, the Departmental Geotechnical Engineer can review structure locations, making sure that survey information agrees reasonably well with observed topography. The Departmental Geotechnical Engineer should look for indications of soft soil and unstable ground. Observation of existing slopes should include vegetation, in particular the types of vegetation that may indicate wet soil. Equisetum (horsetail), cattails, blackberry and alder can be used to identify wet or unstable soils. 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, because many of these structures may be located in engineered fills.

Surface and subsurface conditions that could affect constructability of the foundations, such as the presence of shallow bedrock, or cobbles and boulders, should be identified.

19.1.3 Field Investigation

If the available geotechnical data and information gathered from the site review is not adequate to make a determination of subsurface conditions as required herein, then new subsurface data shall be obtained. Explorations consisting of geotechnical borings, test pits and hand holes or a combination thereof shall be performed to meet the investigation requirements provided herein.
As a minimum, the subsurface exploration and laboratory test program should be developed to obtain information to analyze foundation stability, settlement, and constructability with respect to:

- Geological formation(s)
- Location and thickness of soil and rock units
- Engineering properties of soil and rock units such as unit weight, shear strength and compressibility
- Groundwater conditions (seasonal variations)
- Ground surface topography
- Local considerations, (e.g., liquefiable soils, expansive or dispersive soil deposits, underground voids from solution weathering or mining activity, or slope instability potential)

Standard foundations for sign span structures, cantilever signs, cantilever signals and strain pole standards are based on allowable lateral bearing pressure and angle of internal friction of the foundation soils. The determination of these values can be estimated by Standard Penetration Test (SPT). Portable Penetrometer Tests (PPT) may be used to obtain the soil data provided the blow count data is properly converted to an equivalent standard penetrometer “N” value. The designer should refer to NYSDOT GDM Chapter 8 for details regarding the proper conversion factors of PPT to SPT.

Specific field investigation requirements for these structures are addressed in NYSDOT GDM Chapter 4.

19.2 FOUNDATION DESIGN REQUIREMENTS

19.2.1 Cantilever Signs and Sign Span Structures

The NYSDOT Overhead Sign Structure Design Manual presents the requirements for designing overhead sign structures (OSS) in New York State. OSS are defined as span or cantilever structures supported on posts, designed to carry signs over the roadway. Less frequently, overhead signs may be supported by cable structure, mounting to bridge fascias or piers, or other unique structural arrangements.

The Regional Geotechnical Engineer or the Geotechnical Engineering Bureau should be consulted to determine the proper foundation treatment. Typical foundation types can be found in the following Bridge Detail sheets:

- BD-OS-2E  Overhead Sign Structures - Span Structures Selection Table
- BD-OS-3E  Overhead Sign Structures - Span Structures Foundation
- BD-OS-9E  Overhead Sign Structures - Cantilever Structures Selection Table
- BD-OS-10E Overhead Sign Structures - Cantilever Structures Foundations
These types of foundations should not be placed on slopes steeper than 1V on 1.5H. If the foundation is located on a slope that is part of a drainage ditch, the top of the standard foundation can simply be located at or below the bottom of the drainage ditch.

Design for cantilever signals, cantilever signs, sign span structures, and luminaires shall be performed in accordance with the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (AASHTO, 2001).

- 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) or the procedures specified in NYSDOT GDM Chapter 11 for lateral load analysis of deep foundations (e.g., P-y analysis) should be used.

- For shafts in rock, nominal lateral resistance should be estimated based on the procedures provided in NYSDOT GDM Chapter 11. This means that for special lateral load design of shaft foundations, the Departmental Geotechnical Engineer will need to provide P-y curve data to the Structural Designer to complete the soil-structure interaction analysis. For spread footing design, the design methods provided in NYSDOT GDM Chapter 11 to estimate nominal bearing resistance and settlement should be used, but instead of the referenced load groups and resistance factors, 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, and a safety factor of 1.1 should be used for seismic conditions, if seismic conditions are applicable. Note that in general, the foundations for the types of structures addressed in this chapter are not mitigated for liquefaction (see NYSDOT GDM Chapter 9). For anchored footing foundations over bedrock, anchor
depth, spacing, and nominal resistance shall be assessed considering the degree of fracturing and jointing in the rock (see NYSDOT GDM Chapters 6, 11, and 15 for design requirements).

19.2.1.1 Standard Foundation Designs

The standard foundation designs, lengths and quantities are shown on Bridge Detail sheets (BD-OSx) for shafts in soil and footings in soil or rock.

19.2.1.1.1 Design Considerations

If the geotechnical information indicates any of the following, contact the Geotechnical Engineering Bureau for recommendations:

- Ground water is located within the foundation depth.
- Soft clay, organic soil or miscellaneous fill/debris is located within or below the foundation depth.
- The foundation is placed on a slope with a finished grade steeper than two horizontal to one vertical (Minimum cover and overall stability must be checked).

If any of these conditions exist, the Geotechnical Engineering Bureau may recommend increases to the standard foundation size and/or depth. In such a case, a special foundation design is required and it should be presented on a separate plan sheet in the contract documents.

19.2.2 Cantilever Signals

Typical foundation types can be found in the Standard Sheets for Traffic Signals, specifically Standard Sheet 680-01 Traffic Signal Pole Foundations. The Regional Geotechnical Engineer or the Geotechnical Engineering Bureau should be consulted to determine the proper foundation treatment.

19.2.3 Luminaires

Typical foundation types can be found in the Standard Sheets for Highway Lighting System, specifically Standard Sheet 670-01 Lamppost Foundations. The Regional Geotechnical Engineer or the Geotechnical Engineering Bureau should be consulted to determine the proper foundation treatment.

19.3 NOISE BARRIERS

19.3.1 Overview

It is NYSDOT policy to address traffic noise concerns resulting from transportation projects by complying with FHWA regulations for Federal-aid projects and by also applying the policy and procedures to State-funded projects. In accordance with 23 CFR 772.7(b), the NYSDOT
Environmental Manual constitutes NYSDOT noise policy. If a traffic noise impact is identified, the abatement measures must be considered.

A noise barrier (a.k.a. sound wall, sound berm, sound barrier, acoustical barrier) is an exterior structure designed to protect sensitive land uses from noise pollution. Noise barriers are the most effective method of mitigating roadway, railway, and industrial noise sources other than cessation of the source activity or use of source controls.

FHWA design guidance can be found at: http://www.fhwa.dot.gov/environment/noise/noise_barriers/design_construction/

19.3.2 Foundation Design Requirements for Noise Barriers

Footings and foundations for ground-mounted noise barriers are typically limited to concrete cylinders (caissons), spread footings, and continuous footings. When designing these, the following factors contribute to the selection of the type of footing to be used as well as its depth and size:

- The bearing capacity and compressibility characteristics of the surrounding soil or rock;
- Possible ground movements;
- Anticipated future excavation activity adjacent to the foundations;
- Ground water levels;
- Extent of frost penetration;
- Extent of seasonal volume changes of cohesive soils;
- The proximity and depth of foundations of adjacent structures; and
- Overall ground stability, particularly adjacent to cut or fill slopes.

Foundation design for noise barrier shall be conducted in accordance with the most current AASHTO Guide Specifications for Structural Design of Sound Barriers, including interims (AASHTO 1989). Currently, design of noise barriers is based on Load Factor Design (LFD). Therefore, the load factors and safety factors specified in the AASHTO manual for sound barrier foundation design, except as specifically required in this chapter of the NYSDOT GDM, should be used.

In addition, the Departmental Geotechnical Engineer shall perform a global stability analysis of the noise barrier when the barrier 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 1.3 or greater for static conditions and 1.1 for seismic conditions.

19.3.2.1 Spread Footings

For spread footing design, the design methods provided in NYSDOT GDM Chapter 11 to estimate nominal bearing resistance and settlement should be used, but instead of the referenced load groups and resistance factors, the AASHTO Guide Specifications for Structural Design of Sound Barriers (1989) and 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, and a safety factor of 1.1 should be used for seismic conditions, if seismic conditions are applicable. Note that in general, the foundations for noise barriers are not mitigated for liquefaction (see NYSDOT GDM Chapter 9).

The noise barrier 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 noise barrier stability for these two limit states, using service loads.

The Departmental Geotechnical Engineer will also be responsible to estimate foundation settlement using the appropriate settlement theories and methods as outlined in NYSDOT GDM Chapter 11. The Departmental Geotechnical Engineer will report the estimated total and differential settlement.

The soil properties (unit weight, friction and cohesion) shall be determined using the procedures described in NYSDOT GDM Chapter 6.

Noise barrier footings shall be located relative to the final grade to have a minimum soil cover over the top of the footing of 2 ft.

For seismic design, use Mononabe-Okabe analysis in accordance with NYSDOT GDM Chapter 17 to determine the seismic earth pressure if the noise barrier retains soil.

**19.3.2.2 Shaft Foundations**

In general, shaft supported noise barriers are treated as non-gravity cantilever walls for foundation design.

The Departmental Geotechnical Engineer should provide the following information to the Structural Designer:

- Description of the soil units (NYSDOT GDM Chapters 5 and 6).
- Ground elevation and elevation of soil/rock unit boundaries.
- Depth to the water table along the length of the wall.
- Earth pressure diagrams and design parameters developed in accordance with NYSDOT GDM Chapter 17 and this section. Soil unit strength parameters that include effective unit weight, cohesion, φ, K_u, K_p, and K_ac. For shaft foundations, passive pressures are assumed to act over 3 shaft diameters, and a factor of safety of 1.5 should be applied to the passive resistance.
- The allowable bearing resistance for spread footings and estimated wall settlement.
- Overall wall stability.
- Any foundation constructability issues resulting from the soil/rock conditions.
The Structural Designer will use this information to develop the foundation design for the noise barrier.

19.3.3 Construction Considerations

The presence of a high groundwater table could affect the construction of shaft foundations. The construction of noise barriers with shaft foundations would be especially vulnerable to caving if groundwater is present, or in loose, clean sands or gravels. The concrete in all shaft foundations are designed to bear directly against the soils. Generally, temporary casing for drilled shafts should be removed. Special foundations designs may be required if the Departmental Geotechnical Engineer determines that permanent casing is necessary. In this situation, the Structural Designer must be informed of this condition.

19.4 CULVERTS

19.4.1 Overview

This section only addresses culverts, either flexible or rigid, that do not require foundation elements such as footing or piles. Culverts that require foundation elements are addressed in NYSDOT GDM Chapter 11.

19.4.2 Culvert Design and Construction Considerations

The NYSDOT Highway Design Manual presents the requirements for designing reinforced concrete culverts (see HDM Chapter 19). It also provides guidance about the information to include in the contract documents, where to present the information, and details for cast-in-place culverts.

Culvert structures, regardless of span and height of cover, are considered buried structures in regard to foundation design. Thus, there is no requirement for seismic analysis. (This may change in the future as more research is completed).

Culvert design shall utilize the LRFD approach. For culverts, the soil loads and design procedures to be used for design shall be as specified in Sections 3 and 12 of the AASHTO LRFD Bridge Design Specifications. The following design situations are typically encountered regarding culverts:

1. The culvert simply needs to be replaced because of performance problems (e.g., leaking, partial collapse, or undersized), or a new culvert is needed, and open excavation is used to remove and replace the culvert, or to install the new culvert, and the excavation is simply backfilled.
2. The culvert simply needs to be replaced because of performance problems (e.g., leaking, partial collapse, or undersized), or a new culvert is needed, and the culvert is installed by trenchless installation methods through the existing embankment.
3. An existing culvert is extended and new fill is placed over the culvert.

For case 1, little geotechnical design is needed. The soil conditions in the fill and just below the culvert should be investigated, primarily to assess constructability issues such as excavation slopes and shoring design. If soft soils are present near the bottom of the culvert, the feasibility of obtaining stable excavation slopes of reasonable steepness should be assessed. The presence of boulders in the fill or below the fill, depending on the shoring type anticipated, could influence feasibility. However, settlement and bearing issues for the new or replaced culvert should not be significant, since no new load is being placed on the soil below the culvert.

For case 2, the effect of the soil conditions in the fill on the ability to install the culvert via trenchless installation methods through the fill should be evaluated. Very dense conditions or the presence of obstructions in the fill such as boulders could make trenchless installation infeasible. Ground water within the fill or the presence of clean sands or gravels that could “run” could again make trenchless installation problematic, unless special measures are taken by the Contractor to prevent caving. Since a stable jacking platform typically must be established, along with the shoring required to form the entrance and receiving pits, deeper test hole data adequate for shoring design must be obtained and analyzed to assess earth pressure parameters for shoring design, and to design the reaction frame for the jacking operation. See NYSDOT Chapter 21 for additional information on trenchless installation.

For case 3, differential and total settlement along the culvert is the key issue that must be evaluated, in addition to the case 1 issue identified above. See NYSDOT GDM Chapter 12 for the estimation of settlement due to new fill.

For culverts with spans greater than 20 ft., foundation recommendations are provided to the Designer in the Foundation Design Report (FDR). The FDR is prepared by the Geotechnical Engineering Bureau in conjunction with the Office of Structures. When requested, foundation recommendations for culverts with spans less than 20 ft. may be provided by the Geotechnical Engineering Bureau.

The Regional Geotechnical Engineer or the Geotechnical Engineering Bureau should be consulted to determine the proper foundation treatment. Typical foundation treatment types can be found in the following Bridge Detail sheets:

- **BD-CB-1E** Precast Box Culvert Plan and Sections
- **BD-CB-2E** Precast Box Culvert Excavation and Embankment Details (1 of 2)
- **BD-CB-3E** Precast Box Culvert Excavation and Embankment Details (2 of 2)
- **BD-CB-10E** Three Sided Rigid Frame Plan and Sections
- **BD-CB-11E** Three Sided Structure Foundation Types
- **BD-CB-12E** Three Sided Frame Earthwork and Pile Details

Details for stone fill protection for culverts with cut-off walls are provided on Bridge Detail sheet **BD-EE-5E Stream Bank Protection Details.**
19.4.2.1 Precast Wingwalls

When utilizing precast wingwalls, the Regional Geotechnical Engineer or the Geotechnical Engineering Bureau should be consulted to determine the proper geotechnical wingwall design data to be incorporated into the Table on BD-CB-1E Precast Box Culvert Plan and Sections. Cantilever wingwalls should be detailed in accordance with BD-CB-6E Precast Cantilever Wingwall Details. Bin wall wingwalls should be detailed in accordance with BD-CB-5E Precast Binwall Details.

19.5 BUILDINGS

19.5.1 Overview

The provisions of this section cover the design requirements for small building structures typical of NYSDOT rest areas, maintenance and ferry facilities. 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.

19.5.2 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 inch.
### Table 19-1 Allowable Foundation and Lateral Pressure, as Provided in 2003 IBC, in Table 1804.2

In addition to using the 2003 IBC design code, the Departmental Geotechnical Engineer should perform a foundation bearing capacity analyses (including settlement) using the methods outlined in NYSDOT GDM Chapter 11 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:

| Materials                                                                 | Allowable Foundation Pressure (psf)
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Crystalline Bedrock</td>
<td>12,000</td>
</tr>
<tr>
<td>2. Sedimentary and Foliated Rock</td>
<td>4,000</td>
</tr>
<tr>
<td>3. Sandy Gravel and/or Gravel (GW &amp; GP)</td>
<td>3,000</td>
</tr>
<tr>
<td>4. Sand, Silty Sand, Clayey Sand, Silty Gravel, and Clayey Gravel (SW, SP, SM, SC, GM and GC)</td>
<td>2,000</td>
</tr>
<tr>
<td>5. Clay, Sandy Clay, Silty Clay, Clayey Silt, Silt and Sandy Silt (CL, ML, MH and CH)</td>
<td>1,500$^c$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials</th>
<th>Lateral Bearing (psf/ft. below natural grade)</th>
<th>Coefficient of Friction$^a$</th>
<th>Resistance (psf)$^b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Crystalline Bedrock</td>
<td>1,200</td>
<td>0.70</td>
<td>---</td>
</tr>
<tr>
<td>2. Sedimentary and Foliated Rock</td>
<td>400</td>
<td>0.35</td>
<td>---</td>
</tr>
<tr>
<td>3. Sandy Gravel and/or Gravel (GW &amp; GP)</td>
<td>200</td>
<td>0.35</td>
<td>---</td>
</tr>
<tr>
<td>4. Sand, Silty Sand, Clayey Sand, Silty Gravel, and Clayey Gravel (SW, SP, SM, SC, GM and GC)</td>
<td>150</td>
<td>0.25</td>
<td>---</td>
</tr>
<tr>
<td>5. Clay, Sandy Clay, Silty Clay, Clayey Silt, Silt and Sandy Silt (CL, ML, MH and CH)</td>
<td>100</td>
<td>---</td>
<td>130</td>
</tr>
</tbody>
</table>

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 on 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.
## Table 19-2 Minimum Factors of Safety for ASD Foundation Design

The results of the ASD foundation bearing capacity analyses, after reducing the foundation bearing capacity by the specified FS from Table 19-2, 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 sandy soils may alternatively be designed for bearing and settlement by using Figure 19-2. When using Figure 19-2, a FS from Table 19-2 does not need to be applied, as the bearing stresses in the figure represent allowable bearing resistances. The design bearing resistance in Figure 19-2 has been developed assuming footing settlement will be limited to no more than 1 inch. 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 (see NYSDOT GDM Chapter 8).
Figure 19-2 Design Chart for Proportioning Shallow Footings on Sand
(After 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. For cut and fill design, see NYSDOT GDM Chapters 12 and 13. For the stabilization of unstable ground, see NYSDOT GDM Chapter 16. If ground improvement is required, see NYSDOT GDM Chapter 14. If retaining walls are required, see NYSDOT GDM Chapter 17.

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 that in general, the foundations for the types of structures addressed in this chapter are not mitigated for liquefaction (see NYSDOT GDM Chapter 9). 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.

19.6 REFERENCES


American Association of State and Highway Transportation Officials (AASHTO), *LRFD Bridge Design Specifications*, Washington, D.C.


