# Table of Contents

## 1 Introduction
1.1 Scope
1.2 Background
1.3 General Guidance in Selecting OSS
1.4 Applicable Specifications
1.5 Definitions

## 2 Method 1 - Standard OSS Selection Using BD Sheets
2.1 Sign Selection and Layout
2.2 Electronic BD Sheets
2.3 Sign Structure Identification Number
2.4 Maximum Post Height
2.5 OSS Span or Arm Length
2.6 Limitations of the Standard OSS Selection Procedure
2.7 Structure Type Selection
2.8 Foundation Selection
2.9 Cantilever Trussed Arm Spacing Selection
2.10 Additional Information Required on BD-OS1 / BD-OS8
2.11 Additional OSS
2.12 Assembly of Appropriate BD Sheets for the PS&E
2.13 Contractor/Fabricator Options

## 3 Method 2 - Special Design - Independent Analysis
3.1 Special Design Applications
3.2 Overview
3.3 Special Design Procedure

## 4 References

### Appendices
- Appendix A Major Changes from the 1968 Design Manual and the 2000 Interim Steel Design (EI 00-035)
- Appendix B Design Assumptions Used for Standard OSS on BD-OS1 through BD-OS14
- Appendix C Issues and Options Evaluated During the Development of the Standard OSS Designs
- Appendix D Foundation Loads at Standard Structures
OVERHEAD SIGN STRUCTURE DESIGN MANUAL

1 INTRODUCTION

1.1 Scope

This manual describes the procedures to be used to design and detail cantilever and span overhead sign structures (OSS) in the State of New York. These procedures shall be used for the design of all OSS.

Overhead signs include signs over any portion of the roadway, including the shoulders, requiring vertical clearance for vehicles to pass underneath. Overhead signs are used to provide the traveling public with clear messages under a variety of conditions, directly over the roadway. The NYS MUTCD contains the requirements for determining when and where overhead signs shall be used.

Typically, overhead signs are supported by OSS. For purposes of this manual, 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 structures, mounting to bridge fascias or piers, or other unique structural arrangements.

This manual is limited in scope to typical OSS, consisting of post-supported span or cantilever structures. Non-typical support structures shall be designed on a case by case basis using the parameters and references presented in this manual.

Two separate design/selection methods are presented:

Method 1 STANDARD OSS SELECTION USING BD SHEETS applies only to structures supporting 3 mm thick aluminum signs. These standard designs are expected to cover the great majority of OSS requirements in NYS.

Method 2 SPECIAL DESIGN - INDEPENDENT ANALYSIS, is used for OSS that fall outside the limits covered by the BD sheet standard selection tables, including those that support sign panels greater than 3 mm in thickness.

The scope of this manual does not include design guidance for protection of OSS as fixed objects, determining the location and type of signs to be supported by the structure, or determining whether or not an OSS is needed in lieu of a ground mounted sign. Such guidance may be found in the NYS Highway Design Manual (HDM) and the NYS Manual of Uniform Traffic Control Devices of the New York Codes, Rules and Regulations Volume 17B (MUTCD). In addition, traffic signal pole design is not addressed.

1.2 Background

The Department had been designing and building OSS using the 1968 Manual in combination with standard Sheets and Drawings almost exclusively until October 2000. The 1968 method used aluminum tri-chord trusses with steel posts for spans, and either steel or aluminum elements for cantilevers.

The Department recognized that the AASHTO recommendations for forces and loads used in the design of overhead sign structures had changed since 1968. New factors, including the issue of
Heat Affected Zone for welded aluminum structures, fatigue loads and analyses, changes in height and exposure factors, new wind pressure formulas and changes in group load combination factors were being investigated and incorporated into AASHTO criteria. As a result, in 1997 the Department began to update and replace the 1968 Design Criteria for Sign Structures, to reflect these new factors.

In addition to the changes occurring in AASHTO criteria, in 1996 a pilot program was initiated in Region 10 to field inspect OSS. When this program was completed in 2000, a statewide inspection program was initiated for all OSS. These inspection programs revealed that the most significant and common problem observed was cracked welded aluminum connections. Further analyses, based on recent AASHTO criteria, have confirmed that steel welds have 2 to 3 times the Constant Amplitude Fatigue Life (CAFL) as equivalent aluminum welds.

As a result of the new AASHTO criteria and inspection results, the Department issued interim steel designs for span structures in October 2000 (EI 00-035) and discontinued the use of aluminum OSS. EI 00-035 issued interim steel designs for span-type structures only. Cantilever designs continued using the 1968 Design Criteria with steel elements only.

This manual supersedes EI 00-035 and the 1968 Design Criteria for Sign Structures. The design methods presented here are intended to result in long-life, readily-fabricated, fatigue-resistant designs for OSS.

1.3 General Guidance in Selecting OSS

The NYS MUTCD continues to be the authoritative source in determining what signs are necessary and where they are to be located. Ground mounted signs may be considered in lieu of overhead signs, if permitted by the MUTCD. In all instances, signs should be placed in a manner that will minimize potential danger and confusion caused by motorist uncertainty.

When an overhead sign is needed, the proper means of support shall be selected. The following is basic guidance for typical circumstances and is not intended to be comprehensive.

1. When the signage is intended for the under roadway, use a nearby bridge fascia if the bridge is structurally adequate for the required loads and forces and the skew angle of the existing bridge is not excessive (depending upon the width of the sign, a skew of up to about 20 degrees may be accommodated by the structural mounting attachments). The bridge shall be located within the limits specified by the MUTCD for the overhead sign. This option usually has a substantially lower initial cost than an OSS and will minimize traffic disruption during future OSS inspections. (Note: Not all bridges are suitable for supporting overhead signs and standard details do not exist for mounting attachments. The Regional Structures Engineer [RSE] shall be consulted. A full analysis shall be performed to develop a suitable attachment design for the specific signage.) An analysis is required to determine if the bridge is structurally adequate to support the overhead signage. A load rating calculation, including the signage and its mounting attachment, shall be completed and included in the Bridge Identification Number (BIN) folder.

2. Avoid using an OSS to span both directions of a divided highway to support signs intended for only one direction. Instead, use a structure spanning one direction with a median support, or use a cantilever, depending on the sign location. (Note: A median support foundation will
involve a special design if it is located within a barrier. In other cases it may require protection as a fixed object; see HDM Chapter 10.)

An OSS spanning two traffic directions will generally be three to four times more costly than an equivalent one direction structure due to its greater length and required section. Additionally, a structure spanning two traffic directions will be approximately twice as costly to inspect and cause twice the traffic disruption and potential hazard compared to an equivalent one direction structure.

3. Cantilever structures shall generally be used to support signs over the shoulder and/or the travel lane nearest the post. Long arm cantilevers will generally be more costly than equivalent spans and are subjected to much greater fatigue loads than span type structures. In addition, they are less redundant than the current dual post, span type OSS standard designs. On the other hand, cantilevers with shorter arms for signs over the shoulder or travel lane nearest the post will generally be less costly to construct and inspect. In certain cases, two small cantilevers may be considered in lieu of an OSS spanning two directions, depending on site specific conditions.

4. Avoid placing an OSS on a bridge when the signage is intended for the over roadway. This type of structure requires specially designed post supports and connections. In addition, bridge vibrations may effect the OSS. If there is no alternative to an OSS on a bridge, use a span structure in lieu of a cantilever. Cantilever structures supported on bridges should be avoided due to the resulting load and force combinations.

5. Avoid using cantilever structures to support variable message signs (VMS) due to the eccentricity of the VMS dead load, the magnitude of fatigue forces and the potential for out of plane bending.

1.4 Applicable Specifications

1.4.1 Design Specifications

The New York State Department of Transportation Standard Design Specifications for Overhead Sign Structures, latest version.

1.4.2 Construction and Material Specifications

The Standard Specifications, Construction and Materials, New York State Department of Transportation, Office of Engineering (latest version), with all additions and modifications current at time of design.
1.5 Definitions

Sign Height: The overall vertical dimension of the sign, including all supplementary panels.

Sign Area: The summation of the areas of all signs (actual or future) to be placed on the structure.

Nominal Post Height: The distance from the centerline of truss to the bottom of base plate.

Quad-Truss: An assembly consisting of four chords, connected by bracing in four planes and internal bracing to distribute loads among the planes.

Exposure Factor, Kz: A dimensionless coefficient that corrects the magnitude of wind pressure referenced to a height above the ground of 10 m for the variation of wind speed with height.
2  METHOD 1 - STANDARD OSS SELECTION USING BD SHEETS

BD sheets BD-OS1 through BD-OS14 provide a simple procedure for designers to select the appropriate OSS for their project. These BD sheets also include all appropriate details required and shall be used as contract sheets in the plans, specifications and estimate (PS&E). The BD sheets are labeled BD-OS1 through BD-OS14 and do not require modification when Method 1 is used. The designer need only enter required information on BD-OS1 (for span structures) and/or BD-OS8 (for cantilever structures).

The standard selection tables contained in the BD sheets have been developed to satisfy the great majority of requirements for typical cantilever and span OSS supporting standard 3 mm thick aluminum sign panels, within specified limits as noted in Section 2.6. When requirements for OSS exceed these limits, Method 2 for special design procedures shall be used, as described in Section 3. Special design procedures shall also be used for butterfly, multi-span or combination span and cantilever sign structures.

The procedure for selecting an OSS and completing the BD sheets for incorporation into the contract plans follows in Sections 2.1 through 2.12. Instructions for the EIC to record the constructed foundation types are included in Section 2.13.

2.1  Sign Selection and Layout

Determine the size, type and location of sign panels to be supported by the OSS. Evaluate whether future sign panel size increases are likely. If changes are expected, the sign structure shall be designed to accommodate the larger of either the current or future sign area. Determine the total sign area to be supported by the OSS by summing all sign panel areas.

Based on the sign locations and sign areas, determine if a span or cantilever type OSS is needed. Generally, cantilever structures should only be used to support signs over the shoulder or lane closest to the post. (Note: Refer to Section 2.6 and BD-OS2 / BD-OS9 for limitations on span and cantilever structures.)

2.2  Electronic BD Sheets

Electronic copies of the BD sheets BD-OS1 through BD-OS14 are located on the NYSDOT Web site at: www.dot.state.ny.us/caddinfo/structures/bd.html.

2.3  Sign Structure Identification Number

The RSE will maintain a list of Sign Structure Identification Numbers (SINs) for all OSS in the State and will issue a number for each new OSS. Contact the RSE to obtain the SINs for the OSS in the contract. Insert these numbers into the fill-in tables in the contract plans on BD-OS1/BD-OS8. In this way, each structure will have a unique identifying number for reference before, during and after the completion of the contract. The standard specifications require that the fabricator stamp this
number into the base plate and that the contractor affix cutout numbers to the post of each structure. As a result, it is necessary to establish and present this number at the design stage.

2.4 Maximum Post Height (ref. BD-OS1/BDD-OS8)

Determine the actual nominal post heights (from the bottom of base plate to the centerline of sign or truss) by establishing the required minimum vertical clearance across the width of the entire roadway section. The minimum vertical clearance shall be provided to all points on the structure, signs, sign attachments (including lighting) and, if applicable, future anticipated signs and attachments. The minimum vertical clearance shall be 300 mm greater than that required for new overpass structures on the route, which should already include the additional 150 mm for future resurfacing. For spans, the actual nominal post height shall be determined separately for each side of the roadway to obtain the required vertical clearance with a level line established at the vertical centerline of the truss (neglecting camber). The higher of the two actual nominal post heights shall be used to determine the post height category for the span structure.

2.5 OSS Span or Arm Length (ref. BD-OS1/BDD-OS8)

Establish the required span length or cantilever arm length by locating the foundations and sign panels relative to the roadway.

2.6 Limitations of the Standard OSS Selection Procedure (ref. BD-OS2/BDD-OS9)

BD-OS2 and BD-OS9 contain OSS selection tables for span and cantilever structures supporting only standard 3 mm thick aluminum sign panels and their associated lighting, where required. OSS supporting walkways or VMS shall be designed using the special design procedures described in Section 3.

The limits shown for each structure in the tables or notes for span or arm length, total sign area, sign height and nominal post height cannot be exceeded. In addition, OSS cannot be designed or selected by extrapolating beyond the limits of the tables. When any of these limits are exceeded, use the special design procedures described in Section 3. A summary of the limitations for the structures contained in the tables follows. (Note: An OSS supporting several signs requires a special design if the height or panel thickness limits are exceeded for any one of the signs.)
BD-OS2 Span Structures
- Maximum nominal post height = 9, 11 or 13 m, depending on governing post height
- Maximum sign panel height = 6 m - all types
- Maximum height of centerline truss above surrounding terrain = 20 m (height/exposure factor of 1.16)
- Maximum span length = 15 to 65 m in 5 m increments
- Maximum total sign area = 30, 60 and 90 m² depending on span and type
- Sign panel thickness = 3 mm - all types

BD-OS9 Cantilever Structures
- Maximum Nominal Post Height = 10 m - all types
- Maximum sign panel height, trussed arm type = 6 m for sign areas greater than 20 m²
- Maximum sign panel height, trussed arm type = 4 m for sign areas less than or equal to 20 m²
- Maximum sign panel height, single arm type = 1.5 m
- Maximum height of centerline arm/truss above surrounding terrain = 20 m (height/exposure factor of 1.16)
- Maximum Arm length = 4 to 16 m in 1 m increments depending on type
- Maximum Sign Area, single arm type = 3, 5, or 8 m² depending on type
- Maximum Sign Area, trussed arm type = Dependent upon arm length and type - see table on BD-OS9
- Sign Panel thickness = 3 mm - all types

2.7 Structure Type Selection (ref. BD-OS1, BD-OS2, BD-OS8 and BD-OS9)
For span type structures, select the Structure Type from the table on BD-OS2, using the tabulated span length equal to or larger than the actual span length, the tabulated sign area equal to or larger than the total expected sign area and the tabulated nominal post height equal to or larger than the maximum actual nominal post height. The maximum actual nominal post height is the greater of the two actual nominal post heights, left or right. Enter the Structure Type code in the fourth column of the Span Structure Table, on BD-OS1. The standard Structure Type defines the size of the chords, diagonals and struts, posts, post base type, foundation type and minimum pedestal diameter. Details of these elements for span structures are located on BD-OS1 through BD-OS7 and BD-OS13 and BD-OS14.

For cantilever structures, select the Structure Type from the table on BD-OS9, using the tabulated arm length equal to or larger than the actual arm length and the tabulated sign area equal to or larger than the total expected sign area. Enter the Structure Type code in the fourth column of the
Cantilever Structure Table on BD-OS8. The standard sign Structure Type defines the size of the chords, diagonals and struts and post and the post base type, foundation type and minimum pedestal diameter. Details of these elements are presented on BD-OS8 through BD-OS14. (Note: BD-OS9 presents tables for both Single Arm Cantilevers and Trussed Arm Cantilevers. Signs greater than 1.5 m high or greater than 8 m² in area will require a trussed dual arm structure. For signs less than 1.5 m high and areas less than 8 m², a single arm cantilever structure may be used.)

Note: The Structure Types on BD-OS2 and BD-OS9 are categorized by incremental span and arm lengths, nominal post heights and sign areas. However, the designer shall enter the actual dimensions for the Truss Span, Arm Length, Total Sign Area, BL, XL, Height A, etc. which apply to the specific structure, in the columns on BD-OS1 and BD-OS8. The OSS shall be fabricated and constructed to the actual required dimensions included in the tables on BD-OS1 and BD-OS8.

2.8 Foundation Selection (ref. BD-OS1/BD OS8 and BD-OS3/BD-OS10)

2.8.1 Subsurface and Site Conditions

Review available geotechnical information as the first step in selecting the OSS foundation. Depending on the availability of existing geotechnical information, it may be necessary to take borings at the specific location of the sign structure foundations. Consult the Regional Geotechnical Engineer for input if necessary.

2.8.2 Substrate Information

The standard foundation designs, lengths and quantities shown on BD-OS2, BD-OS3, BD-OS9 and BD-OS10 are for shafts in soil and footings in soil or rock. If rock is not expected to be encountered within the depth of the foundation selected, indicate an “S” for soil in the table on BD-OS1 or BD-OS8 in the column titled “Substrate” (see exceptions for special foundations below). If rock is expected to be encountered within the depth of foundation (shaft or footing), indicate a substrate type “R.” At shafts, when rock is expected, show in parenthesis the total length of shaft and its embedment in rock in the “Substrate” column (with the embedment in rock determined as described in Section 2.8.4). For example, indicate “R(4.1/3.0)” for a shaft with a total length (HS) of 4.1 meters and an embedment into rock of 3.0 meters.

If the geotechnical information indicates any of the following, contact the Geotechnical Engineering Bureau (GEB) 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 GEB may recommend increases to the standard foundation size and/or depth shown on BD-OS2, BD-OS3, BD-OS9 and BD-OS10. In such a case, design a
special foundation and present it on a separate drawing in the contract package. Recompute foundation concrete quantities for the estimate. On BD-OS1 or BD-OS8, as applicable, insert a dash (“-”) in the “Substrate” column, indicate “Special” in the “Foundation Type” column and reference the new drawing where the special foundation details may be found in the “Remarks” column.

2.8.3 Select Foundation Type

For substrate types indicated as soil or rock, choose the foundation type, footing or shaft, to support the OSS and enter this selection on BD-OS2 or BD-OS9 in the column titled “Foundation Type”. Shaft foundations have been found to be more economical in a variety of site and subsurface conditions when compared to spread footings. Therefore, select the shaft foundation unless there are specific reasons a footing would be a more appropriate choice (note that the shaft foundations shown on BD-OS9 and BD-OS10 are for shafts in soil above the groundwater; for other conditions, as noted in 2.8.2, contact the GEB for a recommendation).

The specifications for shafts allow the contractor the option to choose the footing at no extra cost to the State. The specifications for footings allow the contractor the option to choose the shaft at no extra cost to the State. In some cases one of the foundation types, either the footing or the shaft, may not be suitable due to MPT requirements, groundwater depth, utility interference, rock depth or other conditions. In such a case, specify the required foundation type as “Footing” or “Shaft” in the column titled “Foundation Type” on BD-OS1 or BD-OS8 and indicate in the “Remarks” column “No Foundation Option” for cantilever structures, or “No Foundation Option at Right” (or Left, or Both), at span structures.

If a special foundation is required, see Section 2.8.2.

2.8.4 Shafts in Rock Supporting Span Structures

If sound rock is expected to be encountered within the shaft depth (based on the shaft length [HS] shown on BD-OS2), contact the GEB to determine the required embedment of the shaft in rock. As noted in Section 2.8.2, indicate the total shaft length and embedment in rock in the Span Structures Table in the “Substrate” column. If the GEB recommends a total shaft length different from that indicated on BD-OS2, revise the concrete quantity accordingly for the estimate.

2.8.5 Shafts in Rock Supporting Cantilever Structures

If sound rock is expected to be encountered within the shaft depth (based on the shaft length [HS] shown on BD-OS9), reduce HS such that the shaft penetrates a minimum of one diameter into sound rock. However, provide a total embedment in soil and rock not less than one diameter plus 600 mm. If sound rock is within one diameter of the bottom of the proposed shaft, use the shaft length shown on BD-OS9. As noted in 2.8.2, indicate the total shaft length and length in rock in the Cantilever Structure Table in the “Substrate” column. If the total shaft length is different from that indicated on BD-OS9, revise the concrete quantity accordingly for the estimate.
2.8.6 Depths of Footing Foundations
The footings shown on BD-OS3 and BD-OS10 have been designed using the soil overburden to resist overturning. For simplicity, the standard footings have used the same depth criteria for both soil and rock substrates. If it is determined that the footing depth needs to be reduced for a specific design reason (for instance where borings show sound rock at a shallow depth) a special footing shall be designed. Design the special footing using the forces presented in Appendix D, providing adequate resistance to overturning with the reduced overburden. Present the special foundation information as indicated in Section 2.8.2.

2.9 Cantilever Trussed Arm Spacing Selection
When it has been determined that a trussed dual arm cantilever is required, establish the spacing of the trussed arms and insert the spacing into the column titled “Truss Depth, D” on BD-OS8. Establish the arm spacing at 1.5, 2.0, 2.5 or 3.0 meters, dependent upon the maximum heights of the current (or future) signage in accordance with the following table:

<table>
<thead>
<tr>
<th>MAXIMUM ACTUAL (OR FUTURE) SIGN HEIGHT</th>
<th>CANTILEVER ARM SPACING</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.0 m</td>
<td>1.5 m</td>
</tr>
<tr>
<td>4.0 m</td>
<td>2.0 m</td>
</tr>
<tr>
<td>5.0 m*</td>
<td>2.5 m</td>
</tr>
<tr>
<td>6.0 m*</td>
<td>3.0 m</td>
</tr>
</tbody>
</table>

* Note: Sign heights greater than 4.0 m have restricted application as shown in the selection table on BD-OS9.

2.10 Additional Information Required on BD-OS1/BD-OS8
Complete the site and project specific information required in the Span Structure Table on BD-OS1 (span structures) or the Cantilever Structure Table on BD-OS8 (cantilevers). The column labeled “Loc. No.” is intended to identify the location of the OSS on the general highway plans. As indicated above, in Section 2.7, all dimensions and areas in the tables after the Structure Type column shall be the actual dimensions or areas for the proposed structure, not the incremented categories used to select the Structure Type. Each structure shall be sized to fit its site-specific requirements.
2.11 Additional OSS
Complete the steps identified in Sections 2.1 through 2.10 for each sign structure included in the PS&E. If there are more than seven span structures, or more than eight cantilever structures, in the contract, use supplemental BD sheets BD-OS1 or BD-OS8 and label them BD-OS1A or BD-OS8A, as appropriate.

2.12 Assembly of Appropriate BD Sheets for the PS&E
Assemble contract drawings for the required sign structures by selecting appropriate BD sheets for inclusion in the contract. The only drawings requiring that information be entered by the design engineer are BD-OS1 and BD-OS8, as described above in Sections 2.1 to 2.11. BD sheets BD-OS1 through BD-OS7 and BD-OS13 and BD-OS14 shall be included if span structures are to be constructed. BD-OS8 through BD-OS14 shall be included if cantilever structures are to be constructed. If both span and cantilever structures are to be constructed, the full set of BD sheets, BD-OS1 through BD-OS14, shall be included. (Note: Drawings labeled OS1A or OS8A are only needed if the number of structures in the project exceeds the limits of available lines in the tables on BD-OS1 or BD-OS8.)

The full drawings shall be used in the contract package. Modify the BD sheets prior to their inclusion in the construction package by replacing the BD border with a standard contract plan border, adding a note stating that all dimensions are in millimeters unless otherwise noted and placing the drawing number in the lower right title block as it corresponds to the BD sheet name, without the prefix BD (e.g. BD-OS1 becomes Drawing Number OS1, etc). This naming convention is important since it preserves the notes and cross-references contained on the BD sheets.

2.13 Contractor/Fabricator Options
In order to obtain cost effective overhead sign structures, the Department has provided certain Contractor/Fabricator options on the BD sheets. The options include: rectangular footings or drilled shafts; bolted or welded connections at certain specific locations; pipe or double angle horizontal diagonals, struts and cross braces for span trusses; and single angle, pipe or double angle diagonals and struts at trussed posts. With the exception of the foundation type, these options will be clarified on the shop drawings submitted by the Contractor and maintained as records with the project documents.

The foundation type, rectangular footing or drilled shaft, is not expected to be part of the Contractor submittals and will therefore only be available to field staff during construction. Separate columns have been provided on BD-OS1 and BD-OS8 to allow the EIC to record which type of foundation has been constructed by the Contractor at each OSS support.
3  METHOD 2 - SPECIAL DESIGN - INDEPENDENT ANALYSIS

3.1  Special Design Applications

Use the special design procedure explained in this section if the requirements for an OSS exceed the limits for sign thickness, nominal post height, span or arm length, sign panel height, height, exposure factor or total sign area. These limits are summarized in Section 2.6.

Examples of structures that require a special design include:

1. a 43 m long span structure carrying 102 m² of signage;
2. a 7 m long cantilever structure carrying 36 m² of sign area;
3. any span structure with a nominal post height greater than 13 m;
4. any cantilever structure with a nominal post height greater than 10 m;
5. any sign structure carrying a VMS or other sign with a thickness greater than 3 mm;
6. a structure whose height above the surrounding terrain is greater than 20 m; or
7. a structure utilizing a walkway or other horizontal access platform.

3.2  Overview

In the special design procedure, the designer analyzes selected structure types from BD-OS2 or BD-OS9 in an iterative process to determine if they are adequate for all the specific loads and forces required. Using this method, the structure shall be fully analyzed, including all connection details (welds, plates, bolts etc.) and foundations, to verify the structural adequacy of all structural elements.

There are two possible outcomes to this iterative analysis process. In the first, a structure type from BD-OS2 or BD-OS9 is analyzed and determined to be structurally adequate. This structure type is then included on BD-OS1 or BD-OS8, as appropriate, with a note indicating that it is a special design in the Remarks column. In this case, the standard BD sheets require no modification to be included in the PS&E. The standard BD sheets shall be used and assembled in the same manner described in Method 1, Section 2.12.

In the second outcome, the iterative process shows that no standard structure type on BD-OS2 or BD-OS9 satisfies the design requirements. In this case, the designer shall develop an appropriate engineered design. Completely new and separate contract sheets, showing all required OSS details for members, connections and foundations shall be developed. However, to the extent that it is reasonable, the special design shall use details and options similar to those presented on the BD sheets.

In accordance with the standard design specifications, sign structure designs follow allowable stress design (ASD) procedures. However, since recommendations for the design of hollow structural sections (HSS) are not available in ASD, connections of pipe members shall follow
3.3 Special Design Procedure

3.3.1 Establish Basic Design Information

Follow the steps defined in Sections 2.1 to 2.5 of the Standard OSS Selection Procedure. Using the actual (or future, if governing) total sign area, nominal post height and span or arm length, select the structure type from the table on BD-OS2 or BD-OS9 which most closely satisfies these requirements. This structure will serve as the initial trial structure in the iterative design process.

3.3.2 Determine Loads

Determine the loads and forces to be applied to the trial structure selected in Section 3.3.1 using the latest version of the NYSDOT Standard Design Specifications for OSS. For the special design, use the actual or projected future (whichever governs) sign panel sizes and locations to be supported by the structure.

3.3.3 Iterative Analysis and Selection Process

Analyze the structure for the actual loads and forces determined in Sections 3.3.1 and 3.3.2. Investigate each aspect and detail of the structure for the appropriate loads and forces using the specified design parameters identified in Section 3.3.2. In particular, investigate the connections to assure that they meet the requirements of the specific structure and its loads.

If the analysis determines that any part of the structure (including connection details) is inadequate, the next larger structure from the selection tables on BD-OS2 or BD-OS9 shall be checked and the analysis process shall be repeated.

If the analysis determines that the structure is adequate, the next smaller structure from the selection tables on BD-OS2 or BD-OS9 shall be investigated. The iterative process shall continue until the standard structure type that satisfies all design requirements is identified. (Note that the structure types listed on BD-OS2 and BD-OS9 use the details presented in the remaining BD sheets. In addition to the primary and secondary members, all connections and other members shall be analyzed to determine that the structure is adequate for the design loads and forces established in Section 3.3.2.)

Enter the appropriate information for the selected structure type in the table on BD-OS1 or BD-OS8 following steps defined in Sections 2.8 to 2.12 of Method 1. Indicate in the Remarks column of the Span Structure Table on BD-OS1 or the Cantilever Structure Table on BD-OS8 that the structure is a special design. Also note which of the structure’s features fall outside the limits of the normal standard design (sign area, nominal post height, sign height, sign thickness, and/or exposure factor). (Note: See Section 3.3.5 for VMS signs or other signs with thickness greater than 3 mm.)
3.3.4 Special OSS Designs Not Using BD Sheets OS1 through OS14

3.3.4.1 Design Alternatives

If the analyses described in Section 3.3.3 determines that no standard structure type listed on BD-OS2 or BD-OS9 (as detailed on the remaining BD sheets), satisfies the design requirements, the designer shall develop an appropriate alternative.

For span structures, the alternative may include a quad truss with revised details, thicker base plates, larger bolts, thicker gussets, different welds, larger chords, greater truss depth, heavier diagonals, and/or heavier posts than those listed on BD-OS2. For cantilevers, similar revisions may be appropriate. However, cantilever structures larger or heavier than the planar trusses and single arm structures shown on BD-OS9, may not be feasible. Quad truss cantilevers, or other special unique designs, may be required. In certain cases, it may be necessary to use a span structure in lieu of a cantilever. In all cases, each aspect and detail of the structure, including all supports, connections and foundations, shall be designed for the appropriate loads and forces using the specified design parameters identified in Section 3.3.2.

All OSS designs shall conform to the latest version of the NYSDOT Standard Design Specifications for OSS and the Standard Specifications, Construction and Materials, NYSDOT Office of Engineering (latest version), with all additions and modifications current at the time of design.

3.3.4.2 Drawings for Special OSS Designs

The designer shall prepare drawings for the special design developed in Section 3.3.4.1 showing all required plans and details. It is the Department’s intent that these special designs conform to the general details presented on BD-OS1 through BD-OS14 and allow similar contractor options for foundations and secondary members in order to achieve cost effective designs. However, these special design drawings shall be separate from the drawings for standard designs (OS1 through OS14) in the PS&E package to avoid confusion. Drawing numbers OS1 through OS14 shall be used only for standard designs that do not require modifications to the BD sheets except for the inclusion of site specific information in the tables on BD-OS1 and BD-OS8. Note: See Section 3.3.5 for VMS signs or other signs with thickness greater than 3 mm.

3.3.5 Special Considerations for OSS Structures Carrying VMS or Signs with Greater than 3 mm Thickness

OSS carrying VMS or signs with thickness greater than 3 mm shall be analyzed for all required forces as defined in the latest version of the NYSDOT Standard Design Specifications for OSS. Special designs for these structures shall follow the procedures defined in Sections 3.3.3 and 3.3.4 as required.

As noted in Section 1.3, cantilever structures shall not be used to support VMS unless there is no alternative, due to the unique fatigue loads induced as a result of the sign shape and eccentricity. When VMS must be supported on cantilever structures, the thickness of the VMS shall not exceed 380 mm (15 inches) and the load on the VMS, including its resulting out-of-plane bending, shall be accounted for in the design process.

For special designs completed under Section 3.3.3 for OSS supporting VMS, the designer shall modify the Structure Table on BD-OS1 or BD-OS8 to include columns for not-to-exceed dimensions...
for height, length and thickness and not-to-exceed weights for the signs. This will ensure that the signs installed in the contract correspond to the design assumptions.

For special designs completed under Section 3.3.4 that do not use BD-OS1 through BD-OS14, the designer shall also include not-to-exceed dimensions for height, length and thickness and not-to-exceed weights for the signs in tables on the plans to insure that the signs installed in the contract correspond to the design assumptions.

4 REFERENCES

1. New York State Department of Transportation Standard Design Specifications for Overhead Sign Structures, April 2003


APPENDIX A

MAJOR CHANGES FROM THE 1968 DESIGN MANUAL AND THE 2000 INTERIM STEEL DESIGN (EI 00-035)

A.1 Standard Drawings/Standard Sheets/BD Sheets

Prior to the issuance of this Design Manual, span type OSS were selected from tables distributed in October 2000 by EI 00-035. Cantilever designs continued to use the 1968 Design Criteria for Sign Structures. Details for both span and cantilever OSS were included on Standard Drawings and Standard Sheets. The Standard Drawings were inserted into the contract plans and had blank tables that were filled in by the designer. The Standard Sheets could generally be used as is and needed only to be referenced on the front sheet of the contract plans to merit inclusion. With the BD sheets included in this manual, the designer will need to fill in the Span Structure Table on BD-OS1 and/or the Cantilever Structure Table on BD-OS8 and insert into the contract package all sheets necessary to clearly specify the members and details of the OSS.

A.2 Fatigue-Resistant Details for Cantilever Structures

Connection details for cantilever structures have been substantially improved to increase fatigue resistance.

A.3 Refined Designs for Span Structures

The dimensions of the quad-trusses used in the Interim Steel Design (EI 00-035) were not optimized. The post spacings were variable and the details associated with base plates and sign attachments referenced existing Standard Sheets. The structures presented on the new BD sheets utilize only two basic quad-truss sizes and constant post spacing for each of the basic truss sizes, allowing for uniform foundation configurations. The details for base plates and sign attachments have been modified to accommodate the new truss configurations. In addition, the fatigue resistance of the base plate welding has been improved.

A.4 Elimination of Grout Cap

A significant problem identified during the sign structure inspection program, was the accumulation of water and debris inside post bases. Although drainage grooves had generally been provided, they were not functioning as designed and did not allow the post bases to drain freely. To address this problem, the new design has eliminated the grout cap so that the open-based post is supported directly on the anchor bolt leveling nuts. Protective screening material is used to prevent birds or small animals from nesting inside the posts.
A.5 Pedestal Height

The previous standard called for the pedestal to project above the finished grade by 200 mm (8 inches) at the centerline of the pedestal. This relatively small projection left very little clearance above the top of the ground at the edge of the pedestal. As a result, during the inspection program, many of the base plates and anchor bolts at existing sign structure foundations were found to be buried or surrounded by vegetation preventing drainage and accelerating deterioration. The new design increases the height of the pedestal above grade to 600 mm (24 inches) at the centerline of the pedestal, which is expected to reduce or eliminate the problem.

A.6 Handhole Location

The handhole for span structures was located on the back of the post, away from traffic. This location prevents the intrusion of deicing salts into the post base in the event that the handhole cover is missing or improperly sealed. However, the handhole for cantilever structures was located on the front face, or traffic side, of the cantilever post, making the post susceptible to salt spray. The original intent of the front face location is believed to have been an attempt to place the opening in a zone of compressive stress. The new design provides sufficient reinforcing at the post opening in order to allow the hand hole to be placed opposite traffic for all posts, offering additional protection against salt spray.

A.7 Truss Connections

The previous standard in use prior to the issuance of the Interim Steel Design called for steel posts and aluminum trusses at span structures and steel posts and either steel or aluminum arms at cantilever structures. In these structures, generally the diagonal to chord and strut to chord connections were made using tube to tube welds. Tube to tube welds have a comparatively low resistance to fatigue. The Interim Steel Design called for steel members for all sign support structures with split tube gusset plate connections and eliminated aluminum as an option. The gusset plate split tube connections were also an improvement since they are much more fatigue resistant than the tube to tube connections. However, the gusset plate connections do not allow as much flexibility in the location of sign attachments as the tube-to-tube connections. Therefore, closer coordination is required between the sign structure fabricator and the sign panel manufacturer to ensure that the sign panel attachments can be properly installed on the structure.
APPENDIX B

DESIGN ASSUMPTIONS USED FOR STANDARD OSS ON BD-OS1 THROUGH BD-OS14

B.1 General

The standard OSS shown on BD-OS1 through BD-OS14 were designed using the NYSDOT Standard Design Specifications for OSS, April 2003 and the additional design assumptions and clarifications contained in this appendix.

B.2 Loads

B.2.1 Dead Load

<table>
<thead>
<tr>
<th>Material</th>
<th>Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>7850 kg/m³ (490 pcf)</td>
</tr>
<tr>
<td>Sign panels, including stiffeners and attachments</td>
<td>35 kg/m² (7 psf)</td>
</tr>
<tr>
<td>Concrete in foundation design</td>
<td>2400 kg/m³ (150 pcf)</td>
</tr>
<tr>
<td>Soil in foundation design</td>
<td>1920 kg/m³ (120 pcf)</td>
</tr>
</tbody>
</table>

Members are assumed to extend from joint to joint, with no deduction for intersecting members.

B.2.2 Live Load

No live load has been used in the design of the standard structures. No walkways or service platforms are included on the standard structures.

B.2.3 Ice and Snow Loads

Ice load has been applied to the standard structures in accordance with the NYSDOT Standard Design Specifications for OSS, April 2003. No snow load has been applied.
B.2.4 Wind Load

Wind loads on the structures have been established based on the methodology described in the NYSDOT Standard Design Specifications for OSS, April 2003 (AASHTO 2001, Appendix C, alternate method).

V: a wind velocity of 129 km/h (80 mph) has been used for the entire State, for simplicity of design;

Cd: the drag coefficient has been set at 1.2 for all signs, span trusses and span posts. For cantilever posts, arms and truss members, Cd varies between 0.45 and 1.1 according to the formula in NYSDOT Standard Design Specifications for OSS, April 2003, Table C-2;

Kz: the height and exposure factor has been set at 1.16, reflecting a height of 20 m;
resulting in:

\[ P_z = 1859 \text{ Pa (38.5 psf)} \]  on all signs, span trusses and span posts, and
\[ P_z = 1700 \text{ Pa (35.3 psf)} \]  maximum for cantilever trusses and posts.
Pz varies depending upon the value of Cd.

B.2.5 Sign Location

For the purposes of developing the standard tables, the sign area has been assumed to be represented by a single large sign with a height of 4 m and 6 m for trussed-arm cantilevers, 1.5 m for single-arm cantilevers and 6 m for span structures. Cantilever OSS have been designed assuming the sign mounted at the most outboard position. For spans, the OSS has been designed assuming the sign mounted separately at the two worst case positions: (1) at the center of the span and (2) as close as possible to one of the posts.

B.3 Materials

- Pipe is normal carbon steel with a minimum yield strength of 240 MPa (35 ksi).
- Plate is normal carbon steel with a minimum yield strength of 250 MPa (36 ksi).
- Anchor bolts are ASTM F1554, Grade 55, galvanized full length.
- Vertical Z-Bars are 6061-T6 aluminum extrusions.
- Reinforcing steel is ASTM A615, Grade 420 deformed billet steel bars.
- Concrete for foundations is Class A, with a 28 day strength of 21 MPa (3000 psi)
B.4 Allowable Stresses

Allowable stresses are in accordance with the *NYSDOT Standard Design Specifications for OSS, April 2003*.

Allowable fatigue stress ranges have been established based on the Constant Amplitude Fatigue Limit (CAFL) for each type of connection detail used in the structure. The design of the members has been governed by the CAFL indicated in the *NYSDOT Standard Design Specifications for OSS, April 2003*, using the following detail categories:

- The connections of the cantilever arm to end plate and the post pipe to base plate have been detailed as full penetration welds with welded backer rings, resulting in Detail Category E.
- The connection of the box connection side plate to the post pipe has been detailed as a fillet weld, resulting in Detail Category ET.
- The connection of the chord to splice plate, for both cantilever and span splices, has been detailed as a socketed, fillet-welded connection, resulting in Detail Category E’. [Note that splice locations for the span trusses are not defined in the standards and may be established at any location except at the ends of the span].
- The connection of the gusset plate to the arm, chord or post has been detailed as a fillet-welded connection, Detail Category E for the main member and Detail Category ET for the weld of the gusset to the main member.
- The connection of the diagonal, strut or cross-brace to the gusset plate has been detailed with a coped hole, Detail Category E.

B.5 Deflection and Camber

Deflection and camber for the standard structures have been established in accordance with the *NYSDOT Standard Design Specifications for OSS, April 2003*.

The deflection at the top of cantilever posts due to dead load only has been limited to a slope of 30 mm per m (0.35 inches per foot). There is no specified upper limit for deflection of cantilever arms. Their design is generally governed by the galloping fatigue load.

Deflection for span structures has been computed from the Group I loading of Dead Load and Ice. Due to the stiffness of the quad-truss configuration used in the span structures, deflection in the standard span structures does not approach the limiting value of L/150.

Camber requirements have been established by adding L/1000 to the calculated dead load deflection of the cantilever arm or L/1000 to the calculated dead load plus ice deflection of the span truss.
B.6 Structural Configurations

In preparation for the development of this manual, a number of structural configurations were investigated. All configurations utilized round pipe for the primary structural elements, since the circular surface attracts the least wind load. Constant diameter pipe was used to simplify connections.

B.7 Connections

The model used in the analysis of the trussed arm cantilever structures assumes that 50% of the primary longitudinal wind force is transmitted to each arm.

The model used in the analysis of the span structures assumes that welded connections are rigid (fixed) in the plane of the gusset plate and flexible (pinned) in the direction perpendicular to the gusset plate. Bolted connections are assumed to be flexible (pinned) in both planes.

In accordance with the NYSDOT Standard Design Specifications for OSS, April 2003, sign structure designs follow allowable stress design (ASD) procedures. However, since recommendations for the design of hollow structural sections (HSS) are not available in ASD, connections of pipe members follow strength design procedures, in accordance with the AISC Hollow Structural Sections Connection Manual.

B.8 Foundations

Two types of foundations have been presented on the BD sheets, formed rectangular footings and cast-in-place drilled shafts.

The parameters used in the development of the foundation designs include:

1. Allowable Soil Pressure: 200 kPa (2 tsf)
2. Allowable Rock Pressure: 500 kPa (5 tsf)
3. Soil Friction Angle: 28 degrees
4. Coefficient of Sliding Friction: 0.50

The standard foundations assume one of two possible substrates, either sound rock or soil free of soft clay and organic deposits.

Groundwater is assumed to be below the bottom of the foundation.

For the purposes of foundation design, the allowable soil and rock stresses have not been increased by the percentages of allowable stress listed in Table 3-1 of the NYSDOT Standard Design Specifications for OSS, April 2003. Conversely, the applied loads have not been decreased by those percentages.
The depths of the footing foundations shown on BD-OS3 and BD-OS10 have been established using the maximum finished transverse slope of 2 horizontal to 1 vertical and a minimum depth to bottom of footing of 1.25 meters, perpendicular to the slope, at the low edge of the footing. The load of the average depth of soil overburden at the centerline footing has been included in the calculation of the overturning resistance.

The resultant substrate pressures have been adjusted to reflect the absence of tension between the footings and their substrates.

A minimum overturning factor of safety of 1.5 has been used for footings on either soil or rock. A minimum sliding factor of safety of 2.0 has been used for footings on either soil or rock.
APPENDIX C

ISSUES AND OPTIONS EVALUATED DURING THE DEVELOPMENT OF THE STANDARD OSS DESIGNS

C.1 General

Many options and issues were investigated during the development of the standard designs presented on BD sheets BD-OS1 through BD-OS14. The most appropriate option was identified based on several criteria: ease of selecting the applicable structure; minimization of future structure replacement and cost effectiveness of structure construction.

In order to simplify the structure selection process, it was decided to utilize tables of standard structures based on only three parameters: the span length (or arm length, for cantilevers), the area of sign panel carried and the height of the posts. The height of the posts for cantilevers was set at 10 m maximum, since their height above grade does not vary as much as the height of posts required for span structures.

The variations in length between standard structures (5 m increments for the span structures and 1 m increments for the cantilever structures) were selected in an effort to minimize the number of different configurations and to allow for standardization of the fabrication process, where possible.

The sign areas selected for the standard structures were intended to give the design engineer a wide range of areas to choose from while also including the maximum expected amount of signage on each span or arm length. For span structures, the sign area of 30 m² represents the average amount of signage that structures will normally be expected to carry. The other two span structure sign area options, 60 and 90 m², are expected to be used less frequently.

The nominal post height increments for the standard span structures were established to represent typical structure heights. The 9 m height can generally be used at areas where the roadway cross-section is minimally superelevated and where the posts are fairly close to the edge of shoulder and not placed on a steep fill slope. The other nominal post height increments are intended to cover by far the great majority of normal span structure heights in the State.

Analyses were performed to compare the costs of various alternative designs. In addition, analyses were performed to evaluate the cost impacts of simplifying assumptions used for the standard designs included on BD-OS2 and BD-OS8. These cost studies included:

- Comparing trusses of various depths
- Comparing aluminum and galvanized steel structures
- Tri-chord trusses vs. quad trusses, monotubes and planar trusses
- Full penetration welds at specific locations vs. fillet welds
- Analyzing the cost impacts of simplifying assumptions used for span length, sign locations, sign height, sign area, and exposure factor.
Other issues investigated during the development of this design manual included:

- Structure materials
- Structure configurations
- Foundation types
- Anchor bolts
- Post spacing
- Post height
- Exposure factor
- Support beam at span structure dual posts
- Erection sequence for overhead span truss
- Quad truss size
- Fatigue-resistant weld details
- Welded vs bolted connections
- Single-sided connections
- Maximum pipe sizes
- Stiffeners at splice plates and base plates
- Diagonal and strut options
- Out of plane bending
- Sign connection interference issues
- Two post foundations for spans

Some of the background on the decisions made concerning these issues is presented below.

C.2 Structure Materials

The two most common materials in use for sign structures are steel and aluminum. Other materials, such as Fiber Reinforced Polymers, have been suggested; however their use is considered experimental at this time. Both NCHRP Report 412 and AASHTO (4th Edition, 2001 Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals) indicate that the Constant-Amplitude Fatigue Thresholds for aluminum are quite low compared to the thresholds for steel. As a result, steel is the material that has been selected for use in the standard sign structures. Although weathering steel has some advantages and could be utilized in some circumstances, it is not appropriate statewide and therefore has not been specified in the standard structures. Galvanization is considered to be a long-term, low maintenance method of protecting steel from corrosion; therefore, galvanized steel has been specified.

The types of acceptable pipe steels listed in the specifications were intended to provide ductile, weldable material with a minimum yield strength of 240 MPa. The pipe materials were also
selected to allow the greatest possible availability given the large range of pipe sizes specified in the standard tables.

Gusset plates, splice plates and base plates used in the sign structure construction are intended to be compatible with the pipe materials, ductile and weldable, with a minimum yield strength of 250 MPa (conforming to ASTM A36M).

Steel used in sign structure elements defined as main members are subject to Charpy requirements to ensure ductility.

C.3 Structure Configurations

Span Structures. For the span structures, a number of structural configurations were investigated in addition to the quad-truss configuration presented in the standard tables. Single members spanning between single posts, planar trusses spanning between single posts, monotubes with and without frame action and tri-trusses similar to those being used throughout the State for the past thirty years. The single members, planar trusses and monotube configurations were not included as standards because their applicability is limited to fairly short spans. The tri-trusses were not included as standards because they are less able to carry torsional loads due to the eccentricity of signs, platforms, lighting and other attachments that are commonly placed on sign structures, as well as the torsional loads due to Variable Message Signs. The quad-truss configuration was deemed the most versatile, accommodating all span lengths with good torsional rigidity.

In addition, for simplicity, it was desirable to present a single structure configuration that could meet the strength and detailing requirements of the full range of expected sign structure span lengths and sign areas at reasonable cost. As a result, the four chord quad-truss was selected for the standard tables.

Cantilever Structures. There were also several variations on the configuration of the cantilever structure considered, in addition to the single arm and trussed dual arm configurations detailed on the BD sheets, including the curved monotube and the untrussed dual arm.

The curved monotube can be used for only a limited range of cantilever arm lengths, it involves different details than those required for the standard span structures (implying inefficiencies in fabrication) and it has the same limitation on sign height mentioned above for the span monotube.

The untrussed dual arm requires either that the connections and vertical stiffeners of the sign panel act to transmit vertical load between the two arms or that the full vertical load be carried by each arm acting independently. Since the design of the cantilever arms for many arm lengths is governed by the galloping load, requiring that the full vertical load be carried by a single arm would be very inefficient. Redesign and redetailing of the sign panel connections and vertical stiffeners to transmit the vertical loads to ensure that the loads are shared equally by both arms would introduce additional complexity into the sign elements and require a different approach to sign panel design. Therefore, only the trussed dual arm cantilever has been presented on the BD sheets.
C.4 Foundation Types

Prior to the issuance of this manual and the associated BD sheets, the only foundation type specified for dual post span structure foundations was a formed, rectangular footing. No option was allowed. Presenting an option for a drilled shaft will allow for simplification and economy of construction.

C.5 Anchor Bolts

The field inspections have also noted cases where anchor bolt nuts were loose. In order to ensure that these nuts do not loosen, the new details require double nuts, rather than lock nuts. Also, to provide an additional factor of safety and redundancy, all post bases have been detailed with a minimum of six anchor bolts.

Misalignment encountered when post base plates are mounted on anchor bolts can result from several possible sources. Despite all care, the anchor bolt template may shift during concrete placement; the template may be slightly loose or the baseplate could be slightly rotated from its intended orientation. Exaggerating any minor misalignment, is the increase in the number of anchor bolts from four to at least six. As a result, the size of the holes in the base plate has been increased to allow more space for such minor misalignments of the cast-in-place anchor bolts.

C.6 Post Spacing

In span structures, two new post spacings were established in order to limit the number of sizes for the spacing of the cast-in-place pedestals while accommodating all the various quad-truss configurations presented in the standard selection tables. The simplicity of only two post spacings should allow consistency in the construction of the sign structure foundations, resulting in a higher level of accuracy and quality in foundation placement.

C.7 Post Height

If the sign height is greater than the truss chord spacing, which it generally is, the vertical clearance and post height will be governed by the location of the sign. For simplicity of installation of signs, each sign or sign assembly is intended to be centered on the truss. If there is a supplementary panel associated with a main panel, or multiple panels arranged vertically, the combined height of the panels should be centered about the centroid of the assembly.

The post height used in the standard cantilever structures is 10 m from the bottom of the base plate to the centerline of the trussed arms (and sign panel). The 10 m height is expected to be sufficient for nearly all cantilever structures constructed in the State.

The three post heights used in the standard span structures, 9, 11 and 13 m, are intended to give a sufficient range to accommodate essentially all span structures in the State.
C.8 Exposure Factor

An exposure factor of $K_z = 1.16$ has been used for the standard designs. This exposure factor represents a structure height above surrounding terrain of 20 m. This height was selected because it is expected to include the overwhelming majority of sign structures throughout the State. It is expected that only structures on high bridges or in particularly unusual locations will have exposure factors exceeding the selected value, requiring special designs.

C.9 Support Beam at Span Structure Dual Posts

During the design of the standard structures, the options available for the detail of the support for the span structure quad-truss at the dual posts included a bracket-type support or a support beam. However, the available space between the face of the chord and the face of the post varied widely, as did the vertical load imposed by the chords under combined dead and wind loads. In order to present only two post spacings, the support beam option was selected. The detail at the connection to the post has been designed to transmit the forces resulting from the analysis, including dead load, wind load and thermal load.

The chords have been detailed with a half-height saddle, and double U-bolts at each support. The 180 degree saddle allows the connection to transmit both vertical and horizontal load from the chord into the horizontal support beam. The surface of the saddle has not been machined, since it is expected that the shape of the chord will conform to the shape of the saddle under load.

C.10 Erection Sequence for Overhead Span Truss

The OSS support system has been designed for all dead load of the truss to be carried by the lower support beam. While the trusses may be transported with the upper saddles, U-bolts and support beams attached, it is expected that the lower support beam will be fully connected to the post assembly prior to erecting the overhead span truss. The truss will then be lowered onto the lower support beams at each end with the saddles in place, the bottom chords will be shimmed and leveled as necessary and the U-bolts will be installed at the bottom chords. The top support beam will then be installed and connected to the posts at each end, adjusted for snug fit of the top chord saddles and the U-bolts installed at the top chords. There is not expected to be any dead load in the top support beam.

C.11 Quad Truss Size

The two quad truss chord spacings presented for the span structures, 2.0 m and 2.5 m, are intended to provide cost-effective trusses for the full range of expected sign structure span lengths and sign areas. The most significant constraint for the truss sizes is the size of available galvanizing tanks. It is not expected that either the 2.0 m truss or the 2.5 m truss fully fabricated will fit into existing available galvanizing tanks, therefore, bolted top and bottom diagonals and struts
and cross braces have been presented, so that the front and back welded planar trusses can be galvanized separately and assembly performed after galvanizing.

While a smaller truss chord spacing could have been specified, it was judged to be more beneficial to present only two chord spacings in order to limit the variations in fabrication processes. In addition, the smaller chord spacing investigated, 1.5 m, provided only a limited range of cost-effective application and contained significantly more welded connections per unit of length than the larger trusses.

C.12 Fatigue-Resistant Weld Details

One of the primary reasons for revising the sign structure design presented in the 1968 NYSDOT sign structure design manual was the introduction of more fatigue-resistant weld details. The tube-to-tube welding details presented in the earlier documents for the diagonal and strut connections to the chords and posts result in very low Constant Amplitude Fatigue Limits (CAFL), category ET, and are primarily applicable to aluminum members, which are easier to shape for the complex connection configurations. The revised design replaces the tube-to-tube connections with split-tube gusset plate connections, intended to increase fatigue resistance by simplifying the connection, making it more flexible and increasing the overall length of the weld. The weld of the gusset plate to the chord has been detailed as an all around weld, to avoid the quality issues associated with starting and stopping the welding process and to provide a seal at the ends of the gusset plates. While the gusset-to-chord weld continues to be fatigue category ET, it is expected that the simplified connection will increase the quality of the connection. The radiused transition at the ends of the gusset, as detailed in Example 15 (Figure 11-1(e) of AASHTO, 4th Edition, 2001 Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals), were considered. However, the fatigue stresses in the gusset plates were within the allowables for category ET and therefore the additional complexity of the shaped gusset and ground welds was not justified.

In addition to the revision of the diagonal and strut connections, the connections at the posts to base plates and cantilever arms to end plates have also been revised. These connections were originally detailed as socketed fillet welds, which have a relatively low CAFL detail category of E’. This low CAFL significantly affected the design of the posts and arms. As a result, the socketed, fillet welded details were replaced with full penetration welds, with fillet welded backer rings, resulting in detail category E and nearly doubling the fatigue resistance in the connection.

The splice locations in the span and cantilever structure trusses use socketed welds with detail category E’. It was determined that, at these locations, member sizes were not impacted by the reduced allowable fatigue stress range and, as a result, it would not be cost effective to use the more complex full penetration welds. Therefore, the splice plate connections continue to use the socketed, fillet welded detail.

C.13 Welded vs Bolted Connections

As mentioned above, the span quad-trusses and some of the cantilever trusses are too large to be hot dipped galvanized fully assembled. As a result, bolted connections have been shown in the top
and bottom planes, as well as at the internal cross braces. The front and back trusses are shown fully welded in order to preserve the camber in those elements throughout the fabrication process.

In the cantilever trussed arms, since the spacing of the arms varies, those elements may also increase to the point that fully-assembled galvanization becomes a problem. Therefore the option is available to either weld or bolt the cantilever truss elements. An exception is made at the bay where a splice is introduced into the cantilever chords. In that bay, a bolted diagonal shall be provided, to be assembled, along with the splice, after galvanizing.

Oversize holes have been allowed in certain quad truss bolted connection elements due to the additional complexity of the multi-plane structure and the tolerances involved in its fabrication. Since the cantilever structure is within a single plane, no oversize holes have been allowed in that structure’s bolted configuration.

C.14 Single-Sided Connections

Single-sided connections were investigated at the span truss supports and at split tube bolted connections. Due to the magnitude of the axial loads carried by these members, the single-sided connections introduced significant eccentric loads into the structural elements, increasing the sizes of both primary and secondary members. Symmetric, double-sided connections are presented on the BD sheets, except at the post diagonals and struts, where heavy single angles are an option.

C.15 Maximum Pipe Sizes

The post pipe sizes indicated in the standard cantilever designs are larger than those previously presented in Department standards. These larger pipe sizes generally require special handling during fabrication and additional attention during detailing due to their higher diameter to thickness ratios. However, during the development of the standard cantilever selection tables, it was determined that limited cantilever arm length and sign area combinations would be available if the previous maximum pipe size (NPS 20 XS) were not exceeded. Therefore, pipe sizes up to NPS 36 were used in the design of cantilever posts. Since the larger pipe diameters are less common, only NPS 24, 26, 30 and 36 have been included in the standard selection tables.

C.16 Stiffeners at Splice Plates and Base Plates

The splice plate and base plate connections have been detailed and sized to eliminate the need for stiffeners between the posts or chords and their connection plates. These details are intended to keep the area clean of any possible trapped debris and allow the connections to be self-cleaning. In addition, by eliminating stiffeners, welding has been reduced with the intention that the remaining welding can be closely quality controlled, resulting in higher quality welding at these critical areas.
C.17 Diagonal and Strut Options

The diagonal and strut options presented for the span structures on the BD sheets include: Split tube, single angle or double angle elements. Split tube elements have been allowed in any diagonals or struts, in either the trussed posts or the overhead span truss.

Angle options have only been allowed in specific locations not exposed to primary wind loads, since curved surfaces are more efficient than flat surfaces when exposed to wind.

The single angle diagonal and strut have only been allowed in the dual post assembly for the span truss, since their weight and exposed area precludes the use of these elements in the overhead span truss itself. The single angle connection is an asymmetrical, one sided connection. The heavy angle shown in the selection table has been designed for the eccentricity resulting from the one-sided connection.

Double angles have been allowed at both the trussed posts and the horizontal elements and cross braces of the overhead span trusses.

C.18 Out-of-Plane Bending

The trussed cantilever arms are subject to out-of-plane bending primarily when the wind on the face of the panel is not uniform. With the longer cantilever arms, the differential deflection between the two arms can be significant under non-uniform wind load. Inspections of existing gusset-plated connections have shown that the welds of some of these connections have cracked. It has been postulated that most of these cracked welds have resulted from out-of-plane bending. During the design of the standard cantilever structures, the flexibility of the gusset plate connection was investigated. As a result, the distance from the end of the split tube and the face of the arm was increased from 12 mm to 50 mm, considerably increasing the flexibility of the connection and resulting in more uniform stress in the gusset plate.

C.19 Sign Connection Interference

Since the new standard sign structures utilize gusset plate connections rather than the previous tube-to-tube connections, there was a concern that there could be inadequate space to mount the sign panels. The various configurations of truss chord spacing, including the minimum arm spacing of 1.5 m at the cantilever trussed arms, were investigated to determine whether there would be enough space available for mounting the sign connection U-bolts and vertical zee bars. The most critical situation was at the span structure splice locations, where the U-bolts need to be mounted on either side of the end strut/diagonal connections at the splice. Since this could present difficulties in the required arrangement of sign connections, a note has been added to the sign attachment BD sheet alerting the contractor to the possibility of interference, asking the contractor to coordinate the spacing of the vertical zee bars and the available locations for attachment on the truss and allowing the contractor to shift the sign a small distance if the interference cannot be resolved by respacing the zee-bars.
### C.20 Two Post Foundations for Spans

Two post foundations were selected for all spans due to the increased redundancy when compared to single post foundations.

### C.21 Wire Inlets

Wire Inlets have been provided to accommodate electrical wiring for lighted signs. They are not required when sign lighting is not provided. In order to protect the inlets from damage during transport and erection, galvanized caps have been specified.

The design of the chord members included an investigation of the impact of the reduction in section due to the wire inlets. While most of the chords were unaffected by the reduction, two truss chords, the 15 meter span with 60 square meters of sign and the 40 meter span with 30 square meters of sign, required a larger chord due to the introduction of the wire inlets.
APPENDIX D

FOUNDATION LOADS AT STANDARD OSS

D.1 Introduction

The foundation loads presented in the tables below are the governing loads resulting from the analyses of the standard structures. These loads result from the application of dead load, wind, ice and thermal variations on the OSS. While many loads have been applied to the structures during the investigations in order to evaluate maximum or fatigue stresses in the individual structural members, the loads presented here are those that govern the foundation design. They are presented here to assist the Department in evaluating structures which fall outside the parameters defining standard OSS and those encountering unique site conditions.

For all loads presented in this appendix, the longitudinal direction is perpendicular to the sign, parallel to traffic. The transverse direction is parallel to the sign, perpendicular to traffic.

D.2 Span Structures

The span structure loads are effective at the bottom of base plate at the center of the foundation, midway between the two pedestals or shafts that comprise the foundation. The Foundation Type categories have been established based on groupings of maximum longitudinal moment. These foundation loads represent the loads resulting from the family of OSS included in each of the Foundation Type categories. The categories include from one to 15 standard structures.

Maximum and minimum dead loads are presented because minimum vertical load is a critical loading in some cases. The minimum dead load is that of the lightest structure in the next-smaller category (or, in the case of the 15 meter span, two-thirds of the weight of the lightest structure in the 15 meter span category). For instance, since a structure in the 20 meter span category could actually be 15.1 meters long, the minimum weight listed here would be that of the lightest standard 15 meter span structure.

The Standard Span Structures table on BD-OS2 indicates which structures are included in each of the foundation type categories. Since the foundation type categories were established based on the maximum moment due to wind, it may be noted that the other, associated loads in each category do not necessarily increase consistently from Type S-A through Type S-K. For instance, the maximum dead load for Type S-G is greater than that of Type S-H and Type S-J because Type S-G contains a 65 meter structure with 90 square meters of sign area and a 9 meter high post. Although the dead load of the S65-90-9 structure in Type S-G is greater, the maximum moment is less than that of the S65-60-13 structure that governs Type S-H and the S60-90-13 structure that governs Type S-J.

Although the transverse moment and transverse shear are essentially split between the two pedestals, with each pedestal carrying approximately 50% of the force listed in this table, the longitudinal shear is not evenly distributed between the two pedestals. For design purposes, the actual longitudinal shear at an individual pedestal has been taken to be 90% of the total maximum longitudinal shear listed in the table below.
<table>
<thead>
<tr>
<th>FOUNDATION TYPE</th>
<th>MAXIMUM LONGITUDINAL MOMENT kN-m</th>
<th>MAXIMUM VERTICAL DEAD LOAD kN</th>
<th>MINIMUM VERTICAL DEAD LOAD kN</th>
<th>MAXIMUM TRANSVERSE MOMENT kN-m</th>
<th>MAXIMUM LONGITUDINAL SHEAR kN</th>
<th>MAXIMUM TRANSVERSE SHEAR kN</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-A</td>
<td>600</td>
<td>59</td>
<td>20</td>
<td>80</td>
<td>69</td>
<td>17</td>
</tr>
<tr>
<td>S-B</td>
<td>800</td>
<td>76</td>
<td>23</td>
<td>119</td>
<td>84</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>55</td>
<td>31</td>
<td>113</td>
<td>69</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td>161</td>
<td>54</td>
<td>137</td>
<td>91</td>
<td>29</td>
</tr>
<tr>
<td>S-C</td>
<td>1000</td>
<td>84</td>
<td>27</td>
<td>171</td>
<td>119</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td></td>
<td>86</td>
<td>30</td>
<td>154</td>
<td>84</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>172</td>
<td>54</td>
<td>165</td>
<td>98</td>
<td>33</td>
</tr>
<tr>
<td>S-D</td>
<td>1200</td>
<td>57</td>
<td>35</td>
<td>159</td>
<td>101</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>83</td>
<td>33</td>
<td>232</td>
<td>144</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td></td>
<td>178</td>
<td>70</td>
<td>207</td>
<td>136</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>175</td>
<td>61</td>
<td>248</td>
<td>142</td>
<td>40</td>
</tr>
<tr>
<td>S-E</td>
<td>1400</td>
<td>97</td>
<td>40</td>
<td>242</td>
<td>152</td>
<td>39</td>
</tr>
<tr>
<td></td>
<td></td>
<td>199</td>
<td>70</td>
<td>288</td>
<td>162</td>
<td>47</td>
</tr>
<tr>
<td>S-F</td>
<td>1600</td>
<td>106</td>
<td>55</td>
<td>295</td>
<td>158</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>189</td>
<td>77</td>
<td>364</td>
<td>191</td>
<td>54</td>
</tr>
<tr>
<td>S-G</td>
<td>1800</td>
<td>265</td>
<td>80</td>
<td>445</td>
<td>204</td>
<td>60</td>
</tr>
<tr>
<td>S-H</td>
<td>2000</td>
<td>123</td>
<td>70</td>
<td>350</td>
<td>161</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td></td>
<td>218</td>
<td>113</td>
<td>430</td>
<td>197</td>
<td>53</td>
</tr>
<tr>
<td>S-I</td>
<td>2200</td>
<td>282</td>
<td>88</td>
<td>465</td>
<td>206</td>
<td>56</td>
</tr>
<tr>
<td>S-J</td>
<td>2400</td>
<td>217</td>
<td>121</td>
<td>500</td>
<td>201</td>
<td>53</td>
</tr>
<tr>
<td>S-K</td>
<td>2600</td>
<td>291</td>
<td>171</td>
<td>549</td>
<td>212</td>
<td>56</td>
</tr>
</tbody>
</table>
D.3 Cantilever Structures

These loads are effective at the bottom of base plate at the centerline of the single pedestal or shaft supporting the structure. The Foundation Type categories have been established based on groupings of maximum combined moments (longitudinal and transverse) in the case of the shaft foundations, and footing size in the case of the footing foundations.

D.3.1 Shaft Foundations

These foundation loads represent the loads resulting from the family of OSS included in each moment category used during the design of the shaft foundations for the cantilever structures. Since there is a single shaft per structure, the maximum moments and shears shown are the resultants of the combination of the longitudinal and transverse directions.

<table>
<thead>
<tr>
<th>MAXIMUM MOMENT (kN-m)</th>
<th>SHAFT DIAMETER (m)</th>
<th>SHAFT LENGTH (m)</th>
<th>VERTICAL LOAD (kN)</th>
<th>MAXIMUM TORSION (kN-m)</th>
<th>MAXIMUM SHEAR (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>MAXIMUM</td>
<td>MINIMUM</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>1</td>
<td>3</td>
<td>19</td>
<td>10</td>
<td>40</td>
</tr>
<tr>
<td>200</td>
<td>1</td>
<td>4</td>
<td>22</td>
<td>12</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>3.5</td>
<td>36</td>
<td>16</td>
<td>109</td>
</tr>
<tr>
<td>300</td>
<td>1.2</td>
<td>4</td>
<td>48</td>
<td>21</td>
<td>147</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>4</td>
<td>50</td>
<td>30</td>
<td>173</td>
</tr>
<tr>
<td>400</td>
<td>1.2</td>
<td>4.5</td>
<td>32</td>
<td>26</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>4.5</td>
<td>61</td>
<td>30</td>
<td>203</td>
</tr>
<tr>
<td>500</td>
<td>1.3</td>
<td>5</td>
<td>73</td>
<td>31</td>
<td>241</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
<td>4.5</td>
<td>83</td>
<td>41</td>
<td>332</td>
</tr>
<tr>
<td>600</td>
<td>1.6</td>
<td>4.5</td>
<td>87</td>
<td>55</td>
<td>393</td>
</tr>
<tr>
<td>700</td>
<td>1.4</td>
<td>5</td>
<td>96</td>
<td>70</td>
<td>406</td>
</tr>
<tr>
<td>800</td>
<td>1.6</td>
<td>5</td>
<td>117</td>
<td>54</td>
<td>545</td>
</tr>
</tbody>
</table>
D.3.2  Trussed Arm Cantilever Footing Foundations

The foundation loads presented in this table are the loads at the bottom of the base plate of each of the structures and are the controlling loads within the load combination shown. The footing types have been established by collecting those trussed arm cantilever structures requiring similar footing sizes into groups in order to reduce the number of footing shapes to be constructed. The footing sizes (see BD-OS10) have been set in 0.5 meter increments.

<table>
<thead>
<tr>
<th>FOOTING TYPE</th>
<th>STRUCTURE TYPE</th>
<th>GOVERNING GROUP LOAD COMB.</th>
<th>VERTICAL LOAD kN</th>
<th>LONGITUDINAL SHEAR kN</th>
<th>TRANSVERSE SHEAR kN</th>
<th>TORSION kN - m</th>
<th>LONGITUDINAL MOMENT kN - m</th>
<th>TRANSVERSE MOMENT kN - m</th>
</tr>
</thead>
<tbody>
<tr>
<td>CT-1</td>
<td>CT-4-5</td>
<td>2</td>
<td>15</td>
<td>15</td>
<td>3</td>
<td>38</td>
<td>138</td>
<td>42</td>
</tr>
<tr>
<td></td>
<td>CT-5-5</td>
<td>2</td>
<td>17</td>
<td>16</td>
<td>3</td>
<td>51</td>
<td>145</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>CT-6-5</td>
<td>2</td>
<td>19</td>
<td>16</td>
<td>3</td>
<td>63</td>
<td>152</td>
<td>60</td>
</tr>
<tr>
<td>CT-2</td>
<td>CT-7-5</td>
<td>2</td>
<td>22</td>
<td>17</td>
<td>3</td>
<td>78</td>
<td>160</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>CT-8-5</td>
<td>2</td>
<td>25</td>
<td>18</td>
<td>3</td>
<td>93</td>
<td>170</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>CT-9-5</td>
<td>2</td>
<td>26</td>
<td>19</td>
<td>3</td>
<td>107</td>
<td>175</td>
<td>108</td>
</tr>
<tr>
<td>CT-3</td>
<td>CT-4-10</td>
<td>2</td>
<td>21</td>
<td>25</td>
<td>5</td>
<td>59</td>
<td>236</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>CT-5-10</td>
<td>2</td>
<td>23</td>
<td>26</td>
<td>5</td>
<td>81</td>
<td>244</td>
<td>82</td>
</tr>
<tr>
<td></td>
<td>CT-6-10</td>
<td>2</td>
<td>26</td>
<td>27</td>
<td>5</td>
<td>103</td>
<td>252</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>CT-7-10</td>
<td>2</td>
<td>32</td>
<td>29</td>
<td>5</td>
<td>128</td>
<td>268</td>
<td>119</td>
</tr>
<tr>
<td></td>
<td>CT-10-5</td>
<td>3</td>
<td>43</td>
<td>10</td>
<td>2</td>
<td>63</td>
<td>97</td>
<td>186</td>
</tr>
<tr>
<td></td>
<td>CT-11-5</td>
<td>3</td>
<td>48</td>
<td>11</td>
<td>2</td>
<td>74</td>
<td>103</td>
<td>233</td>
</tr>
<tr>
<td>CT-4</td>
<td>CT-4-15</td>
<td>2</td>
<td>26</td>
<td>35</td>
<td>7</td>
<td>68</td>
<td>333</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>CT-5-15</td>
<td>2</td>
<td>30</td>
<td>36</td>
<td>7</td>
<td>99</td>
<td>345</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>CT-6-15</td>
<td>2</td>
<td>32</td>
<td>37</td>
<td>7</td>
<td>132</td>
<td>354</td>
<td>128</td>
</tr>
<tr>
<td></td>
<td>CT-8-10</td>
<td>2</td>
<td>33</td>
<td>29</td>
<td>5</td>
<td>153</td>
<td>276</td>
<td>138</td>
</tr>
<tr>
<td></td>
<td>CT-9-10</td>
<td>2</td>
<td>36</td>
<td>30</td>
<td>6</td>
<td>177</td>
<td>284</td>
<td>158</td>
</tr>
<tr>
<td></td>
<td>CT-10-10</td>
<td>2</td>
<td>43</td>
<td>31</td>
<td>6</td>
<td>203</td>
<td>292</td>
<td>180</td>
</tr>
<tr>
<td></td>
<td>CT-12-5</td>
<td>3</td>
<td>58</td>
<td>12</td>
<td>2</td>
<td>86</td>
<td>114</td>
<td>300</td>
</tr>
<tr>
<td>CT-5</td>
<td>CT-4-20</td>
<td>2</td>
<td>31</td>
<td>45</td>
<td>9</td>
<td>101</td>
<td>434</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>CT-5-20</td>
<td>2</td>
<td>33</td>
<td>46</td>
<td>9</td>
<td>114</td>
<td>442</td>
<td>133</td>
</tr>
<tr>
<td></td>
<td>CT-6-20</td>
<td>2</td>
<td>41</td>
<td>48</td>
<td>9</td>
<td>149</td>
<td>461</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>CT-7-15</td>
<td>2</td>
<td>36</td>
<td>39</td>
<td>7</td>
<td>166</td>
<td>367</td>
<td>152</td>
</tr>
<tr>
<td></td>
<td>CT-7-20</td>
<td>2</td>
<td>43</td>
<td>49</td>
<td>9</td>
<td>193</td>
<td>470</td>
<td>185</td>
</tr>
<tr>
<td></td>
<td>CT-8-15</td>
<td>2</td>
<td>41</td>
<td>40</td>
<td>8</td>
<td>200</td>
<td>380</td>
<td>175</td>
</tr>
<tr>
<td></td>
<td>CT-9-15</td>
<td>2</td>
<td>42</td>
<td>41</td>
<td>8</td>
<td>234</td>
<td>386</td>
<td>198</td>
</tr>
<tr>
<td></td>
<td>CT-10-15</td>
<td>2</td>
<td>53</td>
<td>42</td>
<td>8</td>
<td>274</td>
<td>401</td>
<td>237</td>
</tr>
<tr>
<td></td>
<td>CT-11-10</td>
<td>2</td>
<td>44</td>
<td>33</td>
<td>6</td>
<td>233</td>
<td>309</td>
<td>214</td>
</tr>
<tr>
<td></td>
<td>CT-12-10</td>
<td>3</td>
<td>65</td>
<td>17</td>
<td>3</td>
<td>133</td>
<td>165</td>
<td>343</td>
</tr>
<tr>
<td></td>
<td>CT-13-5</td>
<td>3</td>
<td>61</td>
<td>13</td>
<td>2</td>
<td>95</td>
<td>117</td>
<td>344</td>
</tr>
<tr>
<td></td>
<td>CT-14-5</td>
<td>3</td>
<td>70</td>
<td>14</td>
<td>2</td>
<td>109</td>
<td>127</td>
<td>431</td>
</tr>
<tr>
<td>FOOTING TYPE</td>
<td>STRUCTURE TYPE</td>
<td>GOVERNING GROUP LOAD COMB.</td>
<td>VERTICAL LOAD kN</td>
<td>LONGITUDINAL SHEAR kN</td>
<td>TRANSVERSE SHEAR kN</td>
<td>TORSION kN - m</td>
<td>LONGITUDINAL MOMENT kN - m</td>
<td>TRANSVERSE MOMENT kN - m</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------</td>
<td>-----------------------------</td>
<td>-------------------</td>
<td>-----------------------</td>
<td>-------------------</td>
<td>-----------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>CT-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT-8-20</td>
<td>2</td>
<td></td>
<td>51</td>
<td>50</td>
<td>10</td>
<td>237</td>
<td>479</td>
<td>211</td>
</tr>
<tr>
<td>CT-9-20</td>
<td>2</td>
<td></td>
<td>55</td>
<td>51</td>
<td>10</td>
<td>284</td>
<td>493</td>
<td>250</td>
</tr>
<tr>
<td>CT-10-20</td>
<td>2</td>
<td></td>
<td>55</td>
<td>54</td>
<td>10</td>
<td>330</td>
<td>509</td>
<td>284</td>
</tr>
<tr>
<td>CT-11-15</td>
<td>2</td>
<td></td>
<td>55</td>
<td>43</td>
<td>8</td>
<td>311</td>
<td>411</td>
<td>267</td>
</tr>
<tr>
<td>CT-12-15</td>
<td>2</td>
<td></td>
<td>57</td>
<td>46</td>
<td>8</td>
<td>355</td>
<td>434</td>
<td>319</td>
</tr>
<tr>
<td>CT-13-10</td>
<td>3</td>
<td></td>
<td>68</td>
<td>18</td>
<td>3</td>
<td>147</td>
<td>168</td>
<td>391</td>
</tr>
<tr>
<td>CT-14-10</td>
<td>3</td>
<td></td>
<td>83</td>
<td>19</td>
<td>3</td>
<td>166</td>
<td>178</td>
<td>481</td>
</tr>
<tr>
<td>CT-15-5</td>
<td>3</td>
<td></td>
<td>73</td>
<td>14</td>
<td>2</td>
<td>120</td>
<td>130</td>
<td>487</td>
</tr>
<tr>
<td>CT-15-10</td>
<td>3</td>
<td></td>
<td>86</td>
<td>19</td>
<td>3</td>
<td>182</td>
<td>182</td>
<td>541</td>
</tr>
<tr>
<td>CT-16-5</td>
<td>3</td>
<td></td>
<td>86</td>
<td>16</td>
<td>3</td>
<td>137</td>
<td>144</td>
<td>599</td>
</tr>
<tr>
<td>CT-7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT-7-25</td>
<td>2</td>
<td></td>
<td>53</td>
<td>59</td>
<td>11</td>
<td>256</td>
<td>569</td>
<td>226</td>
</tr>
<tr>
<td>CT-7-30</td>
<td>2</td>
<td></td>
<td>54</td>
<td>70</td>
<td>14</td>
<td>281</td>
<td>675</td>
<td>259</td>
</tr>
<tr>
<td>CT-8-25</td>
<td>2</td>
<td></td>
<td>54</td>
<td>62</td>
<td>12</td>
<td>312</td>
<td>591</td>
<td>267</td>
</tr>
<tr>
<td>CT-8-30</td>
<td>2</td>
<td></td>
<td>64</td>
<td>71</td>
<td>14</td>
<td>345</td>
<td>685</td>
<td>294</td>
</tr>
<tr>
<td>CT-9-25</td>
<td>2</td>
<td></td>
<td>64</td>
<td>63</td>
<td>12</td>
<td>367</td>
<td>599</td>
<td>301</td>
</tr>
<tr>
<td>CT-10-25</td>
<td>2</td>
<td></td>
<td>71</td>
<td>65</td>
<td>12</td>
<td>430</td>
<td>624</td>
<td>365</td>
</tr>
<tr>
<td>CT-11-20</td>
<td>2</td>
<td></td>
<td>67</td>
<td>55</td>
<td>10</td>
<td>382</td>
<td>526</td>
<td>335</td>
</tr>
<tr>
<td>CT-12-20</td>
<td>2</td>
<td></td>
<td>70</td>
<td>56</td>
<td>11</td>
<td>431</td>
<td>537</td>
<td>375</td>
</tr>
<tr>
<td>CT-13-15</td>
<td>3</td>
<td></td>
<td>87</td>
<td>24</td>
<td>4</td>
<td>197</td>
<td>224</td>
<td>466</td>
</tr>
<tr>
<td>CT-14-15</td>
<td>3</td>
<td></td>
<td>96</td>
<td>24</td>
<td>4</td>
<td>221</td>
<td>234</td>
<td>565</td>
</tr>
<tr>
<td>CT-15-15</td>
<td>3</td>
<td></td>
<td>100</td>
<td>25</td>
<td>5</td>
<td>241</td>
<td>238</td>
<td>634</td>
</tr>
<tr>
<td>CT-16-10</td>
<td>3</td>
<td></td>
<td>96</td>
<td>20</td>
<td>4</td>
<td>203</td>
<td>192</td>
<td>655</td>
</tr>
<tr>
<td>CT-8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT-9-30</td>
<td>2</td>
<td></td>
<td>71</td>
<td>73</td>
<td>14</td>
<td>414</td>
<td>707</td>
<td>352</td>
</tr>
<tr>
<td>CT-11-25</td>
<td>2</td>
<td></td>
<td>82</td>
<td>66</td>
<td>13</td>
<td>489</td>
<td>636</td>
<td>410</td>
</tr>
<tr>
<td>CT-13-20</td>
<td>3</td>
<td></td>
<td>105</td>
<td>29</td>
<td>6</td>
<td>246</td>
<td>286</td>
<td>603</td>
</tr>
<tr>
<td>CT-14-20</td>
<td>3</td>
<td></td>
<td>117</td>
<td>30</td>
<td>6</td>
<td>273</td>
<td>292</td>
<td>682</td>
</tr>
<tr>
<td>CT-16-15</td>
<td>3</td>
<td></td>
<td>116</td>
<td>27</td>
<td>5</td>
<td>272</td>
<td>235</td>
<td>797</td>
</tr>
</tbody>
</table>
D.3.2 Single Arm Cantilever Footing Foundations

The foundation loads presented in this table are the loads at the bottom of the base plate of each of the structures and are the controlling loads within the load combination shown. The footing types have been established by collecting those single arm cantilever structures requiring similar footing sizes into groups in order to reduce the number of footing shapes to be constructed. The footing sizes (see BD-OS10) have been set in 0.5 meter increments.

### SINGLE ARM CANTILEVER FOOTING FOUNDATION LOADS

<table>
<thead>
<tr>
<th>FOOTING TYPE</th>
<th>STRUCTURE TYPE</th>
<th>GOVERNING GROUP LOAD COMB.</th>
<th>VERTICAL LOAD kN</th>
<th>LONGITUDINAL SHEAR kN</th>
<th>TRANSVERSE SHEAR kN</th>
<th>TORSION kN-m</th>
<th>LONGITUDINAL MOMENT kN-m</th>
<th>TRANSVERSE MOMENT kN-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-1</td>
<td>CS-4-3</td>
<td>2</td>
<td>10</td>
<td>8</td>
<td>2</td>
<td>19</td>
<td>74</td>
<td>24</td>
</tr>
<tr>
<td></td>
<td>CS-5-3</td>
<td>2</td>
<td>12</td>
<td>9</td>
<td>2</td>
<td>25</td>
<td>78</td>
<td>29</td>
</tr>
<tr>
<td>CS-2</td>
<td>CS-4-5</td>
<td>2</td>
<td>12</td>
<td>12</td>
<td>2</td>
<td>24</td>
<td>114</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>CS-5-5</td>
<td>2</td>
<td>13</td>
<td>13</td>
<td>3</td>
<td>35</td>
<td>118</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td>CS-6-3</td>
<td>2</td>
<td>14</td>
<td>10</td>
<td>2</td>
<td>32</td>
<td>83</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>CS-7-3</td>
<td>2</td>
<td>15</td>
<td>10</td>
<td>2</td>
<td>40</td>
<td>86</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>CS-8-3</td>
<td>2</td>
<td>16</td>
<td>10</td>
<td>2</td>
<td>47</td>
<td>90</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>CS-9-3</td>
<td>2</td>
<td>17</td>
<td>10</td>
<td>2</td>
<td>55</td>
<td>92</td>
<td>62</td>
</tr>
<tr>
<td>CS-3</td>
<td>CS-6-5</td>
<td>2</td>
<td>15</td>
<td>13</td>
<td>3</td>
<td>46</td>
<td>122</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>CS-7-5</td>
<td>2</td>
<td>18</td>
<td>14</td>
<td>3</td>
<td>57</td>
<td>129</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>CS-8-5</td>
<td>2</td>
<td>20</td>
<td>15</td>
<td>3</td>
<td>69</td>
<td>134</td>
<td>71</td>
</tr>
<tr>
<td></td>
<td>CS-10-3</td>
<td>2</td>
<td>20</td>
<td>11</td>
<td>2</td>
<td>65</td>
<td>100</td>
<td>79</td>
</tr>
<tr>
<td></td>
<td>CS-11-3</td>
<td>2</td>
<td>21</td>
<td>12</td>
<td>2</td>
<td>73</td>
<td>103</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>CS-12-3</td>
<td>3</td>
<td>31</td>
<td>6</td>
<td>1</td>
<td>41</td>
<td>54</td>
<td>143</td>
</tr>
<tr>
<td>CS-4</td>
<td>CS-4-8</td>
<td>2</td>
<td>16</td>
<td>19</td>
<td>4</td>
<td>39</td>
<td>176</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td>CS-5-8</td>
<td>2</td>
<td>18</td>
<td>19</td>
<td>4</td>
<td>48</td>
<td>180</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td>CS-6-8</td>
<td>2</td>
<td>20</td>
<td>20</td>
<td>4</td>
<td>56</td>
<td>185</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>CS-7-8</td>
<td>2</td>
<td>23</td>
<td>21</td>
<td>4</td>
<td>73</td>
<td>192</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>CS-8-8</td>
<td>2</td>
<td>25</td>
<td>21</td>
<td>4</td>
<td>92</td>
<td>198</td>
<td>97</td>
</tr>
<tr>
<td></td>
<td>CS-9-5</td>
<td>2</td>
<td>22</td>
<td>15</td>
<td>3</td>
<td>82</td>
<td>140</td>
<td>87</td>
</tr>
<tr>
<td></td>
<td>CS-10-5</td>
<td>2</td>
<td>26</td>
<td>17</td>
<td>3</td>
<td>96</td>
<td>149</td>
<td>107</td>
</tr>
<tr>
<td></td>
<td>CS-11-5</td>
<td>2</td>
<td>27</td>
<td>17</td>
<td>3</td>
<td>109</td>
<td>152</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>CS-12-5</td>
<td>3</td>
<td>40</td>
<td>9</td>
<td>2</td>
<td>61</td>
<td>81</td>
<td>189</td>
</tr>
<tr>
<td></td>
<td>CS-13-3</td>
<td>3</td>
<td>36</td>
<td>7</td>
<td>1</td>
<td>47</td>
<td>59</td>
<td>181</td>
</tr>
<tr>
<td></td>
<td>CS-14-3</td>
<td>3</td>
<td>37</td>
<td>7</td>
<td>1</td>
<td>52</td>
<td>61</td>
<td>206</td>
</tr>
<tr>
<td>CS-5</td>
<td>CS-9-8</td>
<td>2</td>
<td>30</td>
<td>23</td>
<td>5</td>
<td>112</td>
<td>212</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>CS-10-8</td>
<td>2</td>
<td>32</td>
<td>24</td>
<td>5</td>
<td>131</td>
<td>216</td>
<td>140</td>
</tr>
<tr>
<td></td>
<td>CS-11-8</td>
<td>2</td>
<td>34</td>
<td>24</td>
<td>5</td>
<td>151</td>
<td>222</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>CS-13-5</td>
<td>3</td>
<td>47</td>
<td>10</td>
<td>2</td>
<td>71</td>
<td>87</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>CS-14-5</td>
<td>3</td>
<td>49</td>
<td>10</td>
<td>2</td>
<td>79</td>
<td>89</td>
<td>284</td>
</tr>
<tr>
<td></td>
<td>CS-15-3</td>
<td>3</td>
<td>44</td>
<td>8</td>
<td>2</td>
<td>59</td>
<td>67</td>
<td>255</td>
</tr>
<tr>
<td></td>
<td>CS-16-3</td>
<td>3</td>
<td>46</td>
<td>8</td>
<td>2</td>
<td>65</td>
<td>69</td>
<td>287</td>
</tr>
</tbody>
</table>
### SINGLE ARM CANTILEVER FOOTING FOUNDATION LOADS

<table>
<thead>
<tr>
<th>FOOTING TYPE</th>
<th>STRUCTURE TYPE</th>
<th>GOVERNIN G GROUP LOAD COMB.</th>
<th>VERTICAL LOAD kN</th>
<th>LONGITUDINAL SHEAR kN</th>
<th>TRANSVERSE SHEAR kN</th>
<th>TORSION kN-m</th>
<th>LONGITUDINAL MOMENT kN-m</th>
<th>TRANSVERSE MOMENT kN-m</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS-6</td>
<td>CS-12-8</td>
<td>2</td>
<td>37</td>
<td>25</td>
<td>5</td>
<td>173</td>
<td>231</td>
<td>189</td>
</tr>
<tr>
<td></td>
<td>CS-13-8</td>
<td>2</td>
<td>41</td>
<td>26</td>
<td>5</td>
<td>194</td>
<td>239</td>
<td>213</td>
</tr>
<tr>
<td></td>
<td>CS-14-8</td>
<td>3</td>
<td>64</td>
<td>13</td>
<td>3</td>
<td>107</td>
<td>124</td>
<td>379</td>
</tr>
<tr>
<td></td>
<td>CS-15-5</td>
<td>3</td>
<td>51</td>
<td>10</td>
<td>2</td>
<td>86</td>
<td>92</td>
<td>321</td>
</tr>
<tr>
<td></td>
<td>CS-16-5</td>
<td>3</td>
<td>55</td>
<td>10</td>
<td>2</td>
<td>94</td>
<td>95</td>
<td>360</td>
</tr>
<tr>
<td>CS-7</td>
<td>CS-15-8</td>
<td>3</td>
<td>73</td>
<td>14</td>
<td>3</td>
<td>118</td>
<td>126</td>
<td>427</td>
</tr>
<tr>
<td></td>
<td>CS-16-8</td>
<td>3</td>
<td>76</td>
<td>14</td>
<td>3</td>
<td>129</td>
<td>128</td>
<td>479</td>
</tr>
</tbody>
</table>