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TECHNICAL MEMORANDUM

Contract No.: **T4541-AO**
Test Report No.: **405160-22**
Project Name: **Signs and Light Standard Foundation Design When Installed on 2(H):1(V) or Flatter Slopes**
Sponsor: **Roadside Safety Research Program Pooled Fund Study**

DATE: **February 28, 2012**

TO: **David Olson**
Chair, Pooled Fund

COPY TO: **Rhonda Brooks**, Washington State DOT
Epifania Davila, TTI RDO
D. L. Bullard, Jr., Head, TTI Roadside Safety & Physical Security Systems
Roger P. Bligh, TTI Roadway Safety Program
Rebecca Haug, TTI Roadside Safety & Physical Security Systems

FROM: **William F. Williams**, P.E., Associate Research Engineer, TTI Roadside Safety & Physical Security Systems
Wanda L. Menges, Research Specialist, TTI Proving Ground

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SUMMARY REPORT:

INTRODUCTION

Many steel sign supports and light standards require a concrete foundation. This foundation is usually a 2 ft to 3 ft diameter shaft. When these foundations are located on a slope, the down slope edge of the foundations typically extends more than 4 inches above ground, creating a potential snagging point. These foundations are generally used to support a triangular slip base shown in Figure 1. One option is to install the foundation below grade such that the pipe support with slip base connection does not extend more than 4 inches above grade shown in Figure 2.

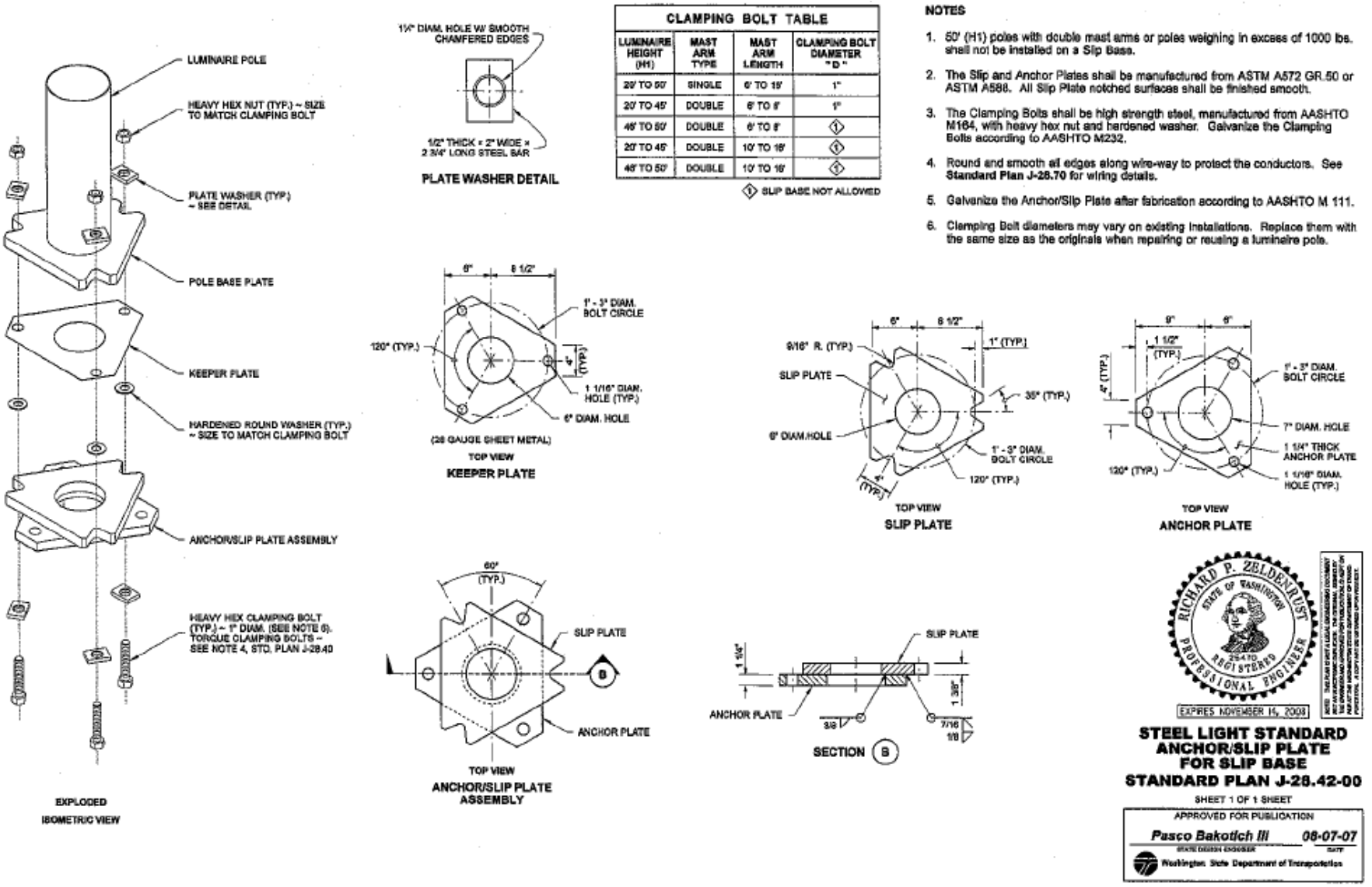


Figure 1 – Triangular Slip Base Details.

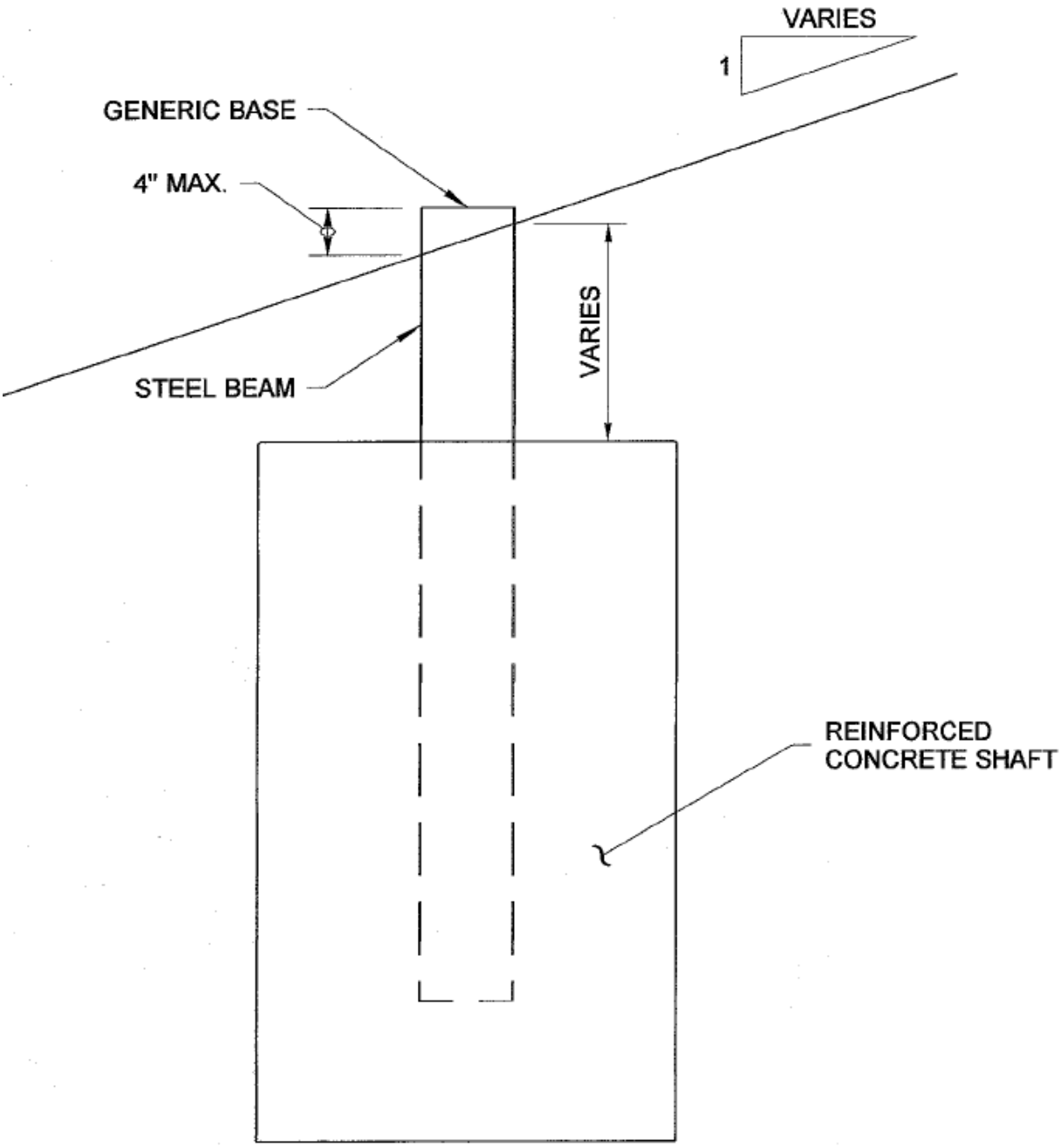


Figure 2 – Typical Foundation Details Installed on Slope

For this project, a foundation was designed for a single sign support that utilizes a multi-directional breakaway sign support. This foundation was designed for a sign area of approximately 30 ft^2 or less with 7 ft from grade to the bottom of the sign. A new foundation was designed and detailed for omni-directional large sign supports that incorporate a larger sign area of approximately 110 ft^2. This design incorporates the use of a proprietary omni-directional

slip base system. For both designs, the structural supports with slip base attachments will extend approximately 4 inches maximum from the down slope grading edge.

BACKGROUND

Sign supports placed on roadside slopes must not allow impacting vehicles to snag on either the foundation or any components extending above the foundation. Surrounding terrain must be graded to permit vehicles to pass over any non-breakaway portion of the installation that remains in the ground or rigidly attached to the foundation. Figure 3 taken from the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals [(1)], illustrates the method used to measure the required 100 mm (4 inches) maximum stub height.

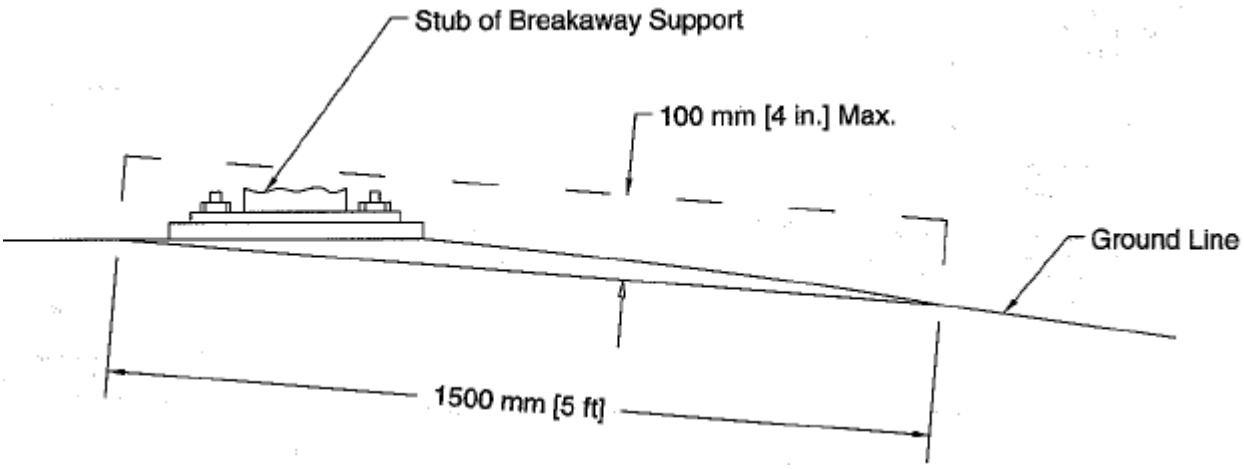


Figure 3 – Breakaway Support Stub Height Limits

In February 2001, Bligh and Buth[(2)] reported on a study that evaluated various configurations of a bolt-down slip base for small sign supports. These different configurations were tested in an attempt to achieve an anchor system that would accommodate design wind loads, be crashworthy in vehicular collision, and have a high degree of reusability after impact. Information and the full-scale testing data from this study and other similar research projects involving sign slip base supports were considered for this project.

OBJECTIVE

The objective of this study was to design a concrete foundation for small sign supports using multi-directional slip base supports that can be constructed completely below grade on a 2(H):1(V) slope or flatter similar to that shown in Figure 2. This new foundation design will incorporate a new steel stub post that is bolted to the foundation with a multi-directional slip base connection at the ground line for the break-away features for the sign. Foundation details as well as slip base anchoring details to the top of the foundation were developed for this project. In addition, engineering calculations were performed for a foundation and sign support attachment to be used for larger signs incorporating multiple supports and using a proprietary omni-

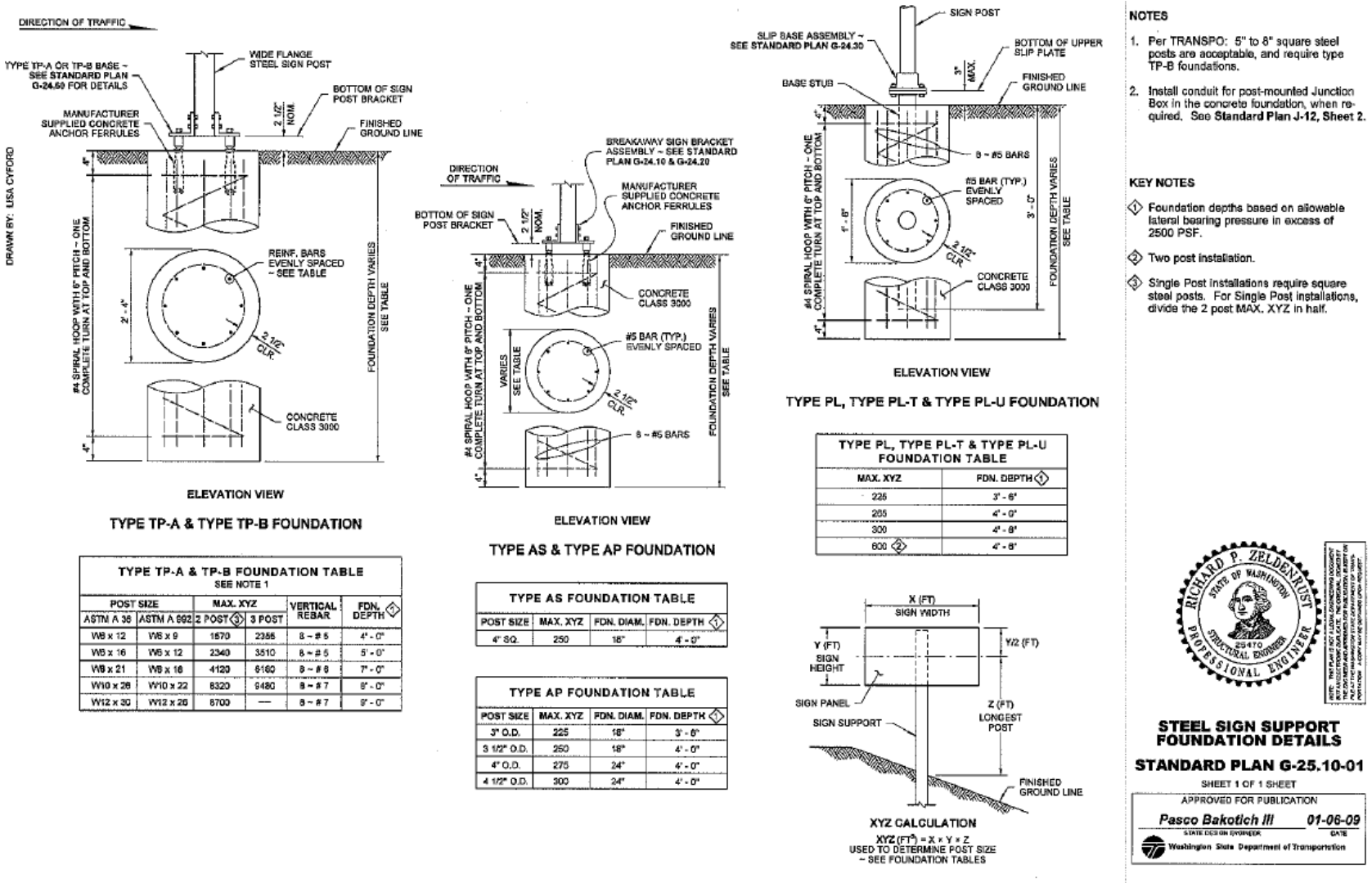
directional slip base system. TTI received design information from Washington State Department of Transportation (WSDOT) for this project. The information provided on WSDOT Standard Plans J-28.30-01, G-24.30, G-25.10-01, G-24.60 were used for this project.

DESIGN SUMMARY AND CONCLUSIONS

Foundation Design for Small Sign Supports on a 2(H):1(V) or Flatter Slopes

Engineering analyses were performed on a typical single sign support installed on a 2(H):1(V) side slope. The sign foundation with breakaway device was oriented similar to the details shown in Figure 2, with 4 inches between the ground surface at the support and the top of stub for the breakaway device. Design information for the sign installation was obtained from Washington State Department of Transportation Standard Plan G-25.10-01 dated January 6, 2009. This drawing is shown as Figure 3. Analyses were performed on a 5.0 ft wide (X) by 6.0 ft high (Y) sign panel located 7 ft above the finished grade. The height to the sign centroid (Z) was calculated to be 10 ft. Based on this information, the XYZ calculation based on Standard Plan G-25.10-01 was 300.0 ft^3. In addition, analyses were performed using a smaller sign area (XYZ = 266 ft^3). The design wind speed used in the analyses was 90 mile per hour. Wind loading on the signs and single sign supports were calculated based on the "American Association of State Highways and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Sign, Luminaires and Traffic Signal, 5th Edition, 2009[3]. Calculations were performed using cohesionless (sand) and cohesive (clay) materials. For the cohesionless soil, a friction angle (φ) equal to 30 degrees was used in the analyses. For cohesive soil, a shear strength of 1000 psf was used in the analyses.

Based on the results of the analyses, and the information provided on WSDOT Standard Plan G-25.10-01, the required minimum depth for an 18-inch diameter foundation supporting signs with maximum XYZ of 265 ft^3 and less, is 5 ft-5 inches. The required minimum depth for sign foundations supporting signs with a maximum XYZ between 265 to 300 ft^3 is 5 ft-6 inches. Therefore, for signs with XYZ less than or equal to 300 ft^3, the recommended foundation diameter and minimum foundation depth are 18 inches and 5 ft-6 inches, respectively. This design is valid for signs oriented in the down slope direction (wind loading on the sign perpendicular to the down slope direction). For additional information on the XYZ parameter, please refer to the details shown in Figure 4. These foundations should have a minimum diameter of 18 inches with eight #4 vertical bars equally spaced inside #3 spiral stirrups, as shown in Figure 5. Figure 5 provides details for foundations using a breakaway pipe support embedded in the foundation. Figure 6 provides details for foundations constructed with a breakaway support welded to a base plate anchored to the foundation. Details of the base plated pipe support are provided in Figure 7. Engineering calculations are provided in Appendix A.



TYPE TP-A & TYPE TP-B FOUNDATION TABLE
SEE NOTE 1

POST SIZE		MAX. XYZ		VERTICAL REBAR	FDN. DEPTH ◇1
ASTM A 36	ASTM A 992	2 POST ◇2	3 POST		
W6 x 12	W6 x 9	1570	2355	8 – # 5	4' - 0"
W8 x 16	W8 x 12	2340	3510	8 – # 5	5' - 0"
W8 x 21	W8 x 16	4120	6180	8 – # 6	7' - 0"
W10 x 26	W10 x 22	8320	9480	8 – # 7	8' - 0"
W12 x 30	W12 x 26	8700	—	8 – # 7	9' - 0"

TYPE AS FOUNDATION TABLE

POST SIZE	MAX. XYZ	FDN. DIAM.	FDN. DEPTH ◇1
4" SQ.	250	18"	4' - 0"

TYPE AP FOUNDATION TABLE

POST SIZE	MAX. XYZ	FDN. DIAM.	FDN. DEPTH ◇1
3" O.D.	225	18"	3' - 6"
3 1/2" O.D.	250	18"	4' - 0"
4" O.D.	275	24"	4' - 0"
4 1/2" O.D.	300	24"	4' - 0"

TYPE PL, TYPE PL-T & TYPE PL-U FOUNDATION TABLE

MAX. XYZ	FDN. DEPTH ◇1
225	3' - 6"
255	4' - 0"
300	4' - 8"
600 ◇2	4' - 8"

NOTES

1. Per TRANSPO: 5" to 8" square steel posts are acceptable, and require type TP-B foundations.
2. Install conduit for post-mounted Junction Box in the concrete foundation, when required. See **Standard Plan J-12, Sheet 2.**

KEY NOTES

◇1 Foundation depths based on allowable lateral bearing pressure in excess of 2500 PSF.

◇2 Two post installation.

◇3 Single Post installations require square steel posts. For Single Post installations, divide the 2 post MAX. XYZ in half.

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STRUCTURAL ENGINEER
PROFESSIONAL ENGINEER

STEEL SIGN SUPPORT FOUNDATION DETAILS

STANDARD PLAN G-25.10-01

SHEET 1 OF 1 SHEET

APPROVED FOR PUBLICATION

Pasco Bakotich III — STATE DESIGN ENGINEER — *01-06-09* — DATE

Washington State Department of Transportation

Figure 3 – Washington State Department of Transportation Standard Plan G-25.10-01

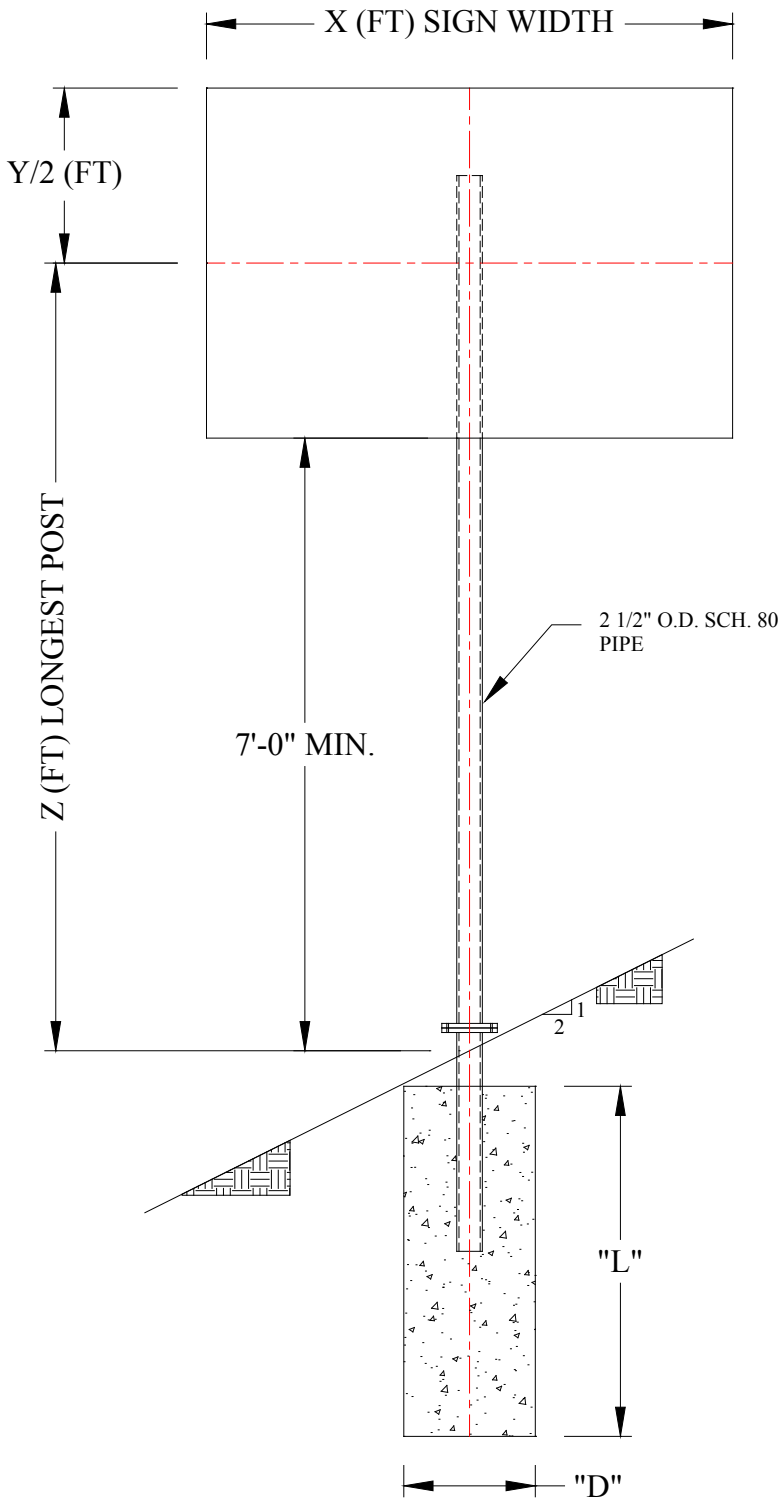
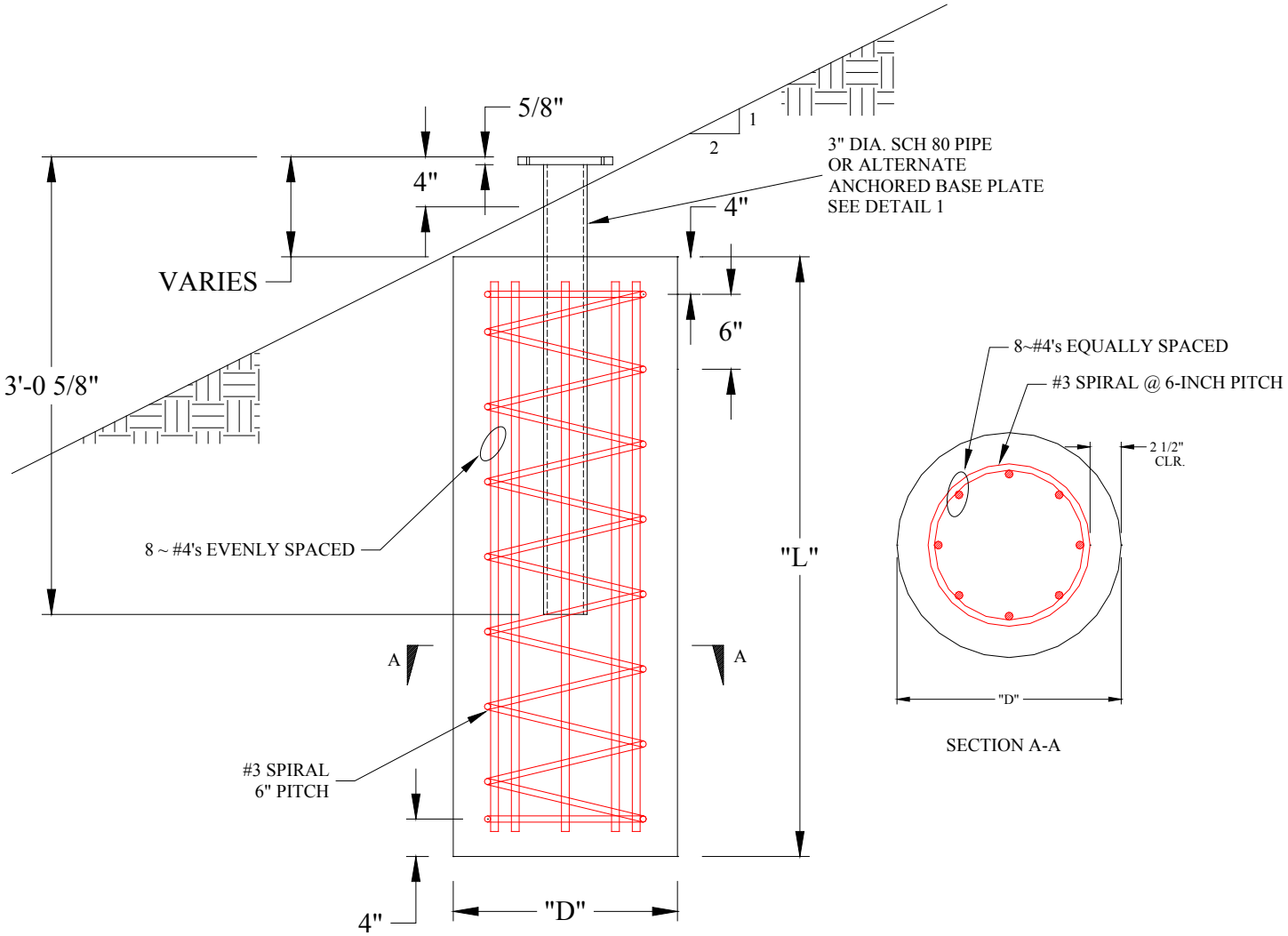
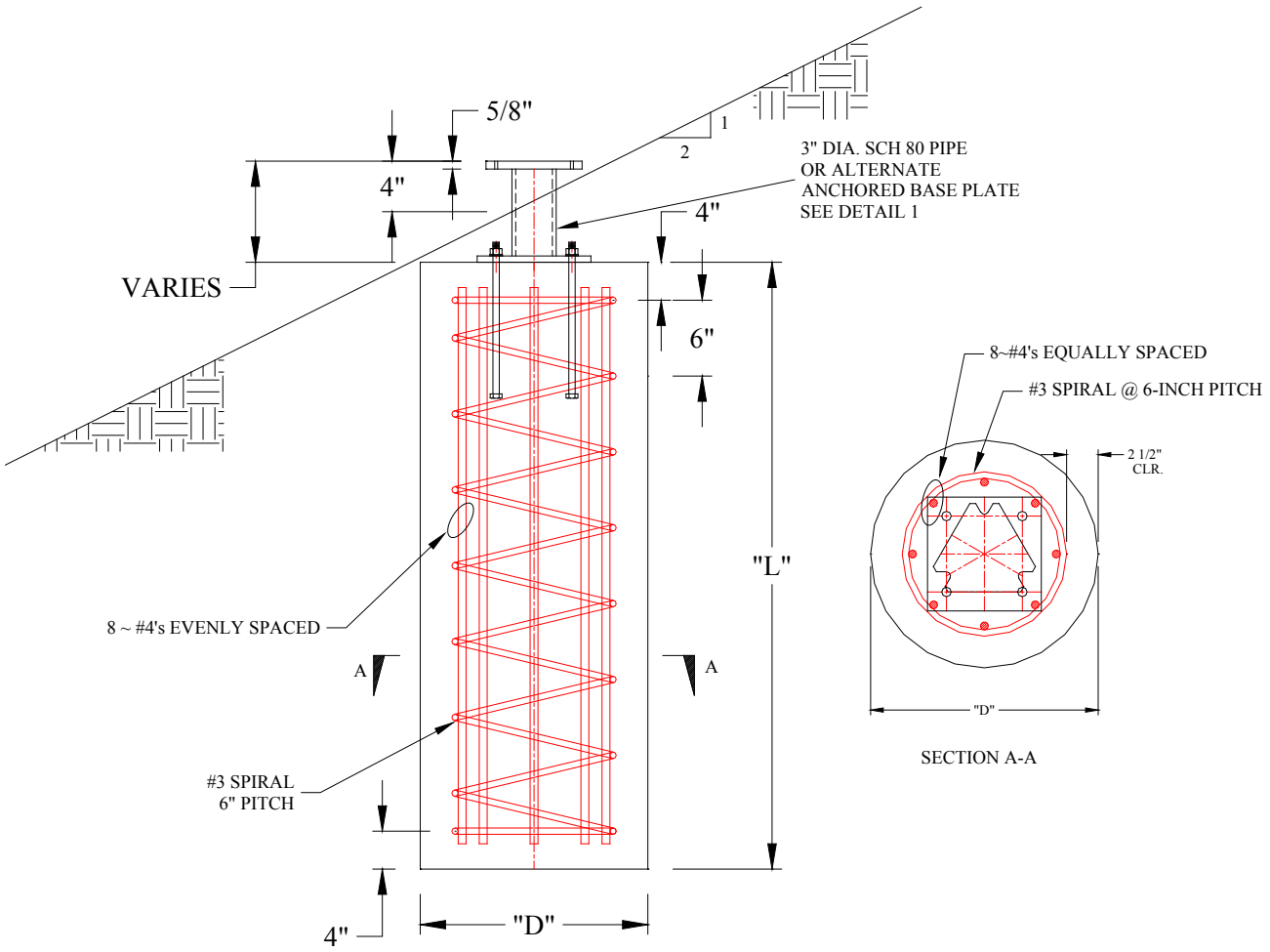


Figure 4 – Sign Details and Parameters from WSDOT Standard Plan G-25.10-01



D = 18 inches
L = 5 ft-6 inches for XYZ of 300 ft^3 and Less

Figure 5 – Foundation Design Details for Small Sign Supports 300 ft^3 and Less Using Embedded Pipe Stub



D = 18 inches
L = 5 ft-6 inches for XYZ 300 ft^3 and Less

Figure 6 – Foundation Design Details for Small Sign Supports 300 ft^3 and Less Using Base Plated Pipe Support

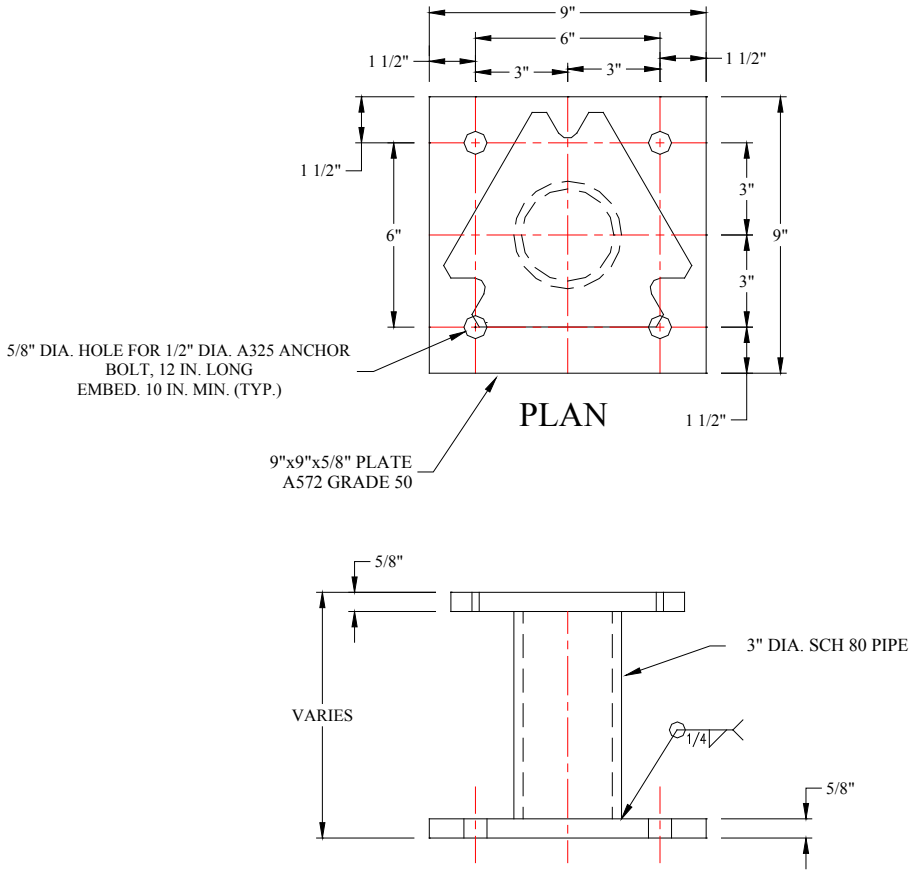


Figure 7 – Detail 1 – Slip Base Anchor Plate Details

Foundation Design for Large Sign Supports on a 2(H):1(V) or Flatter Slopes

Engineering analyses were performed on a typical large multi-post sign support system installed on a 2(H):1(V) or flatter side slope. The sign foundation with breakaway device was oriented similar to the details shown in Figure 2 with 4 inches between the ground surface at the support and the top of stub for the breakaway device. Design information for the sign installation was obtained from Washington State Department of Transportation Standard Plan G-25.10-01 dated January 6, 2009. This drawing is shown as Figure 3. Analyses were performed on a single sign support supporting a sign area 20 ft wide (X) by 9 ft high (Y) with the bottom of the sign located 7 ft from the finished grade. The height to the sign centroid (Z) was calculated to be 11.5 ft. Based on this information, the XYZ calculation based on Standard Plan G-25.10-01 was 2070.0 ft^3. In addition, analyses were performed using a smaller sign area (XYZ = 1170 ft^3). The design wind speed used in the analyses was 90 mile per hour. Wind loading on the signs and sign supports were calculated based on the "American Association of

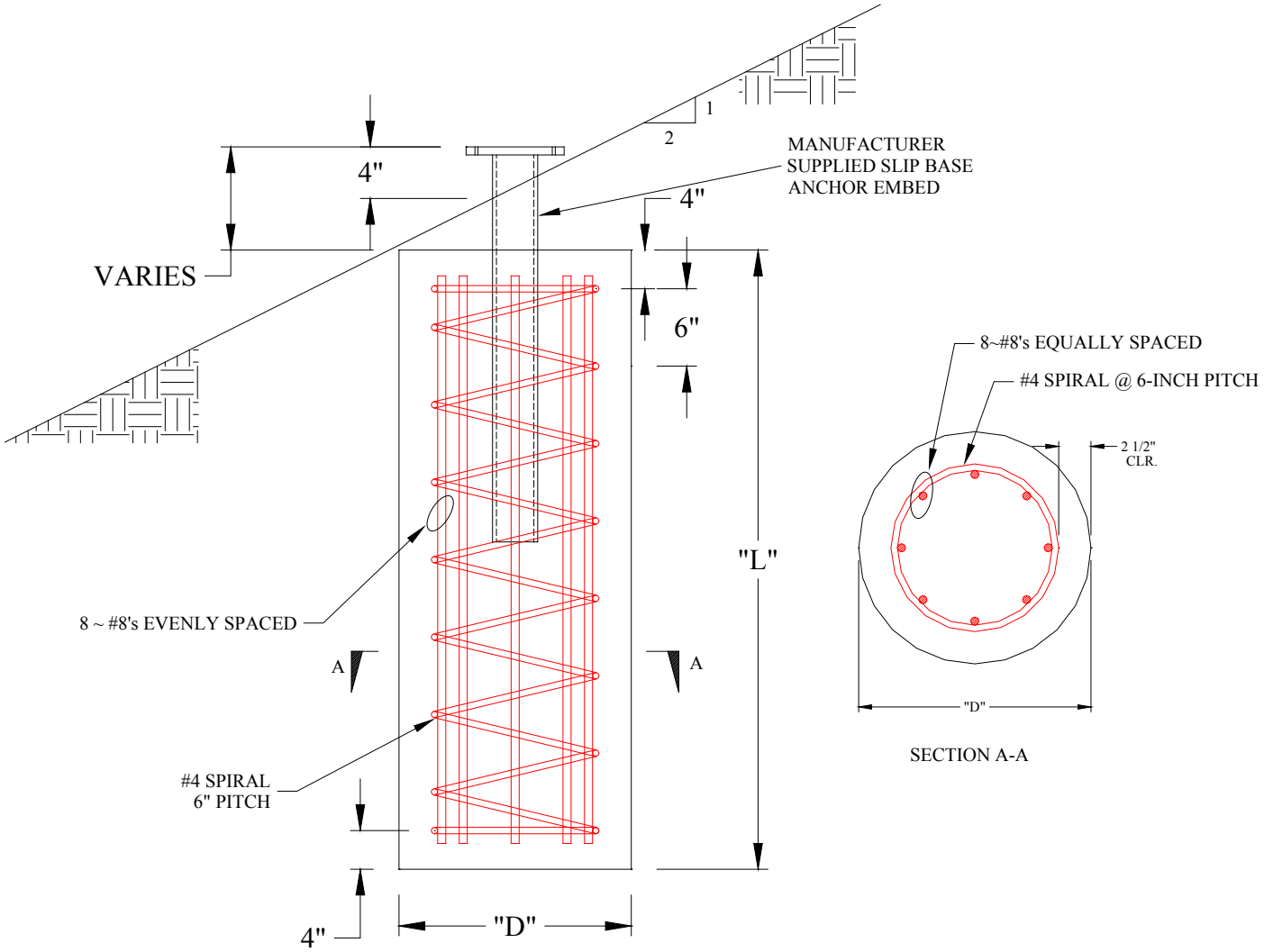
State Highways and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Sign, Luminaires and Traffic Signal, 5th Edition, 2009. Calculations were performed using cohesionless (sand) and cohesive (clay) materials. For the conhesionless soil, a friction angle (φ) equal to 30 degrees was used in the analyses. For cohesive soil, a shear strength of 1000 psf was used in the analyses.

Analyses were performed using a foundation diameter of 30 inches. Based on the results of the analyses, and the information provided on WSDOT Standard Plan G-25.10-01, the required minimum depth for sign foundations with XYZ (sign width × sign height × sign centroid height) between 1170 ft^3 to 2070 ft^3 is 10 ft-6 inches. The recommended minimum depth for sign foundations with XYZ less than 1170 ft^3 is 9 ft-6 inches. This design is valid for signs oriented in the down slope direction (wind loading on the sign perpendicular to the down slope direction). For additional information on the XYZ parameter, please refer to the details shown in Figure 4. These foundations should have a minimum diameter of 30 inches with eight (8) #8 vertical bars equally spaced inside #4 spiral stirrups as shown in Figure 8. Figure 8 provides details for foundations using either a proprietary or nonproprietary breakaway sign support embedded in the foundation. Engineering calculations are provided in Appendix A.

SUMMARY & CONCLUSION

Based on the results of the analyses and the information provided on WSDOT Standard Plan G-25.10-01, the required minimum depth for an 18-inch diameter foundation supporting signs with maximum XYZ of 265 ft^3 and less is 5 ft-5 inches. The required minimum depth for sign foundations supporting signs with a maximum XYZ between 265 to 300 ft^3 is 5 ft-6 inches. Therefore, for signs with XYZ less than or equal to 300 ft^3, the recommended foundation diameter and minimum foundation depth are 18 inches and 5 ft-6 inches, respectively. This design is valid for signs oriented in the down slope direction (wind loading on the sign perpendicular to the down slope direction). These foundations should have a minimum diameter of 18 inches with eight #4 vertical bars equally spaced inside #3 spiral stirrups.

For larger signs, analyses were performed using a foundation diameter of 30 inches. Based on the results of the analyses and the information provided on WSDOT Standard Plan G-25.10-01, the required minimum depth for sign foundations with XYZ (sign width × sign height × sign centroid height) between 1170 ft^3 to 2070 ft^3 is 10 ft-6 inches. The recommended minimum depth for sign foundations with XYZ less than 1170 ft^3 is 9 ft-6 inches. This design is valid for signs oriented in the down slope direction (wind loading on the sign perpendicular to the down slope direction). These foundations should have a minimum diameter of 30 inches with eight #8 vertical bars equally spaced inside #4 spiral stirrups.



D = 30 inches
L = 9 ft-6 inches for XYZ 1170 ft^3 and Less
L = 10 ft-6 inches for XYZ 1170 ft^3 to 2070 ft^3

Figure 8 – Foundation Design Details for Single Large Sign Supports Supporting XYZ = 2070 ft^3 and Less

REFERENCES

1. AASHTO, *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, American Association of State Highway and Transportation Officials, Washington, D.C., 2001.

2. R. P. Bligh, C. E. Buth, W. L. Menges, and B. G. Butler, *Evaluation of Design and Retrofit Concepts for Slip-Base Sign Supports*, Contract No. 7-3911, Texas Transportation Institute, February 2001.

3. AASHTO, *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*, American Association of State Highway and Transportation Officials, Washington, D.C., 2001, 5th Edition, 2009.

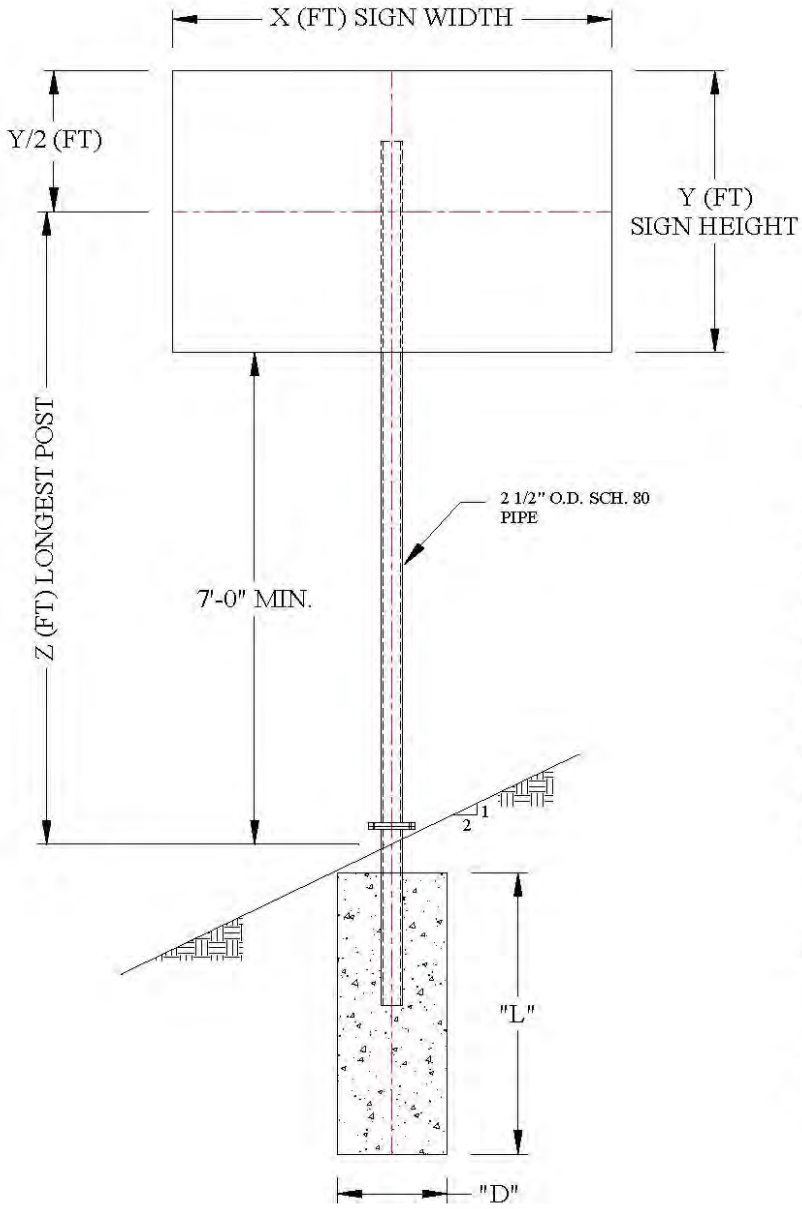
APPENDIX A. ENGINEERING CALCULATIONS

A1. Maximum XYZ of 265 ft^3 and Less at 5 ft-5 inches

Texas Transportation Institute

Subject: **405160-22 - Foundations on Slopes**

1.) Given the following Details and Design Information:



WADOT Type PL, PL-T, & PL-U
Foundations (Small Sign Supports)
WSDOT Standard Plan G-25.10-01
XYZ = 265 ft^3
Sign Properties & Geometry

X=	5.6 ft
Y=	5 ft
Z=	9.5 ft
XYZ=	266 ft^3
X*Y=	28 ft^2

Post Properties

OD_{post} = 2.875 in

Find: The size of the foundation & Depth required on a 2(H):1(V) Slope considering Cohesionless Soil (Sand) and Cohesive Soil (Clay) using the design parameters for each

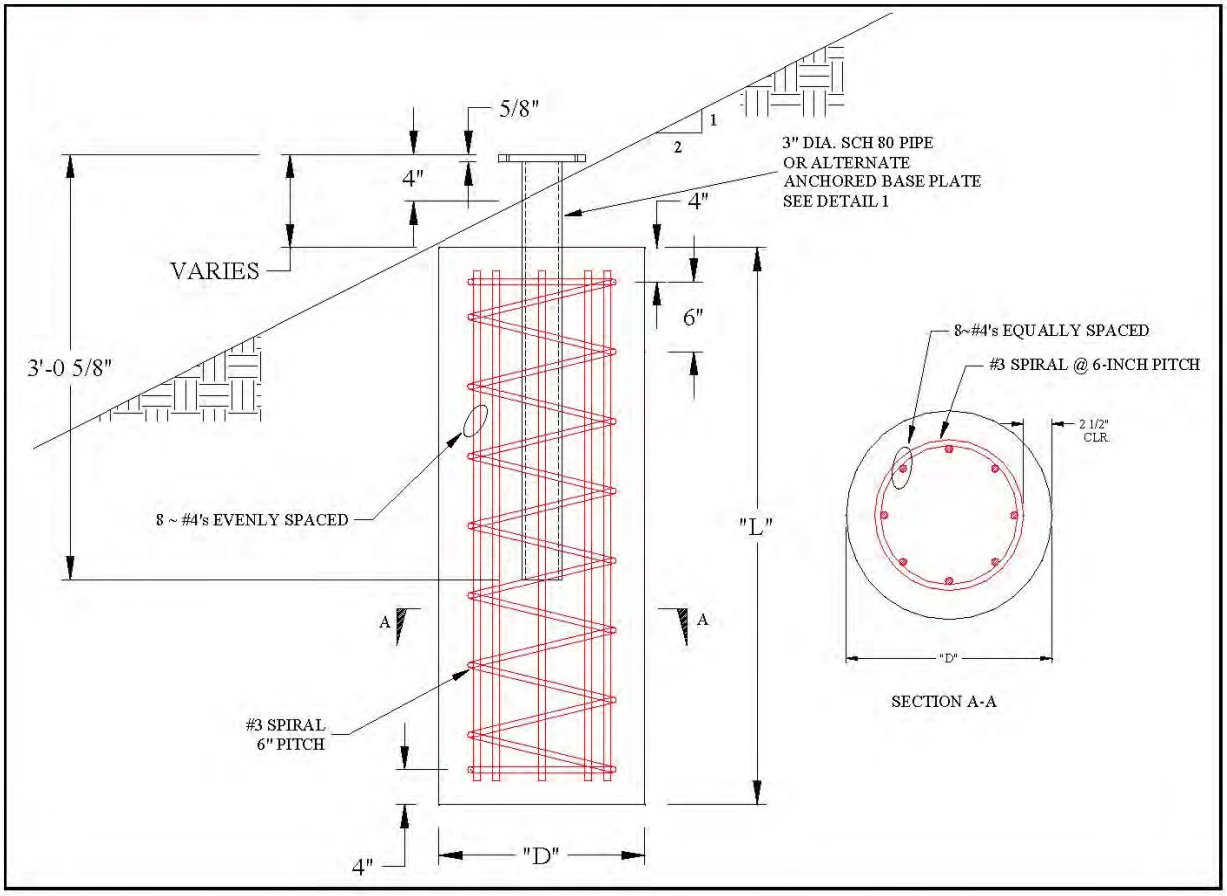
Cohesionless Soil Friction Angle Used in Analysis

ϕ = 30 degrees

Cohesive Soil Strength:

C = 1000 psf

Unit weight of soil = 110 pcf



Reference: Standards Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals Published By AASHTO, 5th Edition 2009

V_{wind}=	90	mph	
Kz=	0.87		See Table 3-5, Page 3-12 for Height 16.4 feet or less
Ir=	0.71		See Table 3-2, page 3-10
G=	1.14		See Section 3.8.5, page 3-12
Cd_{sign}=	1.19		Wind drag coefficient as per Table 3-6, page 3-16
Cd_{tube}=	1.1		Wind drag coefficient on 2.5" Sch. 80 Pipe

3.) Calculate the design Wind Pressure on the sign & post

Pzsign=	17.3762	psf
Pz_{post}=	16.0620	psf

4.) Calculate the Moment & Shear on the Sign due to Wind loading

Sign Area =	28	ft^2	$Area_{post}$ =	1.677083
Z =	9.5	ft		
OD_{post} =	2.875	in		
M_{wind} =	4.712978	kip*ft	Moment applied to the top of foundation	
V_{shear} =	0.51347	kip	Shear applied to the top of the foundation	

5.) Design Information for Footing Design:

Reference: AASHTO Standard Specifications for Structural Supports for Highway Sign, Luminaires And Trafffic Signals, 5th Edition, 2009, Section 13 Foundation Design, pages 13-3 to 13-5

	Degrees	Radians	
ϕ =	30	0.5236	Cohesionless Soil Friction Angle Used in Analysis
α =	-14	-0.2443	Slope Angle for 2(H):1(V) slope, assume sign loaded 4(H):1(V) considering burial as shown in the detail (wind loading perpendicular to slope)
θ =	0	0	Soil face used for Kp calculation (this value is zero for drilled footing application)
δ =	0	0	This value is zero for drilled footing application
FS =	3		Factor of Safety Recommended in Section 13.
γ_{soil} =	0.11	kip/ft^3	Unit weight of cohesionless soil used in the analysis (pcf)
D =	18	in	Diameter of Drilled footing (in.)

Kp =	1.931597

Reference: Principles of Geotechnical Engineering, Braja Das, 2nd Edition, page 387, EQ 5.58. (This equation takes into account a reduced K_p for sloping ground).

6.) Calculate Factored Forces for Design based on FS (Factor of Safety):

V_F =	1.540411	kip	Factored forces used for design of footing
MF =	14.13894	kip*ft	

H =	9.178674		See Section 13

7.) Calculate the required length of footing in Cohesionless Soil (Sand)
as per AASHTO Signs & Luminaires Standards, Section 13, 2009 Edition

Use Trail & Error to determine the required depth needed as per Eq. C13-7, Section 13, page 13-5

L_{sand} =	5.177	ft	Required depth for **Cohesionless Soil (Sand)**
D =	1.5	ft	
V_F =	1.540411	kips	
M_F =	14.13894	kip*ft	
Kp =	1.931597		

EQ-C13-7= -0.01769 Equation converges close to zero "0" for L_{sand} depth (trial & error)

$M_{Fmaxsand}$ = 15.96766 kip*ft Maximum calculated bending moment as per Equation C13-9, Section 13 AASHTO 2009 Specifications in Cohesionless Soil (Sand)

8.) Calculate the required footing depth and bending moment for **Cohesive soil (Clay)**
as per the AASHTO Specifications

c_{clay} = 1000 lbf/ft^2 Assumed undrained shear strength of clay material

H = 9.178674 ft See equation C13-4, Section 13 AASHTO 2009 Specifications

q = 0.114105 ft See Equation C13-5, Section 13 AASHTO 2009

$L_{claysoil}$ = 5.40371 ft Length required in Cohesive Soil (clay) as per Section 13, AASHTO 2009

$M_{Fmaxclay}$ = 18.84805 kip*ft Maximum calculated bending moment as per aaSHTO Section 13 Specifications in Cohesive Soil (clay)

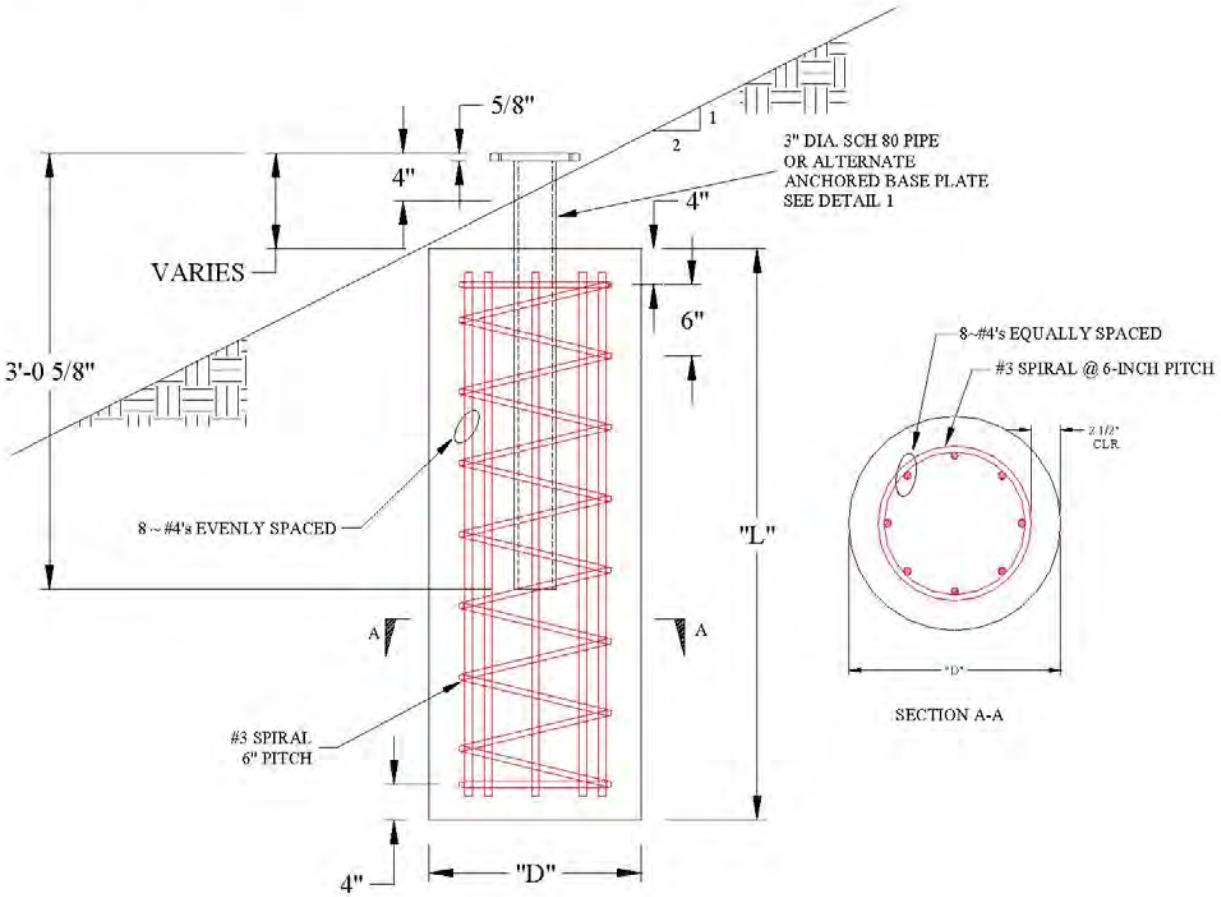
8.) Determine worst case length as per the different soil conditions:

L = 5.40371 ft Worst case (longest length) in clay

9.) Calculate vertical reinforcement as per ACI318-83 Specifications for circular columns

f`c =	4000	psi	Compressive strength of concrete
fy =	60000	psi	Yield strength of rebar
h =	1.5	ft	Diameter of pier (ft.)
cover =	2.5	in	Concrete cover
Tie_{dia} =	0.375	in	Diameter of stirrups
$Vertical_{dia}$ =	0.5	in	
No_{verts} =	8		Number of vertical bars
A_{st} =	1.570796	in^2	Area of Steel provided (in^2)
Ag =	254.469	in^2	Area of footing
ρ_{act} =	0.006173		calculated reinforcement ratio
Υh =	11.75	in	
Υ =	0.652778		
ϕ =	0.9		Strength reduction factor
ϕM_{nact_hAg} =	0.1366		As per ACI318-83 Bending diagram for circular columns
Mn =	57.93411	kip*ft	Nominal moment capacity of footing (kip*ft)

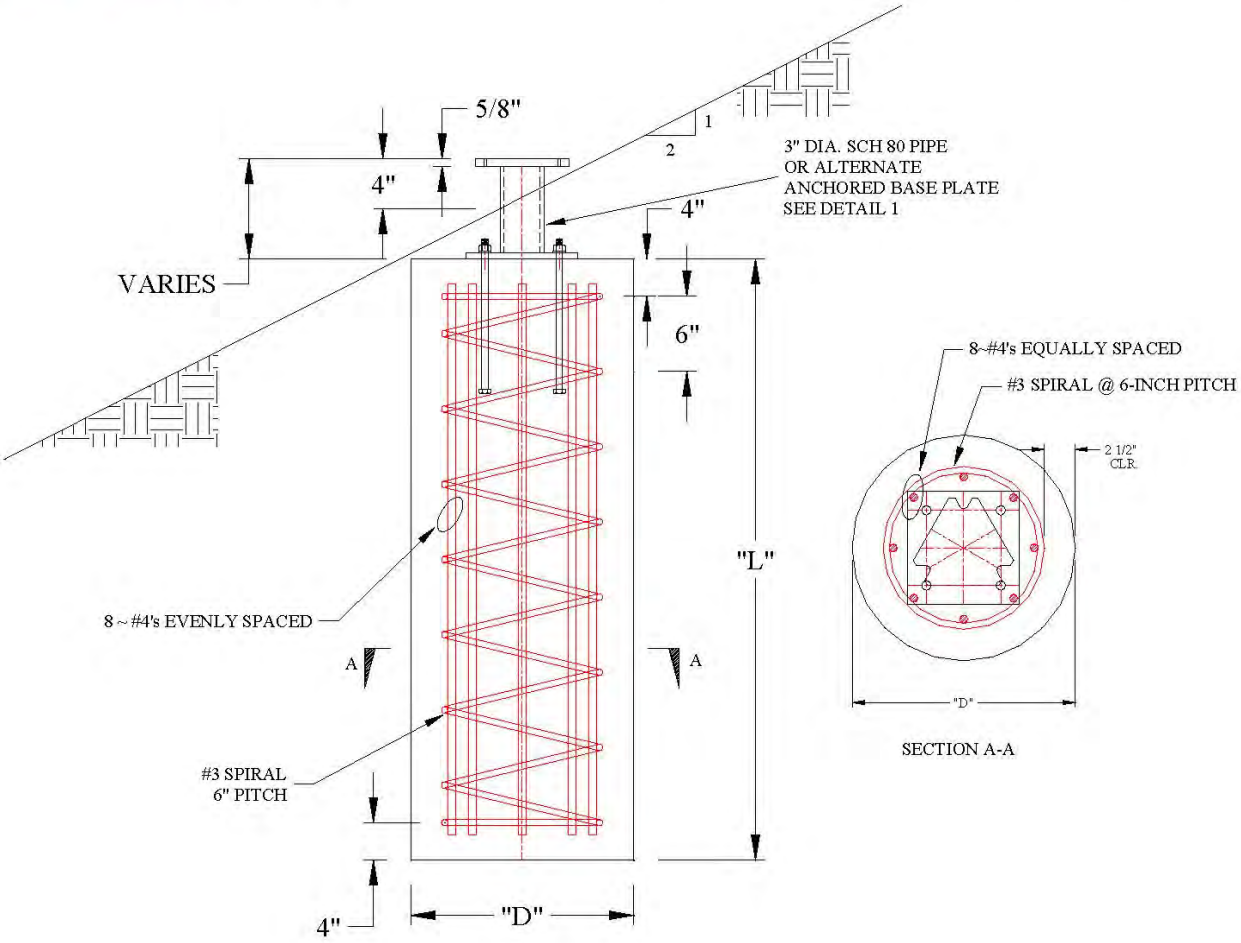
10.) Final Design Details:



D = 18 inches

L = 5'-5" - XYZ 265ft^3 and less

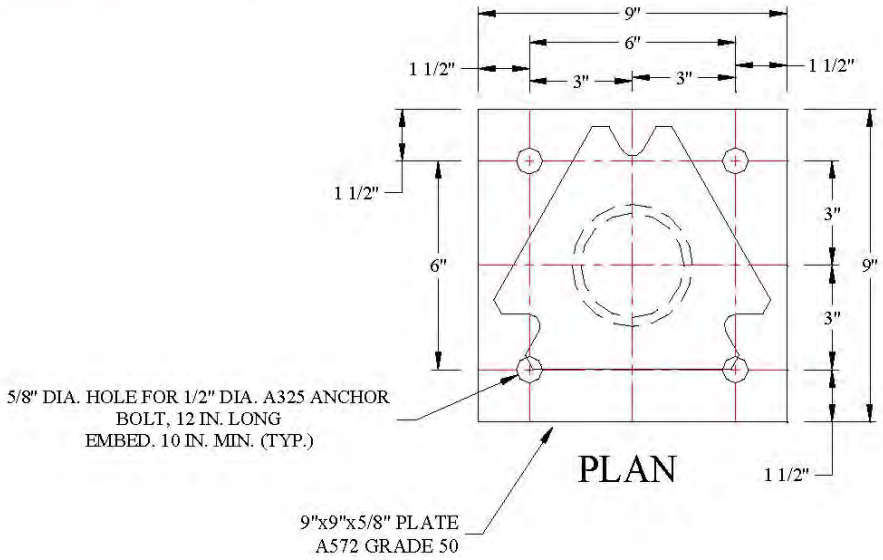
Embedded Pipe Stub Option

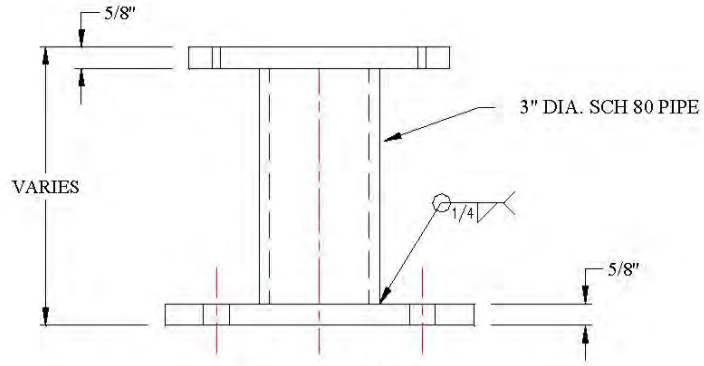


D = 18 inches

L = 5'-5" - XYZ 265ft^3 and less

Base Plated Slip Base Support Option





ELEVATION

DETAIL 1 - SLIP BASE ANCHOR PLATE

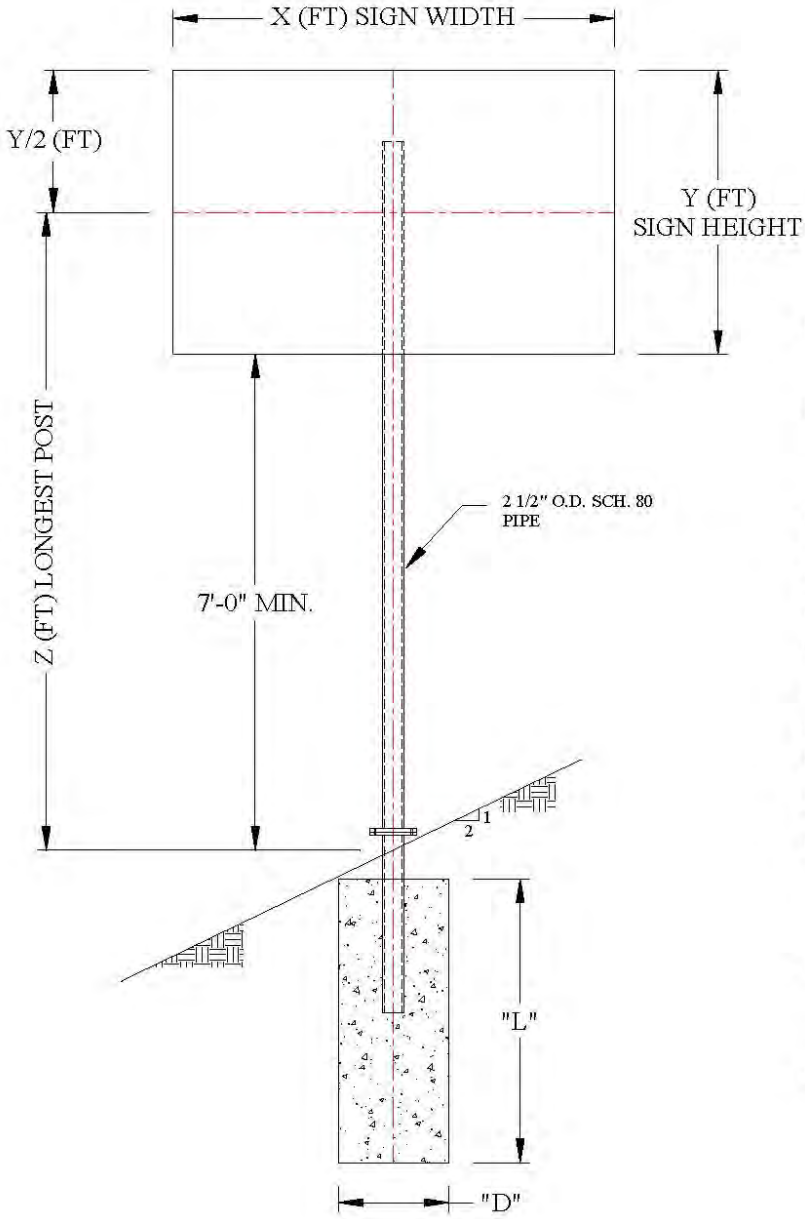
A2. XYZ between 265 to 300 ft^3 at 5 ft-6 inches

Texas Transportation Institute

Subject: **405160-22 - Foundations on Slopes**

WADOT Type PL, PL-T, & PL-U
Foundations (Small Sign Supports)
WSDOT Standard Plan G-25.10-01
XYZ = 300 ft^3

1.) Given the following Details and Design Information:



Sign Properties & Geometry

X=	5 ft
Y=	6 ft
Z=	10 ft
XYZ=	300 ft^3
X*Y=	30 ft^2

Post Properties

OD_{post} = 2.875 in

Find: The size of the foundation & Depth required on a 2(H):1(V) Slope considering Cohesionless Soil (Sand) and Cohesive Soil (Clay) using the design parameters for each

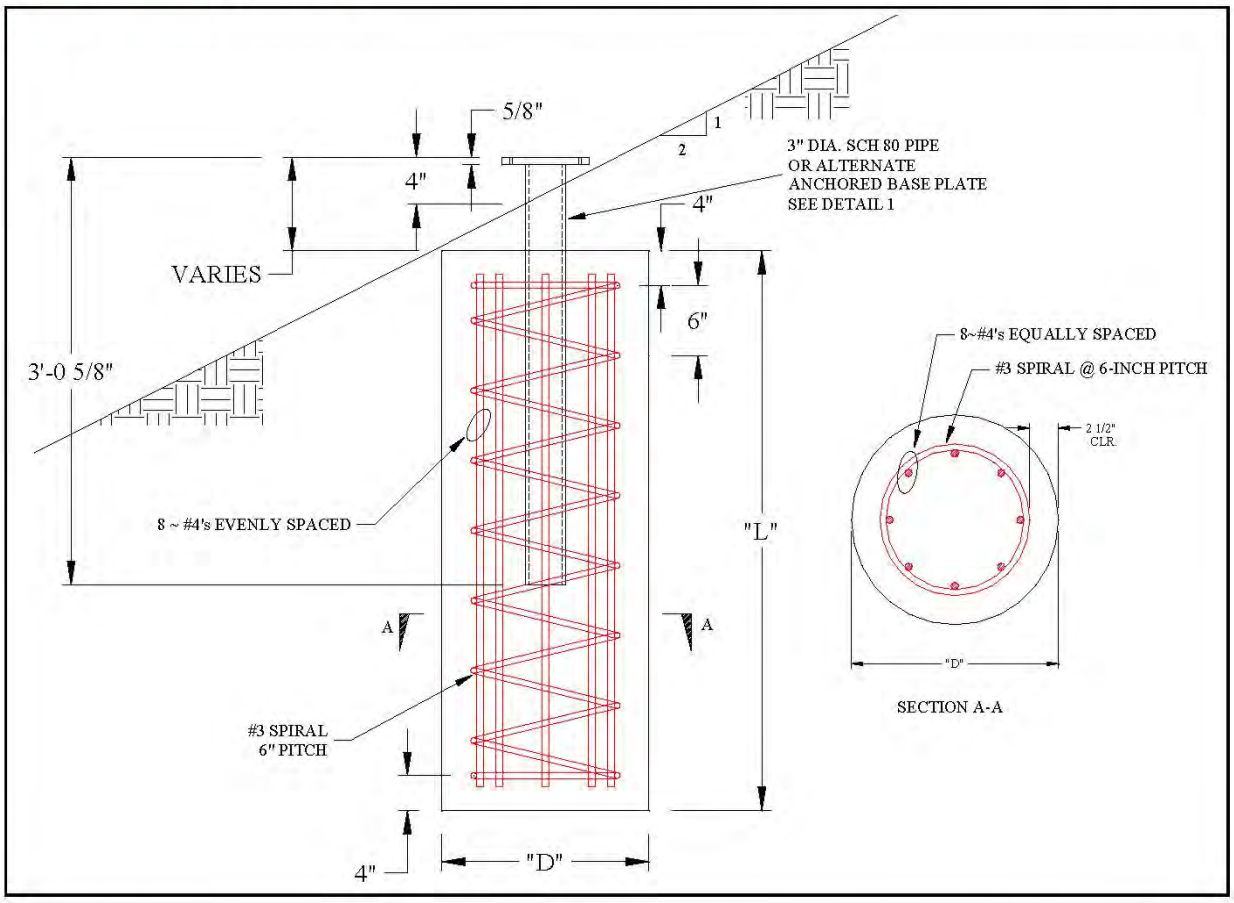
Cohesionless Soil Friction Angle Used in Analysis

ϕ = 30 degrees

Cohesive Soil Strength:

C = 1000 psf

Unit weight of soil = 110 pcf



Reference: Standards Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals Published By AASHTO, 5th Edition 2009

V_{wind}=	90	mph	
Kz=	0.87		See Table 3-5, Page 3-12 for Height 16.4 feet or less
Ir=	0.71		See Table 3-2, page 3-10
G=	1.14		See Section 3.8.5, page 3-12
Cd_{sign}=	1.19		Wind drag coefficient as per Table 3-6, page 3-16
Cd_{tube}=	1.1		Wind drag coefficient on 2.5" Sch. 80 Pipe

3.) Calculate the design Wind Pressure on the sign & post

Pzsign=	17.3762	psf
Pz_{post}=	16.0620	psf

4.) Calculate the Moment & Shear on the Sign due to Wind loading

Sign Area =	30	ft^2	$Area_{post}$ =	1.677083
Z =	10	ft		
OD_{post} =	2.875	in		
M_{wind} =	5.303769	kip*ft	Moment applied to the top of foundation	
V_{shear} =	0.548223	kip	Shear applied to the top of the foundation	

5.) Design Information for Footing Design:

Reference: AASHTO Standard Specifications for Structural Supports for Highway Sign, Luminaires And Trafffic Signals, 5th Edition, 2009, Section 13 Foundation Design, pages 13-3 to 13-5

	Degrees	Radians	
ϕ =	30	0.5236	Cohesionless Soil Friction Angle Used in Analysis
α =	-14	-0.2443	Slope Angle for 2(H):1(V) slope, assume sign loaded 4(H):1(V) considering burial as shown in the detail (wind loading perpendicular to slope)
θ =	0	0	Soil face used for Kp calculation (this value is zero for drilled footing application)
δ =	0	0	This value is zero for drilled footing application
FS =	3		Factor of Safety Recommended in Section 13.
γ_{soil} =	0.11	kip/ft^3	Unit weight of cohesionless soil used in the analysis (pcf)
D =	18	in	Diameter of Drilled footing (in.)

Kp =	1.931597

Reference: Principles of Geotechnical Engineering, Braja Das, 2nd Edition, page 387, EQ 5.58. (This equation takes into account a reduced K_p for sloping ground).

6.) Calculate Factored Forces for Design based on FS (Factor of Safety):

V_F =	1.644669	kip	Factored forces used for design of footing
MF =	15.91131	kip*ft	

H =	9.674476		See Section 13

7.) Calculate the required length of footing in Cohesionless Soil (Sand)
as per AASHTO Signs & Luminaires Standards, Section 13, 2009 Edition

Use Trail & Error to determine the required depth needed as per Eq. C13-7, Section 13, page 13-5

L_{sand} =	5.375	ft	Required depth for **Cohesionless Soil (Sand)**
D =	1.5	ft	
V_F =	1.644669	kips	
M_F =	15.91131	kip*ft	
Kp =	1.931597		

EQ-C13-7=	-0.03357		Equation converges close to zero "0" for L_{sand} depth (trial & error)
$M_{Fmaxsand}$ =	17.92879	kip*ft	Maximum calculated bending moment as per Equation C13-9, Section 13 AASHTO 2009 Specifications in Cohesionless Soil (Sand)

8.) Calculate the required footing depth and bending moment for **Cohesive soil (Clay)**
as per the AASHTO Specifications

c_{clay} =	1000	lbf/ft^2	Assumed undrained shear strength of clay material
H =	9.674476	ft	See equation C13-4, Section 13 AASHTO 2009 Specifications
q =	0.121827	ft	See Equation C13-5, Section 13 AASHTO 2009
$L_{claysoil}$ =	5.538559	ft	Length required in Cohesive Soil (clay) as per Section 13, AASHTO 2009
$M_{Fmaxclay}$ =	20.94549	kip*ft	Maximum calculated bending moment as per aaSHTO Section 13 Specifications in Cohesive Soil (clay)

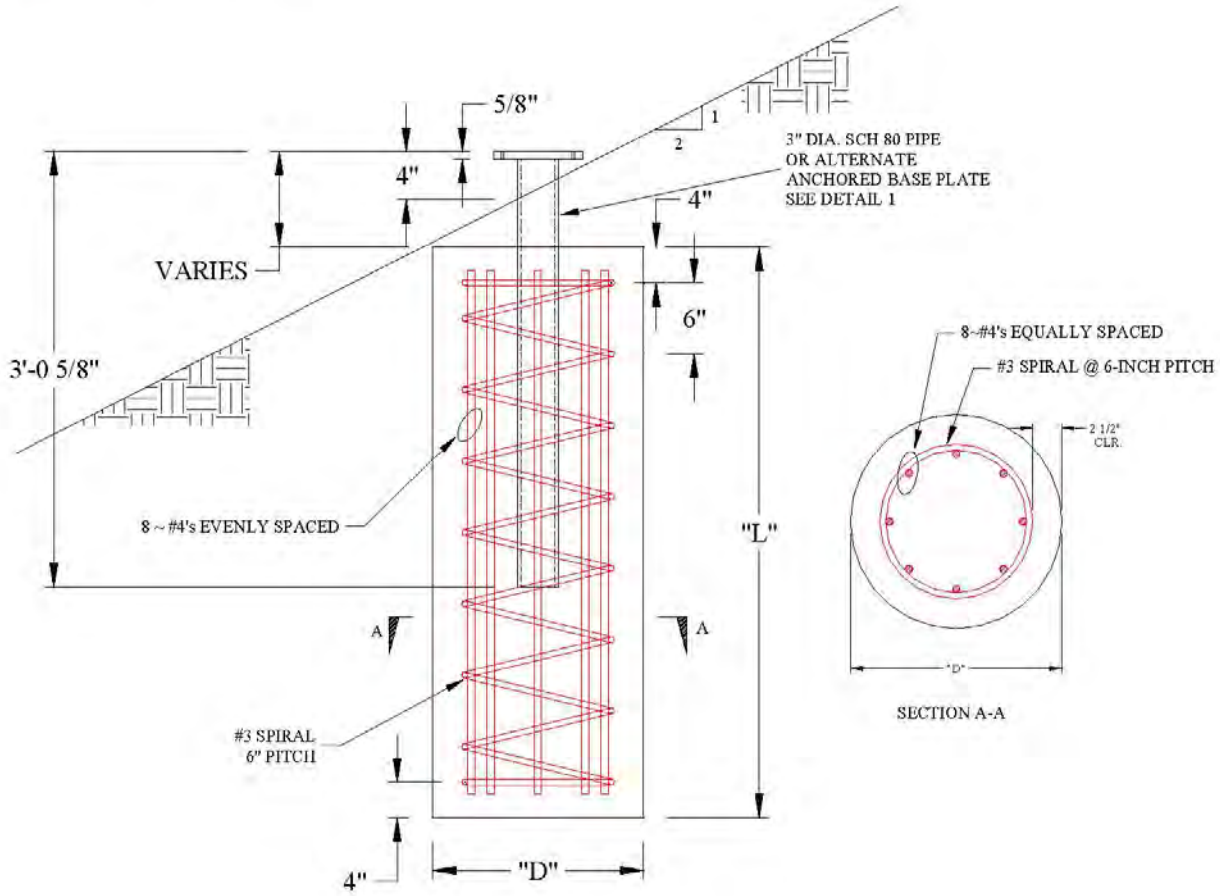
8.) Determine worst case length as per the different soil conditions:

L =	5.538559	ft	Worst case (longest length) in clay

9.) Calculate vertical reinforcement as per ACI318-83 Specifications for circular columns

f`c =	4000	psi	Compressive strength of concrete
fy =	60000	psi	Yield strength of rebar
h =	1.5	ft	Diameter of pier (ft.)
cover =	2.5	in	Concrete cover
Tie_{dia} =	0.375	in	Diameter of stirrups
$Vertical_{dia}$ =	0.5	in	
No_{verts} =	8		Number of vertical bars
A_{st} =	1.570796	in^2	Area of Steel provided (in^2)
Ag =	254.469	in^2	Area of footing
ρ_{act} =	0.006173		calculated reinforcement ratio
Υh =	11.75	in	
Υ =	0.652778		
ϕ =	0.9		Strength reduction factor
ϕM_{nact_hAg} =	0.1366		As per ACI318-83 Bending diagram for circular columns
Mn =	57.93411	kip*ft	Nominal moment capacity of footing (kip*ft)

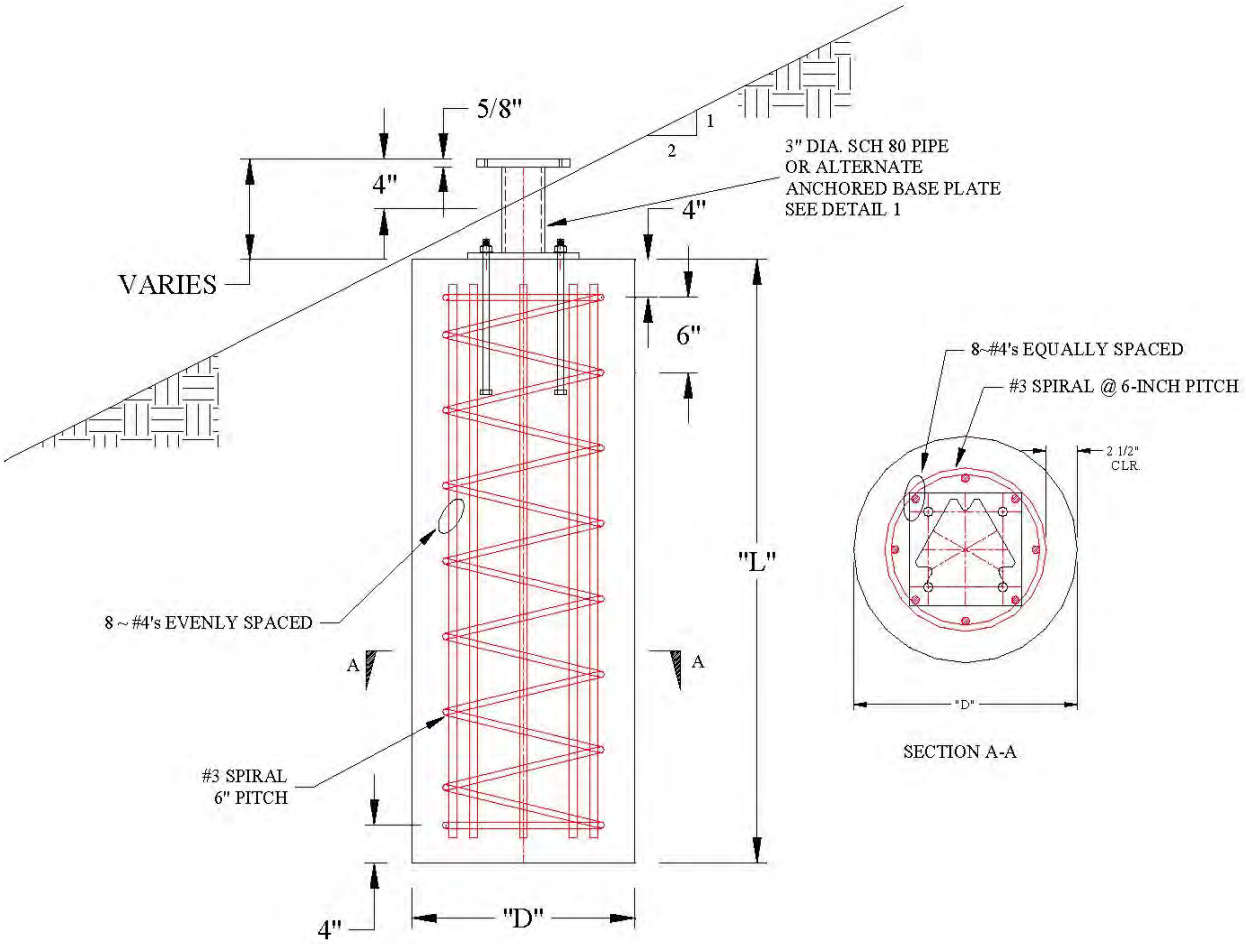
10.) Final Design Details:



D = 18 inches

L = 5'-6" - XYZ 265ft^3 to 300 ft^3

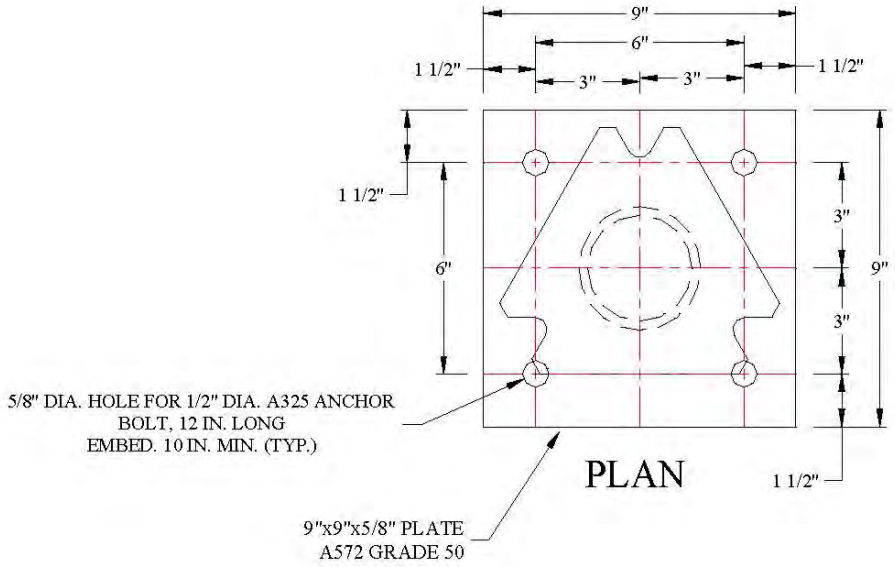
Embedded Pipe Stub Option



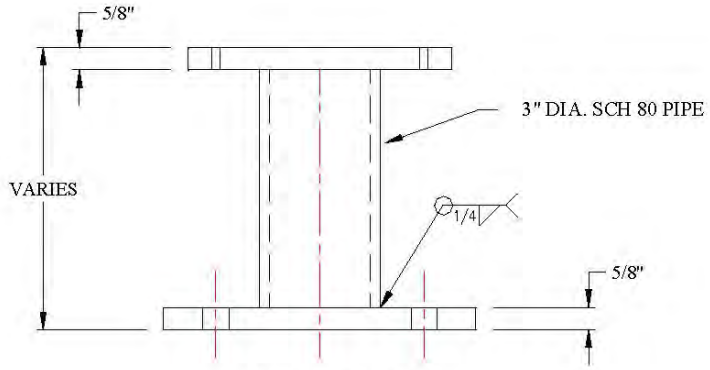
D = 18 inches

L = 5'-6" - XYZ 265 - 300ft^3

Base Plated Slip Base Support Option



PLAN



ELEVATION

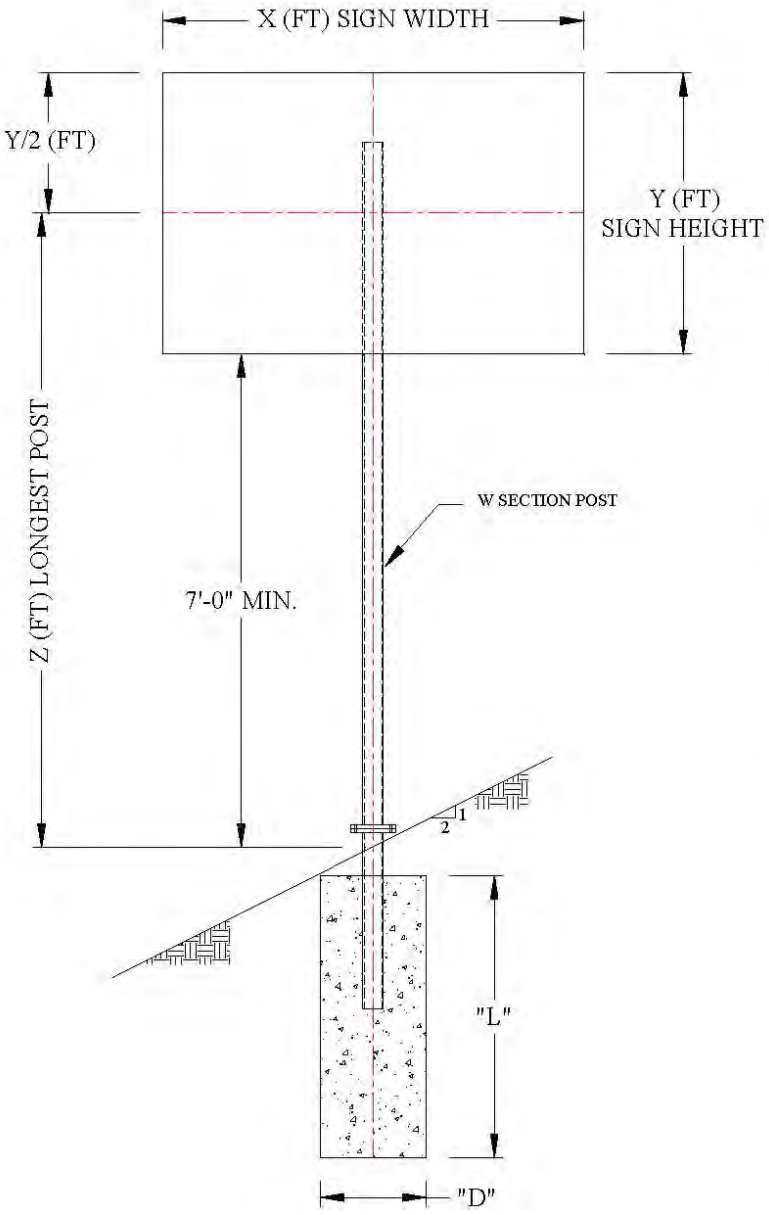
DETAIL 1 - SLIP BASE ANCHOR PLATE

A3. XYZ between 1170 ft^3 to 2070 ft^3 at 10 ft-6 inches

Texas Transportation Institute

Subject: **405160-22 - Foundations on Slopes**

1.) Given the following Details and Design Information:



WADOT Type TP-A & TP-B Fdn.
(Large Sign Support)
WSDOT Standard Plan G-25.10-01
XYZ = 1170 ft^3
Sign Properties & Geometry

X=	15.2	ft
Y=	7.25	ft
Z=	10.625	ft
XYZ=	1170.875	ft^3
X*Y=	110.2	ft^2

Post Properties: Use W6x16

b_f = 4.03 in

Find: The size of the foundation & Depth required on a 2(H):1(V) Slope considering Cohesionless Soil (Sand) and Cohesive Soil (Clay) using the design parameters for each

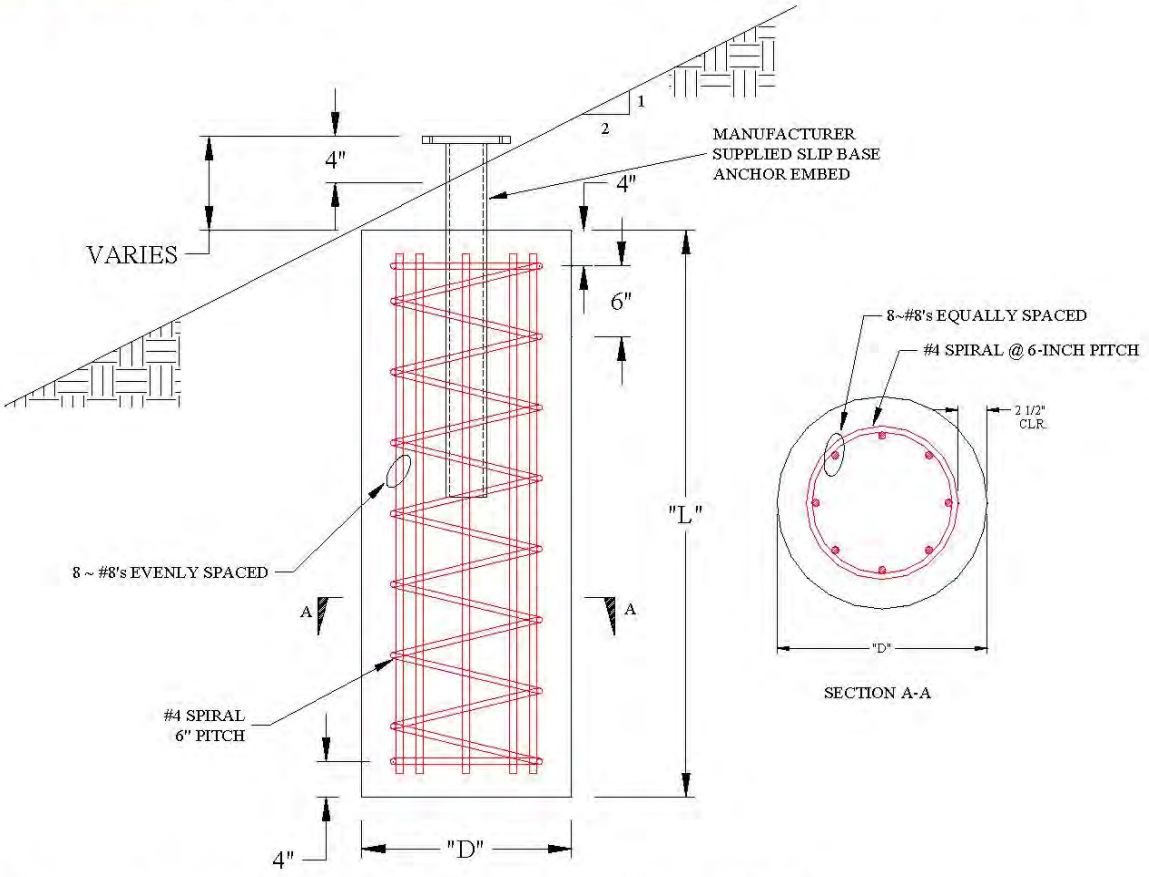
Cohesionless Soil Friction Angle Used in Analysis

ϕ = 30 degrees

Cohesive Soil Strength:

C = 1000 psf

Unit weight of soil = 110 pcf



2.) Given the following Design Information for Wind Loading on Sign:

Reference: Standards Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals Published By AASHTO, 5th Edition 2009

V_{wind}=	90	mph	
Kz=	0.87		See Table 3-5, Page 3-12 for Height 16.4 feet or less
Ir=	0.71		See Table 3-2, page 3-10
G=	1.14		See Section 3.8.5, page 3-12
Cd_{sign}=	1.19		Wind drag coefficient as per Table 3-6, page 3-16
Cd_{tube}=	1.7		Wind drag coefficient, See Table 3-6, page 3-12

3.) Calculate the design Wind Pressure on the sign & post

Pzsign=	17.3762	psf	Calculated Wind Pressures on Sign Area & Post
Pz_{post}=	24.8231	psf	

4.) Calculate the Moment & Shear on the Sign due to Wind loading

Sign Area =	110.2	ft^2	$Area_{post}$ =	2.350833
Z =	10.625	ft		
b_f =	4.03	in	Flange width of post (in.)	
M_{wind} =	20.54229	kip*ft	Moment applied to the top of foundation	
V_{shear} =	1.97321	kip	Shear applied to the top of the foundation	

5.) Design Information for Footing Design:

Reference: AASHTO Standard Specifications for Structural Supports for Highway Sign, Luminaires And Trafffic Signals, 5th Edition, 2009, Section 13 Foundation Design, pages 13-3 to 13-5

	Degrees	Radians	
ϕ =	30	0.5236	Cohesionless Soil Friction Angle Used in Analysis
α =	-14	-0.2443	Slope Angle for 2(H):1(V) slope, assume sign loaded 4(H):1(V) considering burial as shown in the detail (wind loading perpendicular to slope)
θ =	0	0	Soil face used for Kp calculation (this value is zero for drilled footing application)
δ =	0	0	This value is zero for drilled footing application
FS =	3		Factor of Safety Recommended in Section 13.
Υ_{soil} =	0.11	kip/ft^3	Unit weight of cohesionless soil used in the analysis (pcf)
D =	30	in	Diameter of Drilled footing (in.)

Kp =	1.931597

Reference: Principles of Geotechnical Engineering, Braja Das, 2nd Edition, page 387, EQ 5.58. (This equation takes into account a reduced K_p for sloping ground).

6.) Calculate Factored Forces for Design based on FS (Factor of Safety):

V_F =	5.919631	kip	Factored forces used for design of footing
MF =	61.62686	kip*ft	

H =	10.41059		See Section 13

7.) Calculate the required length of footing in Cohesionless Soil (Sand)
as per AASHTO Signs & Luminaires Standards, Section 13, 2009 Edition

Use Trail & Error to determine the required depth needed as per Eq. C13-7, Section 13, page 13-5

L_{sand} =	7.342	ft	Required depth for **Cohesionless Soil (Sand)**
D =	2.5	ft	
V_F =	5.919631	kips	
M_F =	61.62686	kip*ft	
Kp =	1.931597		

EQ-C13-7=	0.096535		Equation converges for L_{sand}
$M_{Fmaxsand}$ =	72.29801	kip*ft	Maximum calculated bending moment as per Equation C13-9, Section 13 AASHTO 2009 Specifications in Cohesionless Soil (Sand)

8.) Calculate the required footing depth and bending moment for **Cohesive soil (Clay)**
as per the AASHTO Specifications

c_{clay} =	1000	lbf/ft^2	Assumed undrained shear strength of clay material
H =	10.41059	ft	See equation C13-4, Section 13 AASHTO 2009 Specifications
q =	0.263095	ft	See Equation C13-5, Section 13 AASHTO 2009
$L_{claysoil}$ =	9.141335	ft	Length required in Cohesive Soil (clay) as per Section 13, AASHTO 2009
$M_{Fmaxclay}$ =	92.00373	kip*ft	Maximum calculated bending moment as per aaSHTO Section 13 Specifications in Cohesive Soil (clay)

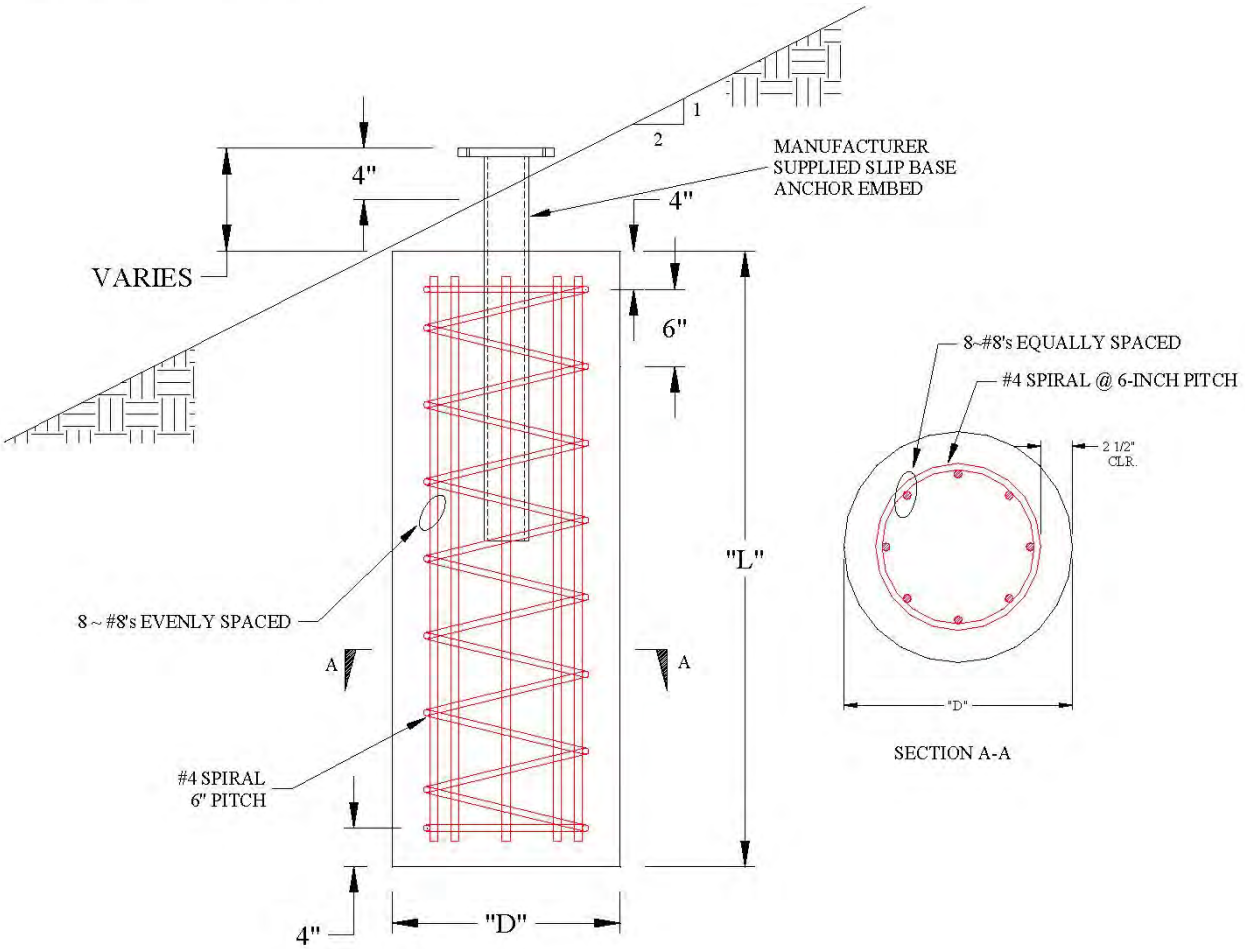
8.) Determine worst case length as per the different soil conditions:

L =	9.141335	ft	Worst case (longest length) in clay

9.) Calculate vertical reinforcement as per ACI318-83 Specifications for circular columns

f`c =	4000	psi	Compressive strength of concrete
fy =	60000	psi	Yield strength of rebar
h =	2.5	ft	Diameter of pier (ft.)
cover =	2.5	in	Concrete cover
Tie_{dia} =	0.5	in	Diameter of stirrups
$Vertical_{dia}$ =	1	in	
No_{verts} =	8		Number of vertical bars
A_{st} =	6.283185	in^2	Area of Steel provided (in^2)
Ag =	706.8583	in^2	Area of footing
ρ_{act} =	0.008889		calculated reinforcement ratio
Υh =	23	in	
Υ =	0.766667		
ϕ =	0.9		Strength reduction factor
ϕM_{nact_hAg} =	0.189		As per ACI318-83 Bending diagram for circular columns
Mn =	371.1006	kip*ft	Nominal moment capacity of footing (kip*ft)... o.k.!

10.) Final Design Details:



D = 30 inches

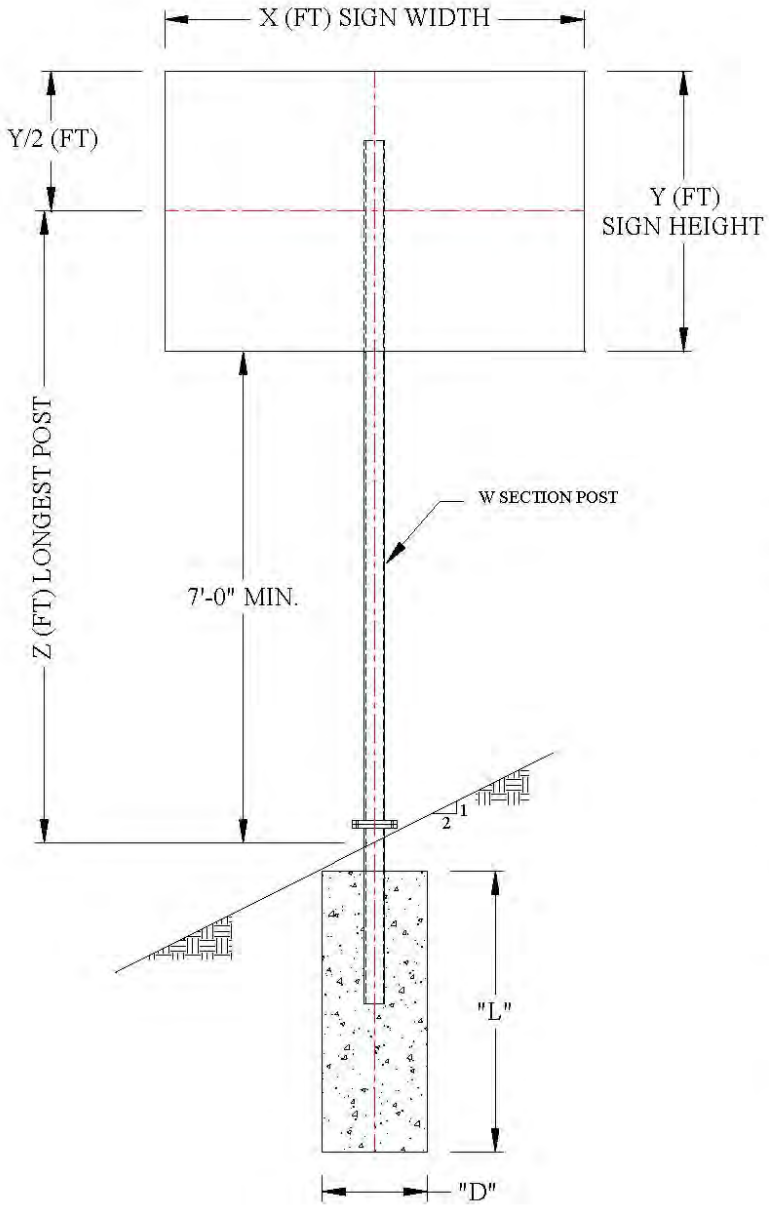
L = 9'-6" for XYZ = 1170 ft^3 and Less

A4. XYZ less than 1170 ft^3 is 9 ft-6 inches

Texas Transportation Institute

Subject: **405160-22 - Foundations on Slopes**

1.) Given the following Details and Design Information:



WADOT Type TP-A & TP-B Fdn.
(Large Sign Support)
WSDOT Standard Plan G-25.10-01
XYZ = 2070 ft^3
Sign Properties & Geometry

X=	20 ft
Y=	9 ft
Z=	11.5 ft
XYZ=	2070 ft^3
X*Y=	180 ft^2

Post Properties: Use W8x21

b_f = 5.27 in

Find: The size of the foundation & Depth required on a 2(H):1(V) Slope considering Cohesionless Soil (Sand) and Cohesive Soil (Clay) using the design parameters for each

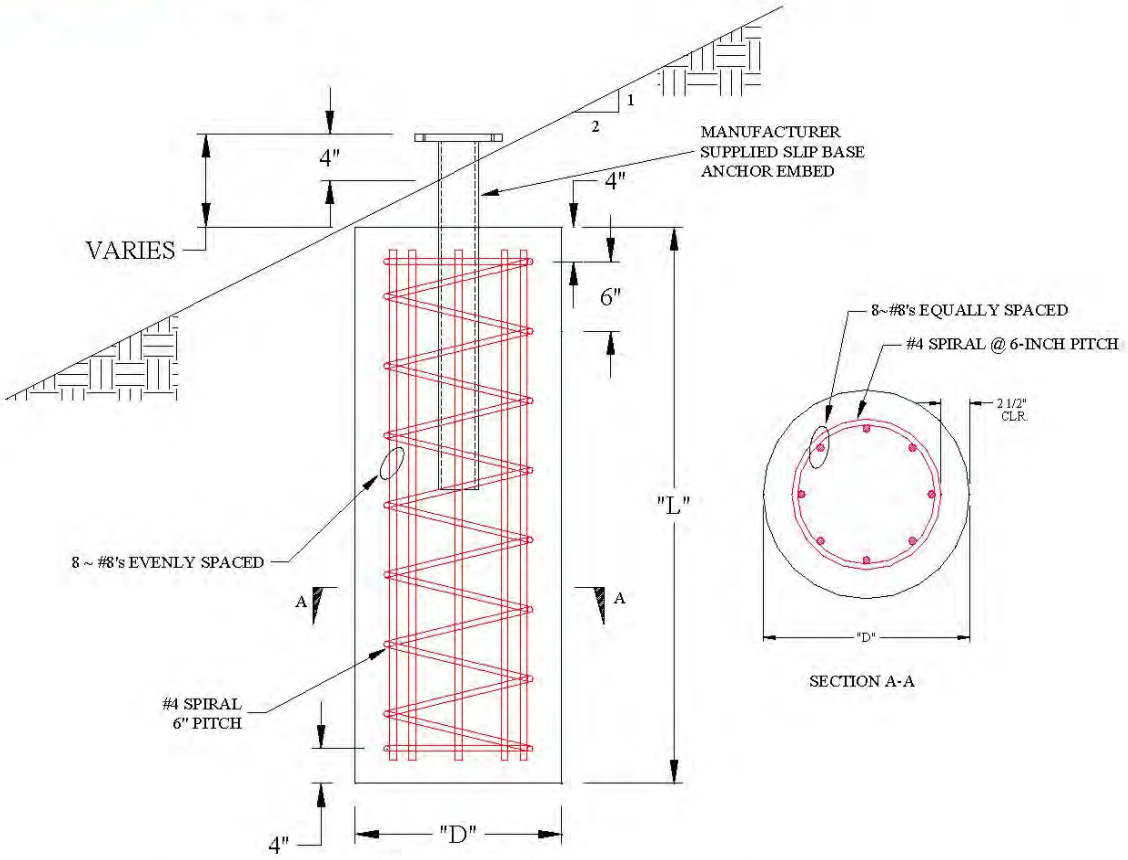
Cohesionless Soil Friction Angle Used in Analysis

ϕ = 30 degrees

Cohesive Soil Strength:

C = 1000 psf

Unit weight of soil = 110 pcf



2.) Given the following Design Information for Wind Loading on Sign:

Reference: Standards Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals Published By AASHTO, 5th Edition 2009

V_{wind}=	90	mph	
Kz=	0.87		See Table 3-5, Page 3-12 for Height 16.4 feet or less
Ir=	0.71		See Table 3-2, page 3-10
G=	1.14		See Section 3.8.5, page 3-12
Cd_{sign}=	1.19		Wind drag coefficient as per Table 3-6, page 3-16
Cd_{tube}=	1.7		Wind drag coefficient, See Table 3-6, page 3-12

3.) Calculate the design Wind Pressure on the sign & post

Pzsign=	17.3762	psf	Calculated Wind Pressures on Sign Area & Post
Pz_{post}=	24.8231	psf	

4.) Calculate the Moment & Shear on the Sign due to Wind loading

Sign Area =	180	ft^2	$Area_{post}$ =	3.074167
Z =	11.5	ft		
b_f =	5.27	in	Flange width of post (in.)	
M_{wind} =	36.22625	kip*ft	Moment applied to the top of foundation	
V_{shear} =	3.204023	kip	Shear applied to the top of the foundation	

5.) Design Information for Footing Design:

Reference: AASHTO Standard Specifications for Structural Supports for Highway Sign, Luminaires And Trafffic Signals, 5th Edition, 2009, Section 13 Foundation Design, pages 13-3 to 13-5

	Degrees	Radians	
ϕ =	30	0.5236	Cohesionless Soil Friction Angle Used in Analysis
α =	-14	-0.2443	Slope Angle for 2(H):1(V) slope, assume sign loaded 4(H):1(V)
			considering burial as shown in the detail (wind loading perpendicular
			to slope)
θ =	0	0	Soil face used for Kp calculation (this value is zero for drilled
			footing application)
δ =	0	0	This value is zero for drilled footing application
FS =	3		Factor of Safety Recommended in Section 13.
γ_{soil} =	0.11	kip/ft^3	Unit weight of cohesionless soil used in the analysis (pcf)
D =	30	in	Diameter of Drilled footing (in.)

Kp =	1.931597

Reference: Principles of Geotechnical Engineering, Braja Das, 2nd Edition, page 387, EQ 5.58. (This equation takes into account a reduced K_p for sloping ground).

6.) Calculate Factored Forces for Design based on FS (Factor of Safety):

V_F =	9.61207	kip	Factored forces used for design of footing
MF =	108.6787	kip*ft	

H =	11.30649		See Section 13

7.) Calculate the required length of footing in Cohesionless Soil (Sand)
as per AASHTO Signs & Luminaires Standards, Section 13, 2009 Edition

Use Trail & Error to determine the required depth needed as per Eq. C13-7, Section 13, page 13-5

L_{sand} =	9.028	ft	Required depth for **Cohesionless Soil (Sand)**
D =	2.5	ft	
V_F =	9.61207	kips	
M_F =	108.6787	kip*ft	
Kp =	1.931597		

EQ-C13-7=	-0.09536		Equation converges for L_{sand}
$M_{Fmaxsand}$ =	130.7585	kip*ft	Maximum calculated bending moment as per Equation C13-9, Section 13 AASHTO 2009 Specifications in Cohesionless Soil (Sand)

8.) Calculate the required footing depth and bending moment for **Cohesive soil (Clay)**
as per the AASHTO Specifications

c_{clay} =	1000	lbf/ft^2	Assumed undrained shear strength of clay material
H =	11.30649	ft	See equation C13-4, Section 13 AASHTO 2009 Specifications
q =	0.427203	ft	See Equation C13-5, Section 13 AASHTO 2009
$L_{claysoil}$ =	10.5354	ft	Length required in Cohesive Soil (clay) as per Section 13, AASHTO 2009
$M_{Fmaxclay}$ =	158.7922	kip*ft	Maximum calculated bending moment as per aaSHTO Section 13 Specifications in Cohesive Soil (clay)

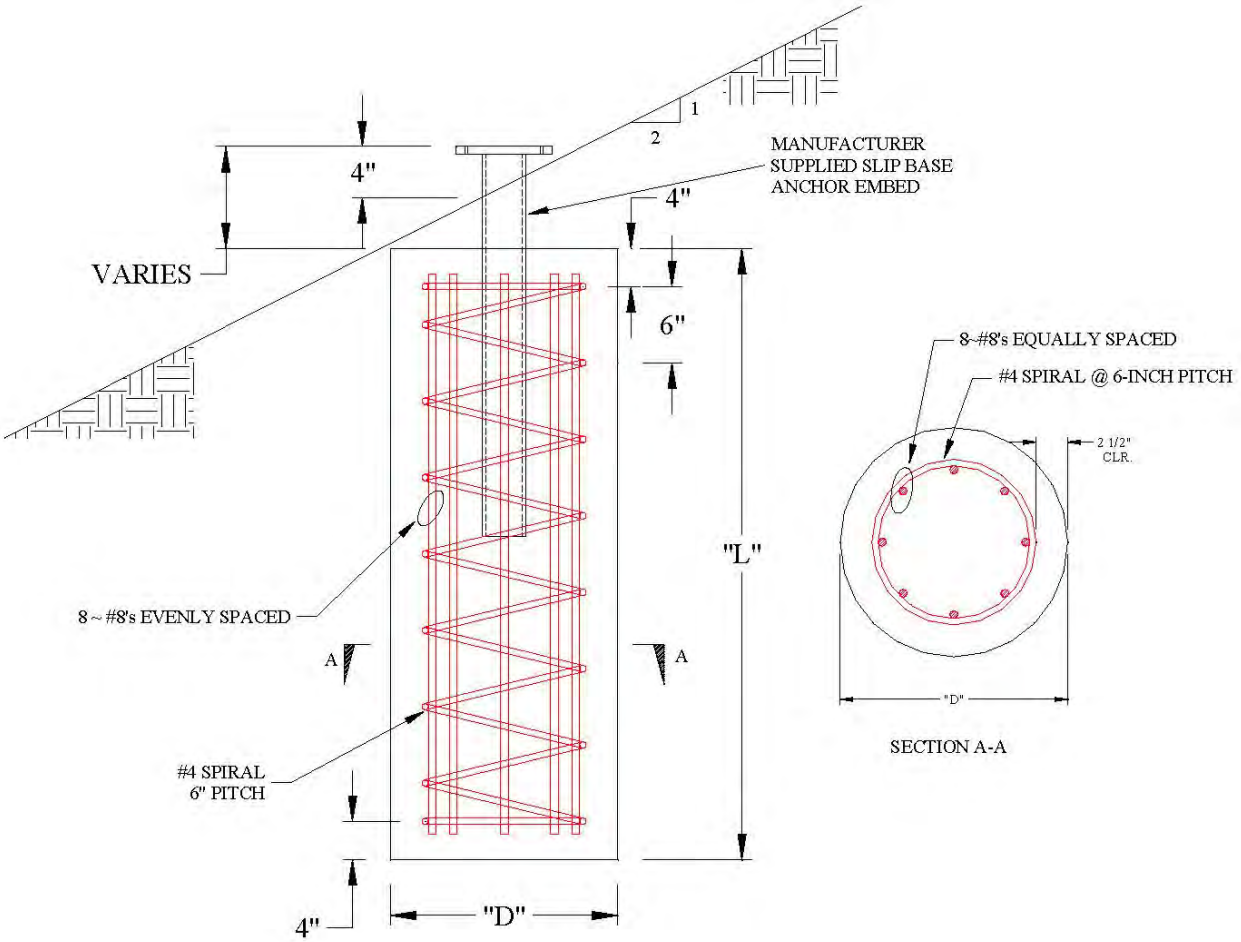
8.) Determine worst case length as per the different soil conditions:

L =	10.5354	ft	Worst case (longest length) in clay

9.) Calculate vertical reinforcement as per ACI318-83 Specifications for circular columns

f`c =	4000	psi	Compressive strength of concrete
fy =	60000	psi	Yield strength of rebar
h =	2.5	ft	Diameter of pier (ft.)
cover =	2.5	in	Concrete cover
Tie_{dia} =	0.5	in	Diameter of stirrups
$Vertical_{dia}$ =	1	in	
No_{verts} =	8		Number of vertical bars
A_{st} =	6.283185	in^2	Area of Steel provided (in^2)
Ag =	706.8583	in^2	Area of footing
ρ_{act} =	0.008889		calculated reinforcement ratio
Υh =	23	in	
Υ =	0.766667		
ϕ =	0.9		Strength reduction factor
ϕM_{nact_hAg} =	0.189		As per ACI318-83 Bending diagram for circular columns
Mn =	371.1006	kip*ft	Nominal moment capacity of footing (kip*ft)... o.k.!

10.) Final Design Details:



D = 30 inches

L = 10'-6" XYZ 1170 ft^3 to 2070ft^3