Session 25

Charlie Harvey

FL. Dept. of Transportation CO

Programs & Standards: Spread Footings ; Signs / Mast-Arms / Cantilevers

Topic Description

What is new in Sign, Mastarm and Spreadfooting programs.

Speaker Biography

Professional Engineer.
20 years with Florida DOT as a Structural Engineer.
Last 5 years in Structural software group in Central Office.

Structures Design Software Update

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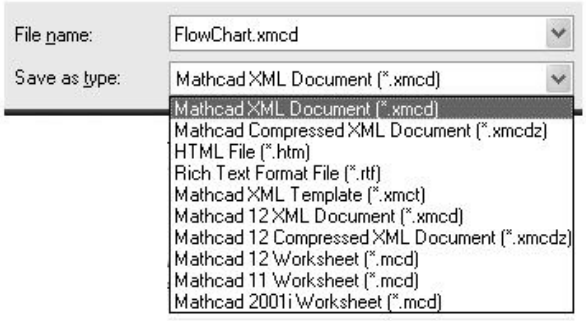
Structures Software Update

- Mathcad 13 compatible
- Mastarm program
- Strain Pole program
- Biaxial Rectangular Footing program

mathcad →13

Mathcad 13

- most programs Mathcad 13 compatible
- .mcd ➔.xmcd
- both Mathcad 13 and 11 versions available



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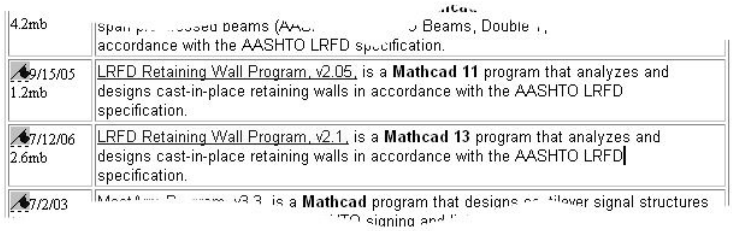

4.2mb	span pr... ...ssed beams (AA... ...) Beams, Double T, accordance with the AASHTO LRFD specification.
9/15/05 1.2mb	LRFD Retaining Wall Program, v2.05, is a **Mathcad 11** program that analyzes and designs cast-in-place retaining walls in accordance with the AASHTO LRFD specification.
7/12/06 2.6mb	LRFD Retaining Wall Program, v2.1, is a **Mathcad 13** program that analyzes and designs cast-in-place retaining walls in accordance with the AASHTO LRFD specification.
7/2/03	Mast... ...v3.3, is a **Mathcad** program that designs ca... ...ilever signal structures ...TO signing and ...

Mastarm Program v4.0

- multiple steps combined into one program
- data files
- Standard Arms B and C
  Standard Poles Q and R

Step 1 Select Member Types

ArmType1 := Arm 2 | ArmType2 := Arm 1 | PoleType := Pole 3 | Type := (ArmType1, ArmType2, PoleType)

Step 2 On the Menu Bar Click on Math then Calculate Worksheet

Step 3 Design Arm 1

Step 4 Design Arm 2 **(optional)**

Step 5 Design Luminaire **(optional)**

Step 6 Design Upright

Step 7 Design Connections

Step 8 Design Drilled Shaft

Step 9 Design Summary

Step 10 **Transfer Design values to Table on FDOT Standard Drawing S-1710**

Arm 1 Properties

Current Values	New Values	
$L_{total.arm1} = 34\,ft$		*feet, 40 ft. max. for 1 piece arms; 78 ft. max. for 2*
$Diameter_{base.arm1} = 13\,in$		*inches, measured flat to flat*
$Dist_{splice.from.base.arm1} = 0\,ft$		*feet, approximate distance, use X to zero out*
$t_{wall.arm1} = \begin{pmatrix} 0.1793 \\ 0 \end{pmatrix} in$		*inches, this value is used for one piece arms*
		inches, for 2 piece arms, this value is for the piece closest to the pole, use X to zero out

Arm 1 Properties

Analyze Arm 1

Summary - Arm 1 Geometry and Loading $WindSpeed = 110\,mph$ $L_{total.arm1} = 34\,ft$

$Diameter_{tip.arm1} = \begin{pmatrix} 8.24 \\ 0 \end{pmatrix} in$ $Diameter_{base.arm1} = \begin{pmatrix} 13 \\ 0 \end{pmatrix} in$ $L_{arm1} = \begin{pmatrix} 34 \\ 0 \end{pmatrix} ft$ $t_{wall.arm1} = \begin{pmatrix} 0.1793 \\ 0 \end{pmatrix} in$

$X_{signal.arm1_{i1}}$	$Sections_{signal.arm1_{i1}}$	$X_{panel.arm1_{j1}}$	$Area_{panel.arm1_{j1}}$
17 ft	3	8 ft	15 ft^2
26	3		
33	3		

Arm 1 Combined Stress Ratio and Deflection

$\max(CSR_{arm1}) = 0.870$ $\max(\Delta_{arm1}) = 2.3\,in$ $2 \cdot deg \cdot \sum L_{arm1} = 14.2\,in$

Mastarm Program v4.0

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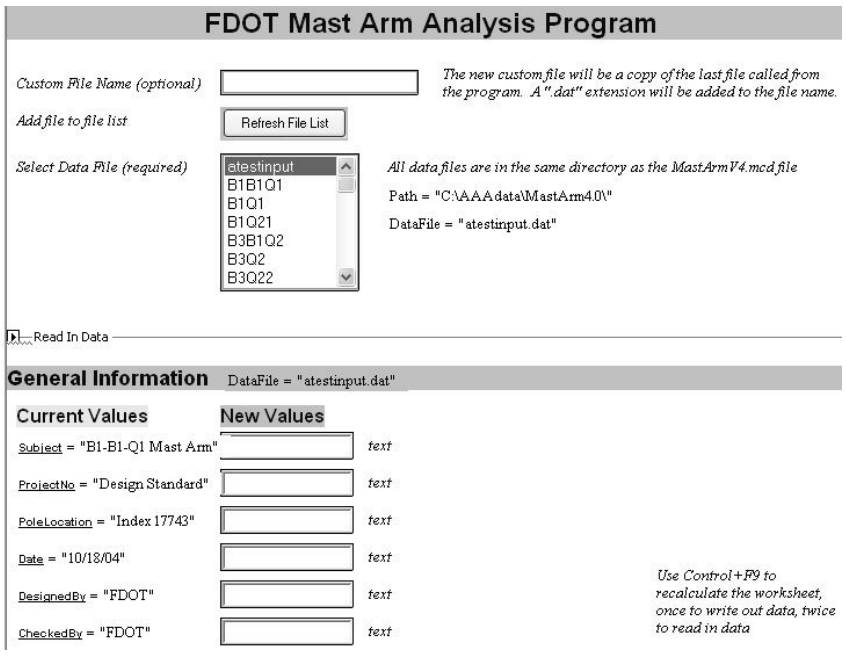

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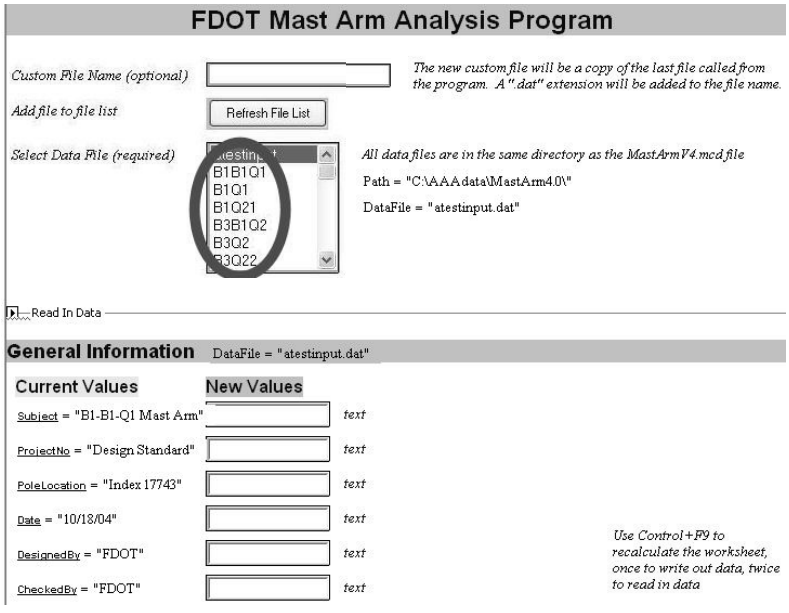
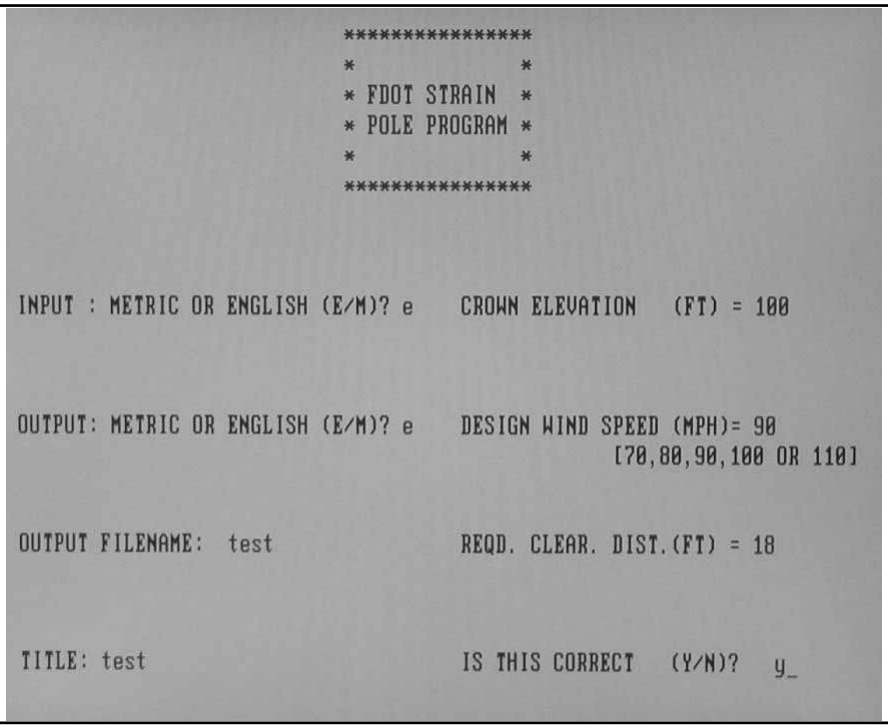
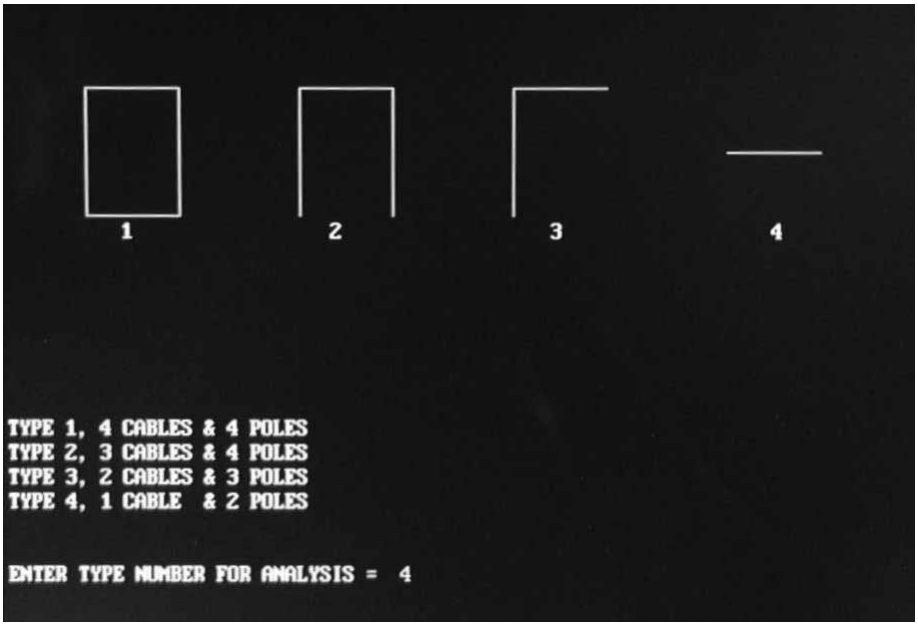
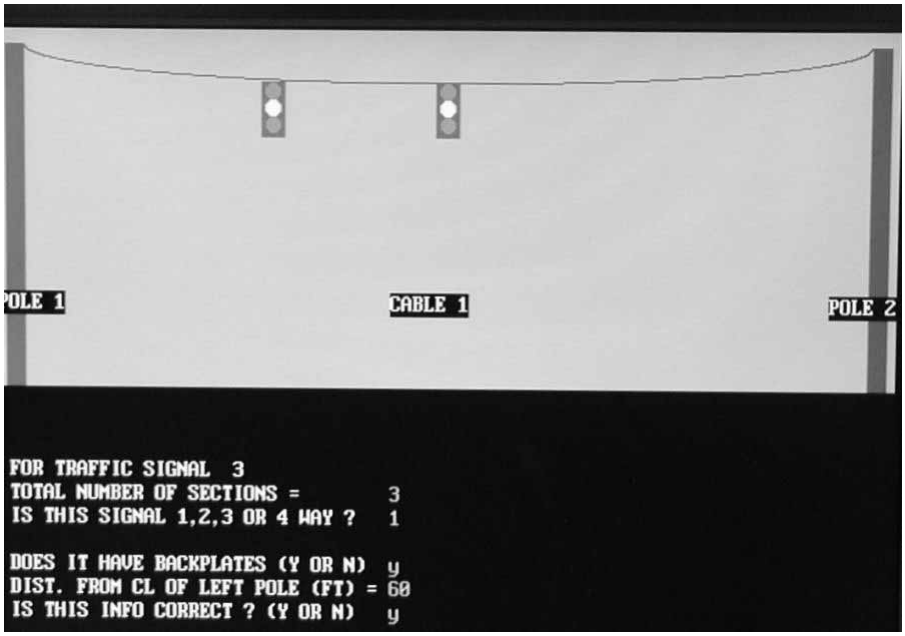


Strain Pole Program

- Strain2001 - new program
- STRAIN v1.7 - old program

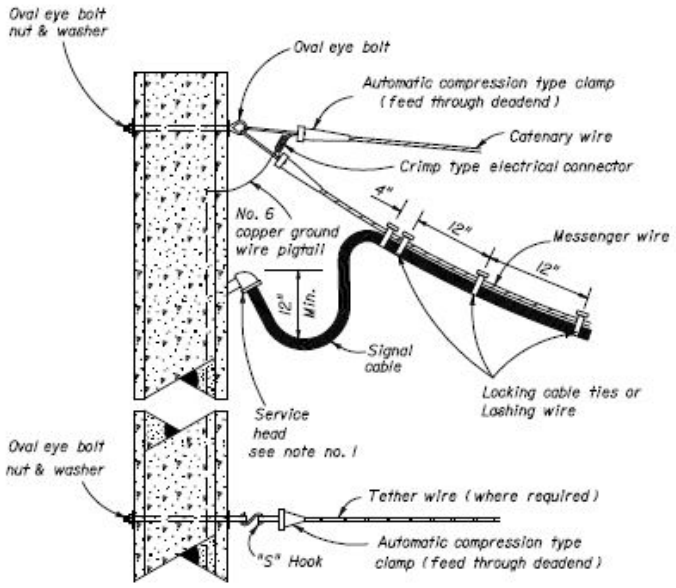



1
2
3
4
TYPE 1, 4 CABLES & 4 POLES
TYPE 2, 3 CABLES & 4 POLES
TYPE 3, 2 CABLES & 3 POLES
TYPE 4, 1 CABLE & 2 POLES
ENTER TYPE NUMBER FOR ANALYSIS = 4


POLE 1
CABLE 1
POLE 2
FOR TRAFFIC SIGNAL 3
TOTAL NUMBER OF SECTIONS = 3
IS THIS SIGNAL 1,2,3 OR 4 WAY ? 1
DOES IT HAVE BACKPLATES (Y OR N) y
DIST. FROM CL OF LEFT POLE (FT) = 60
IS THIS INFO CORRECT ? (Y OR N) y

Strain2001

- Mathcad program
- 2001 AASHTO Sign, Luminaire & Signal Specifications design
- new wind speed loads
- single point attachment



Concrete Strain Pole Design

English Units

SUBJECT Standard Index 17725
PROJECT # _____
DESIGNED BY ____ DATE ____
CHECKED BY ____ DATE ____

GENERAL INFORMATION:

References: *AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and traffic Signals, 2001*

Inputs

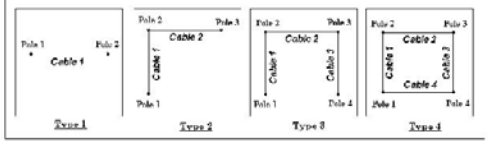
Design Wind Speed & Directions

Wind3peed := 110 · mph Wind3peed = 110 mph

Layout Types: Type 1, 1 Cables and 2 Poles
Type 2, 2 Cables and 2 Poles
Type 3, 3 Cables and 4 Poles
Type 4, 4 Cables and 4 Poles

Type := 1 Type = 1

FIGURE OF LAYOUT TYPES



Span Length (Input your Cable Span length here.)

$$Span := \begin{pmatrix} 100 \\ 0 \\ 0 \\ 0 \end{pmatrix} ft \qquad Span = \begin{pmatrix} 100 \\ 0 \\ 0 \\ 0 \end{pmatrix} ft$$

Cable Parameters

Diameter(in) Weight(lbf/ft) Area(in2) Strength(kips)

$$Cable := \begin{pmatrix} \frac{3}{8} & 0.08 & 0.273 & 4.6 \\ \frac{7}{16} & 0.117 & 0.399 & 7.2 \end{pmatrix}$$

E := 24500 · ksi $E = 2.45 \times 10^4$ ksi

$C_{d\,Cable} := 1.1$ $C_{d\,Cable} = 1.1$

Swing Factor

$$Factor_{swing} := \begin{pmatrix} 0.65 \\ 0.65 \\ 0.65 \\ 0.65 \end{pmatrix} \qquad Factor_{swing_2} = 0.65$$

This factor is 1 if the Signals and Signs are not allowed to swing, and it is 0.65 if the Signals and Signs are allowed to swing.

Signal Parameters

$A_{Signal} := 1.36 \cdot ft^2$ $C_{d\,Signal} := 1.2$ $Weight_{Signal} := 12.3 \cdot lbf$

Disconect and Hanger

$A_{Hanger} := 0.856 \cdot ft^2$ $C_{d\,Hanger} := 1.45$ $Weight_{Hanger} := 16.4 \cdot lbf$

BackPlate

$A_{3sectBP} := 5.28 \cdot ft^2$ $C_{d\,BP} := 1.2$ $Weight_{BP} := 2.0 \cdot lbf$

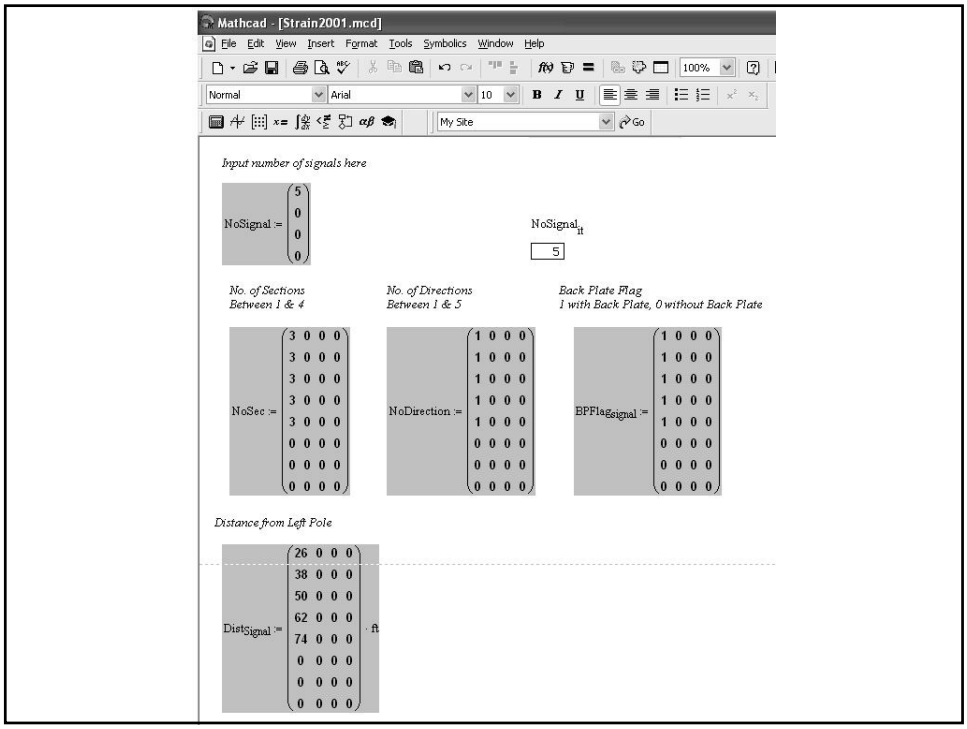
$A_{4sectBP} := 5.97 \cdot ft^2$

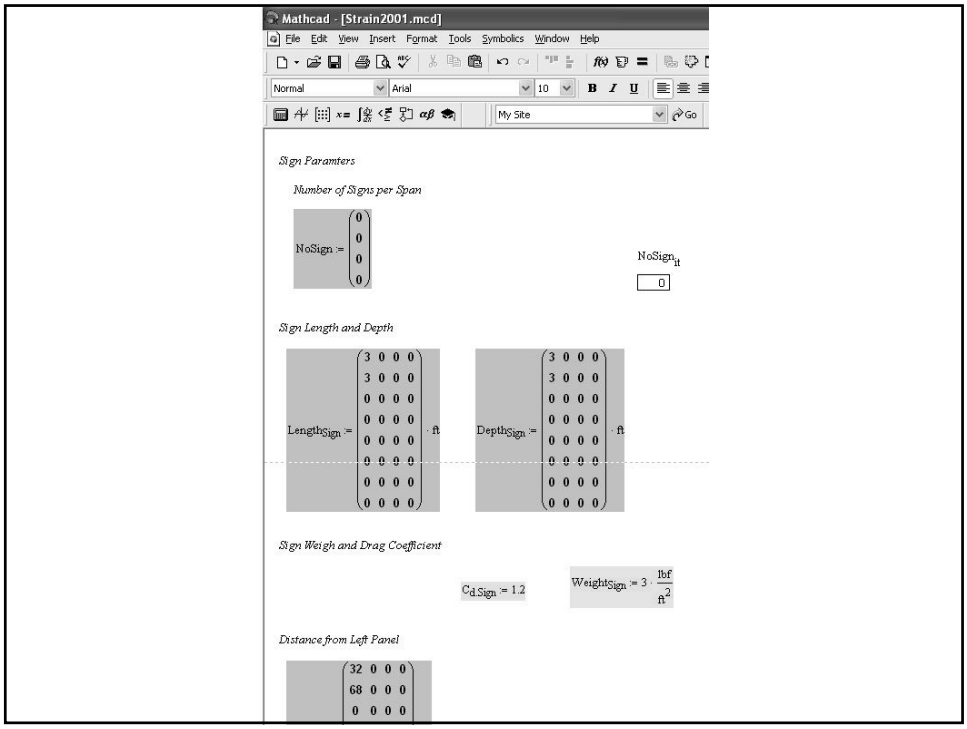
$A_{5sectBP} := 6.3 \cdot ft^2$

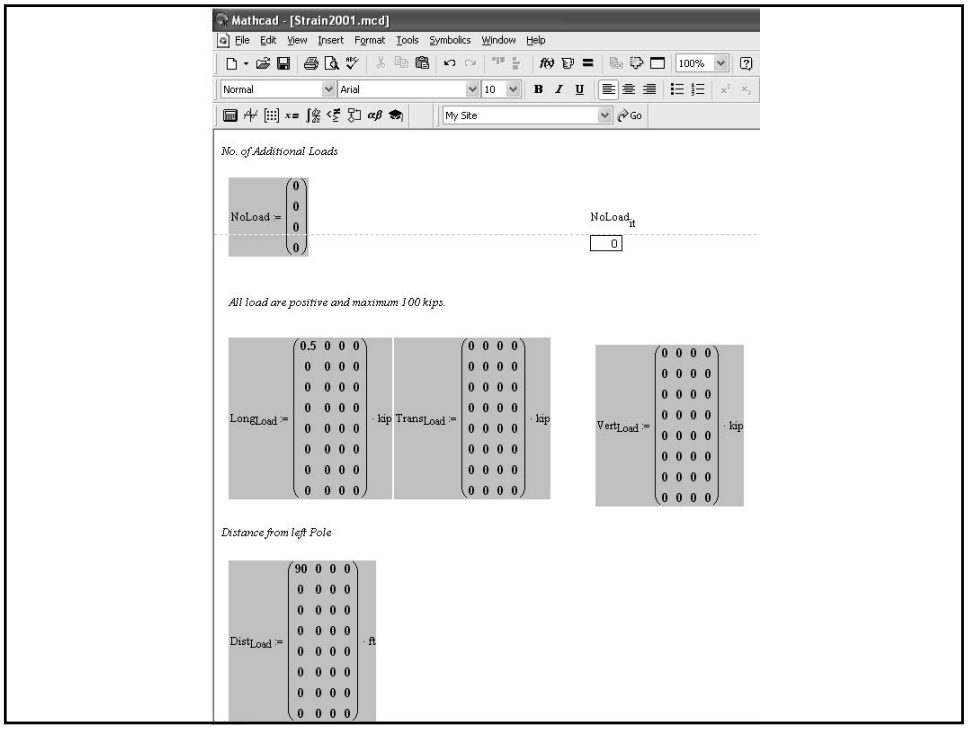
Braket (Cd for Bracket is included in the Effective Area)

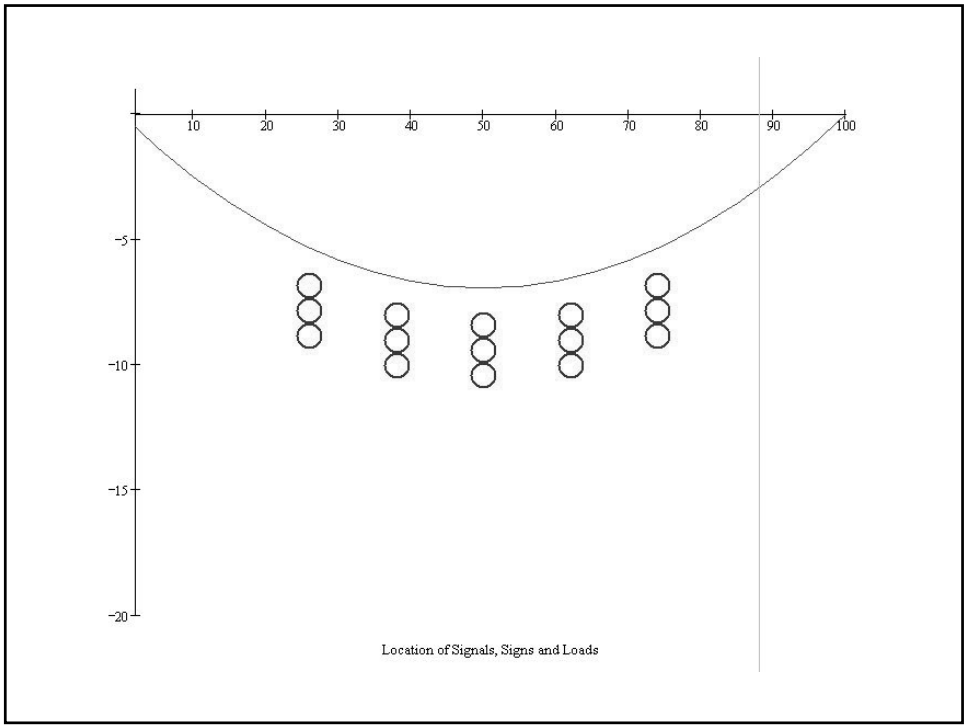
$A_{Bracket\,Cd} := 0.44 \cdot ft^2$ $Weight_{3sectBracket} := 5.3 \cdot lbf$

$Weight_{4sectBracket} := 8.1 \cdot lbf$


Mathcad - [Strain2001.mcd]
File Edit View Insert Format Tools Symbolics Window Help
Normal Arial 10
My Site Go
Input number of signals here
NoSignal :=
NoSignal_it
5
No. of Sections
Between 1 & 4
No. of Directions
Between 1 & 5
Back Plate Flag
1 with Back Plate, 0 without Back Plate
NoSec :=
NoDirection :=
BPFlag_Signal :=
Distance from Left Pole
Dist_Signal :=
ft


Mathcad - [Strain2001.mcd]
File Edit View Insert Format Tools Symbolics Window Help
Normal Arial 10
My Site Go
Sign Paramters
Number of Signs per Span
NoSign :=
NoSign_it
0
Sign Length and Depth
Length_Sign :=
Depth_Sign :=
ft
Sign Weigh and Drag Coefficient
C_d.Sign := 1.2
Weight_Sign := 3 lbf/ft^2
Distance from Left Panel


Mathcad - [Strain2001.mcd]
File Edit View Insert Format Tools Symbolics Window Help
Normal Arial 10
My Site
No. of Additional Loads
NoLoad :=
NoLoad_it
0
All load are positive and maximum 100 kips.
Long_Load :=
Trans_Load :=
Vert_Load :=
kip
Distance from left Pole
Dist_Load :=
ft


10
20
30
40
50
60
70
80
90
100
-5
-10
-15
-20
Location of Signals, Signs and Loads

Maximum of Cable load from the two end reactions

$$TTotal_0 := \max\left(Temp, fTotal\left(Te^{\langle 0 \rangle}\right), fTotal\left(Tf^{\langle 0 \rangle}\right), fTotal\left(Tg^{\langle 0 \rangle}\right), fTotal\left(Th^{\langle 0 \rangle}\right)\right) \cdot lbf$$

$$TTotal_0 = 3.365\,kip$$

$$CheckCableTension_0 := if\left(TTotal_0 \le T_{Strength_0}, "OK", "NoGood"\right)$$

$$CheckCableTension_0 = "OK"$$

Sag under Dead Load only

$$YSag_0 := \frac{\max\left(fEva(V01, A0, RNode01)_2\right) \cdot in}{Span_0}$$

$$YSag_0 = 0.073228$$

Compare to initial sag

$$Sag_0 = 0.06949$$

Maximum Moment

$$M_{Pole_0} = \begin{pmatrix} 1.073 \times 10^3 \\ 1.235 \times 10^3 \\ 874.936 \end{pmatrix} kip \cdot in$$

Maximum Shear

$$S_{Pole_0} = \begin{pmatrix} 4.426 \\ 5.912 \\ 4.245 \end{pmatrix} kip$$

Critical force direction

$$Ang_0 = \begin{pmatrix} 27.997 \\ 23.019 \\ 5.914 \end{pmatrix} deg$$

Wind Directions

X
45 degree
Z

$$M_{Pole_1} = \begin{pmatrix} 872.743 \\ 1.221 \times 10^3 \\ 1.068 \times 10^3 \end{pmatrix} kip \cdot in \qquad S_{Pole_1} = \begin{pmatrix} 4.426 \\ 5.912 \\ 4.245 \end{pmatrix} kip \qquad Ang_1 = \begin{pmatrix} 27.997 \\ 23.019 \\ 5.914 \end{pmatrix} deg$$

$$M_{Allowable_0} = \begin{pmatrix} 179.331 \\ 186.436 \\ 210.85 \end{pmatrix} kip \cdot ft \qquad M_{Allowable_1} = \begin{pmatrix} 213.145 \\ 188.692 \\ 180.069 \end{pmatrix} kip \cdot ft$$

$$CheckPoleStrength_{ip} := \begin{| count \leftarrow 0 \\ for\ \ tt \in 0..2 \\ \quad | count \leftarrow count + 1 \ \ if\ \left(M_{Allowable_{ip}}\right)_{tt} \le \left(M_{Pole_0}\right)_{tt} \\ \quad | count \leftarrow count \ \ otherwise \\ "NG" \ \ if\ \ count > 0 \\ "OK" \ \ otherwise$$

$$CheckPoleStrength = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$$

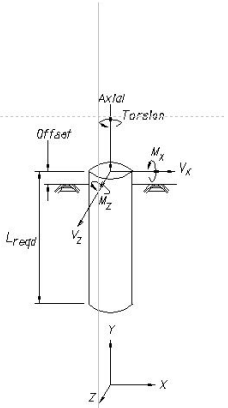
Foundation Design

A. Input (in bold)

SoilType := **1** 0 - clay 1 - sand

SoilWeight := **0.105** · $\frac{kip}{ft^3}$ ShaftDiameter := **4.0** · ft Offset := **0.5** · ft

SoilFrictionAngle := **30** · deg (sand) SoilShearStrength := **1.0** · $\frac{kip}{ft^2}$ (clay)



B. Calculate Shaft Depth Required to Resist Overturning

SF_{ot} := 2 (safety factor against overturning)

γ_{soil} := SoilWeight b := ShaftDiameter

ϕ_{soil} := SoilFrictionAngle c_{soil} := SoilShearStrength

$M_{total_{sp}} := SF_{ot} \cdot M_{Pole_{sp}}$ $P_{total_{sp}} := SF_{ot} \cdot S_{Pole_{sp}}$

$M_{total_0} = \begin{pmatrix} 178.9 \\ 205.9 \\ 145.8 \end{pmatrix}$ kip · ft $P_{total_0} = \begin{pmatrix} 8.852 \\ 11.824 \\ 8.489 \end{pmatrix}$ kip $M_{total_1} = \begin{pmatrix} 145.5 \\ 203.5 \\ 178 \end{pmatrix}$ kip · ft $P_{total_1} = \begin{pmatrix} 8.9 \\ 11.8 \\ 8.5 \end{pmatrix}$ kip

$Length_{Shaft_1} := if[(SoilType) = 1, L_{otClay_1}, L_{otSand_1}]$ $Length_{Shaft} = \begin{pmatrix} 10 \\ 10 \end{pmatrix}$ ft

Biaxial Rectangular Footer

- new Mathcad program
- LFD design check

Biaxial Rectangular Footing Program v1.0

Footing & Pedestal Dimensions:

$L_{footing} := 22 \cdot ft$	*Dimension in y direction*	$L_{footing} = 22.00\ ft$
$W_{footing} := 12 \cdot ft$	*Dimension in x direction*	$W_{footing} = 12.00\ ft$
$t_{footing} := 1.5 \cdot ft$	*Footing thickness*	$t_{footing} = 1.50\ ft$
$t_{pedestal} := 4 \cdot ft$	*Pedestal thickness*	$t_{pedestal} = 4.00\ ft$
$Diameter_{pedestal} := 4.5 \cdot ft$	*Pedestal diameter*	$Diameter_{pedestal} = 4.50\ ft$

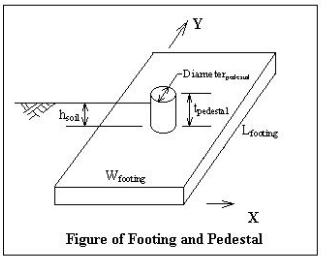


Figure of Footing and Pedestal

INPUT

Reinforcement and Concrete Properties

$f_c := 3400 \cdot psi$ $\gamma_{concrete} := 0.150 \cdot \frac{kip}{ft^3}$ $Cover := 3 \cdot in$

$f_y := 60000 \cdot psi$ $n := 7$

Soil Properties

$\gamma_{soil} := 0.105 \cdot \frac{kip}{ft^3}$ $\phi_{soil} := 30 \cdot deg$ $h_{soil} := 3.5 \cdot ft$

$h_{DepthReduction} := 3 \cdot in$ *Depth at which passive earth pressure of the soil or embankment shall be neglected*

$\mu := 0.5$ *Coefficient of Friction between bottom of slab and soil*

$\phi_{performance} := 0.65$ $q_{ult} := 6000 \cdot \frac{lbf}{ft^2}$

Applied Loads

Loads from upper sign/signal structures at center on top of pedestal. All input values must be positive.

$V_x := 6.5 \cdot kip$ $V_y := 9.1 \cdot kip$ $Torque := 413 \cdot kip \cdot ft$

$AxialForce := 8.4 \cdot kip$ $M_{x.Pedestal} := 281 \cdot kip \cdot ft$ $M_{y.Pedestal} := 98 \cdot kip \cdot ft$

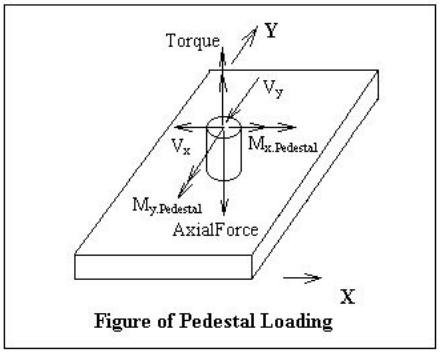


Figure of Pedestal Loading

OVERTURNING

$SF_{min.overturning} := 2$ *Factor of Safety for Overturning*

In the longitudinal direction	*In the transverse Direction*
$M_{x.Resistance} = 1853.70\,kip \cdot ft$	$My_{Resistance} = 1011.11\,kip \cdot ft$
$M_{x.Driving} = 331.05\,kip \cdot ft$	$My_{Driving} = -133.75\,kip \cdot ft$
$checkOverturning_{longitudinal} = 5.60$	$checkOverTurning_{transverse} = 7.56$
$CheckOverturning_{longitudinal} = "OK"$	$CheckOverturning_{transverse} = "OK"$

TORSIONAL CAPACITY

$SF_{min.torque} := 1.5$ *Factor of Safety for Torsional Resistance*

$checkTorque = 1.72$

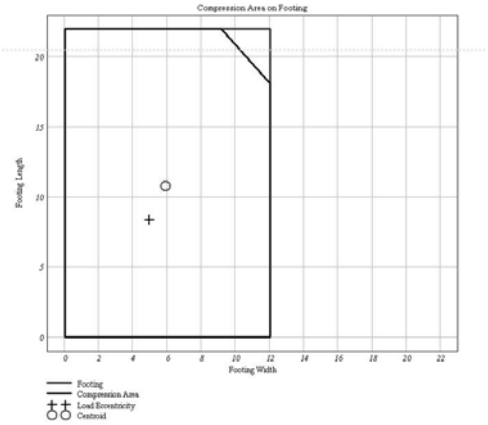
$CheckTorque = "OK"$

Compression region and Centroid

$Coord_{compression_J}$ = $\begin{pmatrix} 0.000 & 12.000 & 12.000 & 9.135 & 0.000 & 0.000 \\ 0.000 & 0.000 & 18.101 & 22.000 & 22.000 & 0.000 \end{pmatrix}$ ft $Centroid_J$ = $\begin{pmatrix} 5.8910 \\ 10.7903 \end{pmatrix}$ ft $case_J$ = 1

Maximum Compressive Pressure $\sigma max_J = 1.401164 \frac{kip}{ft^2}$

Intercepts Pressure and Location $\sigma 13_J$ = $\begin{pmatrix} 0.737 \\ 0.506 \end{pmatrix} \frac{kip}{ft^2}$ $L13_J$ = $\begin{pmatrix} 12.00 \\ 22.00 \end{pmatrix}$ ft



BEARING CAPACITY ON SOIL *(LPD 4.10.6)*

$CheckBearingCapacity_k$ = if(ϕperformance $\sigma ult \geq \sigma max_k$, "OK", "NoGood") $CheckBearingCapacity$ = $\begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$

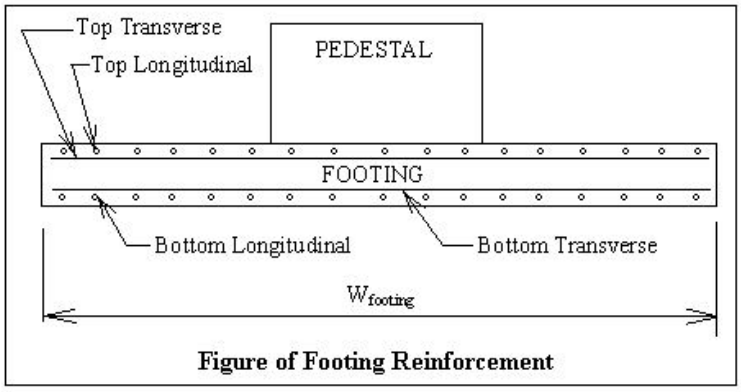


Figure of Footing Reinforcement

Design Checks

$CheckOverturning_{longitudinal} = "OK"$ $CheckOverturning_{transverse} = "OK"$ $CheckTorque = "OK"$

$CheckCase = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$ $CheckBearingCapacity = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$

$CheckBending_{longitudinal} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$ $CheckCracking_{longitudinal} = "OK"$

$CheckMinRein_{longitudinal} = "OK"$ $CheckMinReinforcement_{longitudinal} = "OK"$

$CheckMaxReinforcement_{longitudinal} = "OK"$

$CheckUplift_{longitudinal} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$ $CheckCracking_{top.longitudinal} = "OK"$

$CheckMinRein_{top.longitudinal} = "OK"$ $CheckMinReinforcement_{top.longitudinal} = "OK"$

$CheckMaxReinforcement_{top.longitudinal} = "OK"$

$CheckBending_{transverse} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$ $CheckCracking_{transverse} = "OK"$

$CheckMinRein_{transverse} = "OK"$ $CheckMinReinforcement_{transverse} = "OK"$

$CheckMaxReinforcement_{transverse} = "OK"$

$CheckUplift_{transverse} = "OK"$ $CheckCracking_{top.transverse} = "OK"$

$CheckMinRein_{top.transverse} = "OK"$ $CheckMinReinforcement_{top.transverse} = "OK"$

$CheckMaxReinforcement_{top.transverse} = "OK"$

$CheckOneWayShear_{longitudinal} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$ $CheckOneWayShear_{transverse} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$ $CheckTwoWayShear = "OK"$

$CheckPedMaxiumShearStirupSpacing = "OK"$ $CheckPedShearStirupStrength = "OK"$

$CheckPedMaxStirupStrength = "OK"$

$CheckPedTorsionStrength = "OK"$ $CheckPedMaximumTorsionStirupSpacing = "OK"$

$CheckPedMinimumStirupArea = "OK"$

$CheckPedLongitudinalReinforcement = "OK"$ $CheckPedLongitudinalMinimum = "OK"$

$CheckPedLongitudinalDiameter = "OK"$

Biaxial Rectangular Footer

- checks Overturning and Torsion
- checks soil bearing capacity
- LFD check for slab and pedestal