Cardno
TBE

Cortez Road West at 86th Street Improvements

Structures
Mast Arms Design Documentation

Prepared For

Manatee County,
Florida

December, 2012

Section 1: Table of Contents

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Manatee County, Florida

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Section 2: Design Criteria

Post sizes for single column signs are covered in the ***Design Standards***. The supports for multicolumn signs are not in that reference and must be included in the plans. The designer must provide post sizes and lengths for multicolumn signs. The Structures Design Office has written a program for personal computers that calculates post sizes and lengths for multicolumn signs. This program may be used for these calculations.

Locations and attachments of signs on bridge structures shall be coordinated with the bridge structural designer. Details for signs mounted to bridge structures shall be included in the plans. See ***Structures Design Guidelines***, Section 1.9 for details of and restrictions related to making attachments to bridges.

The design for all overhead sign structures and foundations shall be included in the plans. Refer to ***Section 7.6***, ***Foundation Design***, and ***Chapter 29*** of this volume for more information.

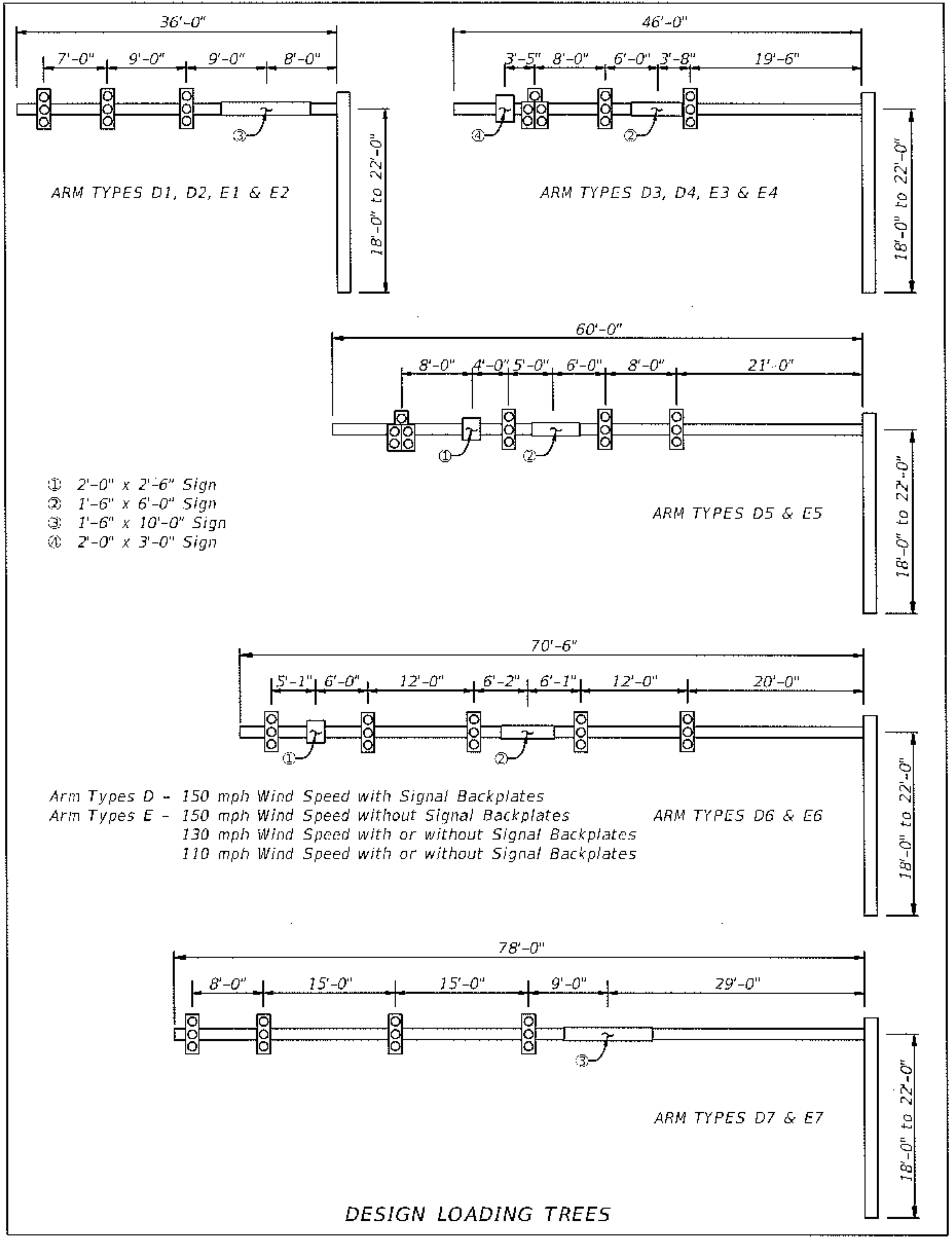
The designer shall determine the lighting requirements for all overhead signs. Only induction lighting fixtures shall be utilized for sign lighting unless otherwise specified. The sign lighting requirements shall be shown in the plans on the Guide Sign Worksheet for each sign. Sign lighting calculations shall be included in the Lighting Design Analysis Report.

7.2.2 Wind Loading Criteria - Signs

The wind loadings given below are based on the ***AASHTO Standard Specification For Structural Supports for Highway Signs, Luminaires and Traffic Signals*** and ***FDOT Structures Manual.*** The Counties are listed by wind loading for the appropriate sign type.

110 mph	Alachua, Baker, Bradford, Clay, Columbia, Gadsden, Gilchrist, Hamilton, Hardee, Jackson, Jefferson, Lafayette, Lake, Leon, Madison, Marion, Polk, Putnam, Sumter, Suwannee, and Union
130 mph	Bay, Brevard, Calhoun, Charlotte, Citrus, DeSoto, Dixie, Duval, Flagler, Franklin, Glades, Gulf, Hendry, Hernando, Highlands, Hillsborough, Holmes, Lee, Levy, Liberty, Manatee, Nassau, Okaloosa, Okeechobee, Orange, Osceola, Pasco, Pinellas, Sarasota, Seminole, St. Johns, Taylor, Volusia, Wakulla, Walton, and Washington.
150 mph	Broward, Collier, Miami-Dade, Escambia, Indian River, Martin, Monroe, Palm Beach, Santa Rosa, and St. Lucie

Figure 1



① 2'-0" x 2'-6" Sign
② 1'-6" x 6'-0" Sign
③ 1'-6" x 10'-0" Sign
④ 2'-0" x 3'-0" Sign

Arm Types D - 150 mph Wind Speed with Signal Backplates
Arm Types E - 150 mph Wind Speed without Signal Backplates
130 mph Wind Speed with or without Signal Backplates
110 mph Wind Speed with or without Signal Backplates

DESIGN LOADING TREES

POLE SELECTION TABLE - SINGLE ARM - WITH & WITHOUT LUMINAIRE					
ARM TYPE	D1	D3	D5	D6	D7
POLE TYPE	S1 & S21 Lum	S2 & S22 Lum	S3 & S23 Lum	S4 & S24 Lum	S6

POLE SELECTION TABLE - DOUBLE ARM - WITHOUT LUMINAIRE										
ARM TYPE	D1 - D1	D3 - D1	D5 - D2	D6 - D2	D4 - D4	D5 - D4	D6 - D4	D5 - D5	D6 - D5	D6 - D6
POLE TYPE	S1	S2	S3	S4	S3	S4	S4	S4	S4	S5

Arm 1 is listed first

ARM DESIGN TABLE - ALL CASES												
ARM TYPE	ARM LENGTH	MAST ARM				ARM EXTENSION				ARM CONNECTION & WELDS		
		FA/SA (ft)	FB/SB (in)	FC/SC (in)	FD/SD (in)	FE/SE (ft)	FF/SF (in)	FG/SG (in)	FH/SH (in)	HT (in)	FJ/SJ (in)	FK/SK (in)
D1	36'-0"	36	8.96	14	0.1793					20	25	2.5
D2	36'-0"	36	8.96	14	0.1793					30	36	3
D3	46'-0"	36.3	8.92	14	0.1793	11.7	13.36	15	0.313	20	25	2.5
D4	46'-0"	36.3	8.92	14	0.1793	11.7	13.36	15	0.313	30	36	3
D5	60'-0"	36	7.96	13	0.1793	26	12.36	16	0.375	30	36	3
D6	70'-6"	39.4	9.49	15	0.1793	33.1	14.37	19	0.375	30	36	3
D7	78'-0"	40	8.44	14	0.1793	40	13.40	19	0.375	30	34	3

Arm Camber Angle = 2 degrees

POLE, CONNECTION AND SHAFT DESIGN TABLE - SINGLE & DOUBLE ARM																										
POLE TYPE	UA (ft)	UC (in)	UD (in)	UE (in)	UG (ft)	UPRIGHT BASE CONNECTION					CONNECTION PLATE DATA									DRILLED SHAFT DATA					
						No. Bolts	BA (in)	BB (in)	BC (in)	BF (in)	HT (in)	FJ/SJ (in)	FL/SL (in)	FN/SN (in)	FO/SO (in)	FP/SP (in)	FR/SR (in)	FS/SS (in)	FT/ST (in)	DA (ft)	DB (ft)	RA	RB	RC	RD (in)
S1	24	12.64	16	0.375		6	30	2.5	1.75	36	20	25	0.75	0.438	15.5	1	2	8	0.438	12	4	11	14	9	12
S2	24	14.64	18	0.375		6	32	2.5	1.75	36	20	25	0.75	0.438	15.5	1	2	8	0.438	12	4.5	11	16	9	12
S3	24	17.64	21	0.375		6	37	2.5	2	40	30	36	0.75	0.438	22	1.25	2.5	12.5	0.438	15	4.5	11	16	10	8
S4	24	22.64	26	0.375		6	42	2.5	2	40	30	36	0.75	0.438	22	1.25	2	12.5	0.438	17	5	11	18	10	8
S5	24	23.64	27	0.375		6	45	2.5	2.25	45	30	36	0.75	0.438	22	1.25	2	12.5	0.438	18	5	11	18	10	8
S6	24	21.64	25	0.375		6	41	2.5	2	40	30	34	0.75	0.5	16.5	1.25	2	12.5	0.5	15	5	11	18	10	8
S21 Lum	39	10.54	16	0.375	37.5	6	30	2.5	1.75	40	20	25	0.75	0.438	11.5	1	2	8	0.438	12	4	11	14	9	12
S22 Lum	39	12.54	18	0.375	37.5	6	32	2.5	1.75	40	20	25	0.75	0.438	12.5	1	2	8	0.438	12	4.5	11	16	9	12
S23 Lum	39	15.54	21	0.375	37.5	6	37	2.5	2	40	30	36	0.75	0.438	15	1.25	2.5	12.5	0.438	14	4.5	11	16	10	8
S24 Lum	39	20.54	26	0.375	37.5	6	42	2.5	2	40	30	36	0.75	0.438	17	1.25	2	12.5	0.438	15	5	11	18	10	8

LUMINAIRE AND LUMINAIRE CONNECTION											
LA (ft)	LB (ft)	LC (in)	LD (in)	LE	LF (ft)	LG (in)	LH (in)	LJ (in)	LK (in)	LL (deg)	UG (ft)
40	10	3	0.125	0.5	8	0.5	0.75	0.25	0.25	0	37.5

Notes:
1. Work this Index with Index No. 17745.
2. Design Wind Speed = 150 mph with Signal Backplates.

"D" MAST ARMS

LAST REVISION	REVISION	DESCRIPTION:	FDOT DESIGN STANDARDS 2013	STANDARD MAST ARM ASSEMBLIES	INDEX NO.	SHEET NO.
01/01/12					17743	1

POLE SELECTION TABLE - SINGLE ARM - WITH & WITHOUT LUMINAIRE

ARM TYPE	E1	E3	E5	E6	E7
POLE TYPE	T1 & T21 Lum	T2 & T22 Lum	T3 & T23 Lum	T4 & T24 Lum	T6

POLE SELECTION TABLE - DOUBLE ARM - WITHOUT LUMINAIRE

ARM TYPE	E1 - E1	E3 - E1	E5 - E2	E6 - E2	E4 - E4	E5 - E4	E6 - E4	E5 - E5	E6 - E5	E6 - E6
POLE TYPE	T1	T2	T3	T4	T3	T4	T4	T4	T4	T5

Arm 1 is listed first

ARM DESIGN TABLE - ALL CASES

ARM TYPE	ARM LENGTH	MAST ARM				ARM EXTENSION				ARM CONNECTION & WELDS		
		FA/SA (ft)	FB/SB (in)	FC/SC (in)	FD/SD (in)	FE/SE (ft)	FF/SF (in)	FG/SG (in)	FH/SH (in)	HT (in)	FJ/SJ (in)	FK/SK (in)
E1	36'-0"	36.0	5.96	11	0.25					22	23	2
E2	36'-0"	36.0	5.96	11	0.25					30	32	2.75
E3	46'-0"	36.3	7.06	12.14	0.25	11.7	11.36	13	0.313	22	23	2
E4	46'-0"	36.3	7.06	12.14	0.25	11.7	11.36	13	0.313	30	32	2.75
E5	60'-0"	36.0	6.10	11.14	0.25	26	10.36	14	0.375	30	32	2.75
E6	70'-6"	39.4	6.63	12.15	0.25	33.1	11.37	16	0.375	30	32	2.75
E7	78'-0"	40.0	7.50	13.10	0.1793	40	12.40	18	0.375	30	32	2.5

Arm Camber Angle = 2 degrees

POLE, CONNECTION AND SHAFT DESIGN TABLE - SINGLE & DOUBLE ARM

POLE TYPE	UA (ft)	UC (in)	UD (in)	UE (in)	UG (ft)	UPRIGHT BASE CONNECTION					CONNECTION PLATE DATA									DRILLED SHAFT DATA					
						No. Bolts	BA (in)	BB (in)	BC (in)	BF (in)	HT (in)	FJ/SJ (in)	FL/SL (in)	FN/SN (in)	FO/SO (in)	FP/SP (in)	FR/SR (in)	FS/SS (in)	FT/ST (in)	DA (ft)	DB (ft)	RA	RB	RC	RD (in)
T1	24	10.64	14	0.375		6	26	2.5	1.5	36	22	23	0.5	0.375	14	1	2.0	9	0.375	11	4	11	14	8	12
T2	24	12.64	16	0.375		6	28	2.5	1.5	36	22	23	0.5	0.375	14	1	2.0	9	0.375	12	4	11	14	9	12
T3	24	15.64	19	0.375		6	35	2.5	2	40	30	32	0.75	0.375	19.5	1.25	2.25	12.5	0.375	12	4.5	11	16	9	12
T4	24	18.64	22	0.5		6	38	2.5	2	40	30	32	0.75	0.375	19.5	1.25	2.0	12.5	0.375	15	4.5	11	16	10	8
T5	24	18.64	22	0.5		6	38	2.5	2	40	30	32	0.75	0.375	19.5	1.25	2.0	12.5	0.375	16	4.5	11	16	10	8
T6	24	18.64	22	0.375		6	38	2.5	2	40	30	32	0.75	0.438	15	1.25	2.0	12.5	0.438	14	4.5	11	16	10	8
T21 Lum	39	8.54	14	0.375	37.5	6	26	2.5	1.5	40	22	23	0.5	0.375	10	1	2.0	9	0.375	11	4	11	14	8	12
T22 Lum	39	10.54	16	0.375	37.5	6	30	2.5	1.75	40	22	23	0.5	0.375	11	1	2.0	9	0.375	12	4	11	14	9	12
T23 Lum	39	13.54	19	0.375	37.5	6	35	2.5	2	40	30	32	0.75	0.375	13	1.25	2.25	12.5	0.375	12	4.5	11	16	9	12
T24 Lum	39	16.54	22	0.375	37.5	6	38	2.5	2	40	30	32	0.75	0.375	15	1.25	2.0	12.5	0.375	14	4.5	11	16	10	12

LUMINAIRE AND LUMINAIRE CONNECTION

LA (ft)	LB (ft)	LC (in)	LD (in)	LE	LF (ft)	LG (in)	LH (in)	LJ (in)	LK (in)	LL (deg)	UG (ft)
40	10	3	0.125	0.5	8	0.5	0.75	0.25	0.25	0	37.5

Notes:
1. Work this Index with Index No. 17745.
2. Design Wind Speed = 150 mph without Signal Backplates.
130 mph with or without Signal Backplates.
110 mph with or without Signal Backplates.

"E" MAST ARMS

LAST REVISION	REVISION	DESCRIPTION:	FDOT DESIGN STANDARDS 2013	STANDARD MAST ARM ASSEMBLIES	INDEX NO.	SHEET NO.
01/01/12					17743	2

29.4 Traffic Signal Structures

29.4.1 General

Mast Arm Assemblies may be Standard Mast Arm Signal Structures, Standard Mast Arms for Site-Specific Loadings or Custom Designs.

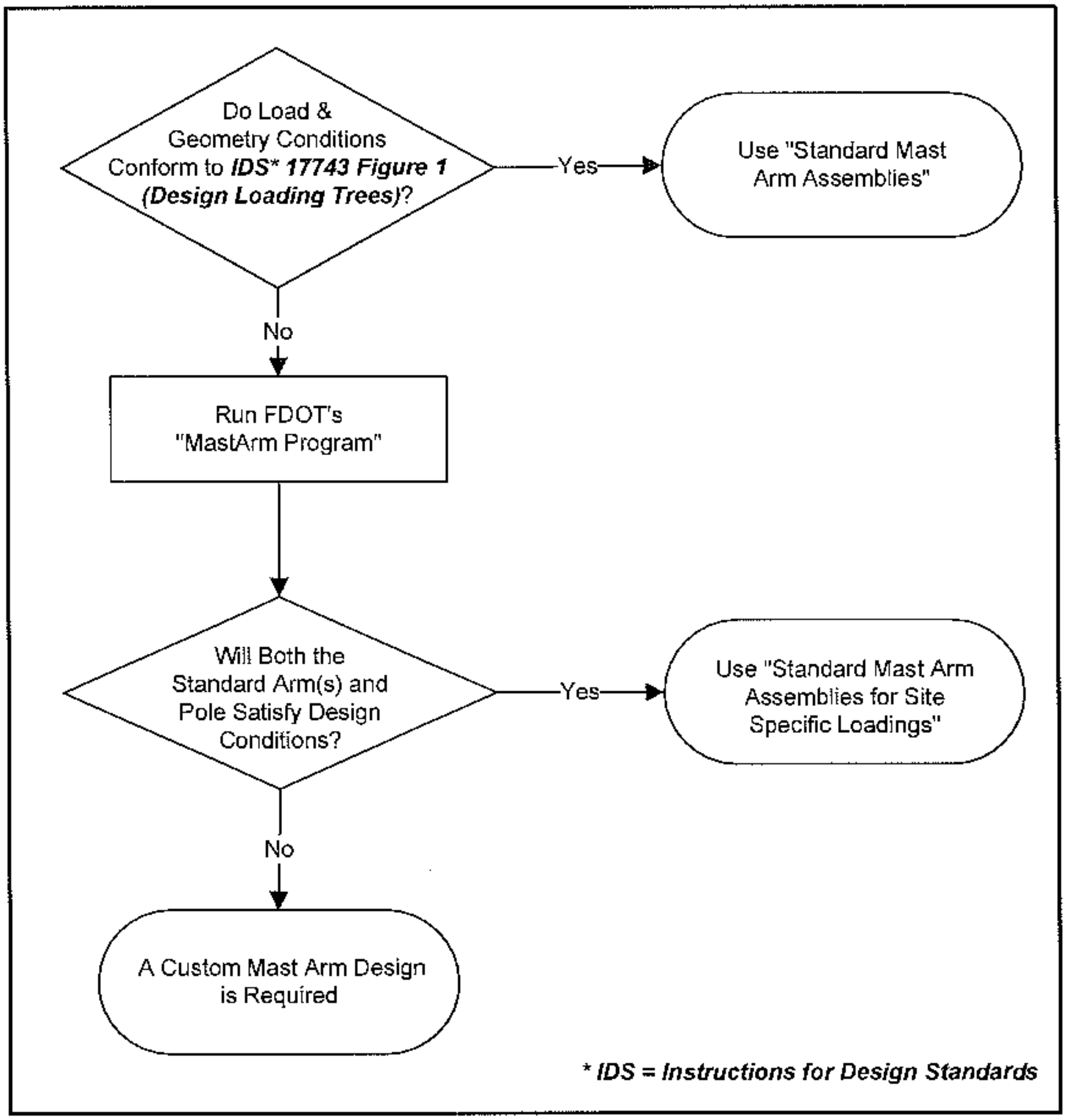
29.4.2 Mast Arm Signal Structures

Design all mast arm traffic signal assemblies with backplates in accordance with ***Section 7.4.17***.

Utilize the Flowchart in ***Figure 29.1*** to determine which type of Mast Arm design is suitable for the particular application.

Refer to ***Design Standards, Indexes 17743***, ***17745*** and their ***Instructions***.

Figure 29.1 Flowchart for Designing and Detailing Mast Arm Assemblies



Index 17743 Standard Mast Arm "D" & "E" Assemblies (Rev. 07/12)

Design Criteria

AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, 5th Edition (LTS-5); ***Structures Manual*** Volume 9, FDOT Modifications to LTS-5; ***Structures Manual*** Introduction, I.6 References.

Design Assumptions and Limitations

The maximum span length of Standard Mast Arm Assemblies is 78 feet. See the ***PPM***, Volume 1, Chapter 29 for additional information.

See notes on the ***Design Standard*** and ***Structures Manual*** Volume 9.

Design all mast arm traffic signal assemblies with backplates in accordance with the ***PPM***, Volume 1, Section 7.4.17

Standard mast arm assemblies must comply with all the requirements and design criteria shown on ***Design Standards*** Index 17745.

Standard Mast Arm Assemblies: Mast arms that utilize all pre-designed components for the selected Load Trees shown in Figure 1.

Standard Mast Arm assemblies are limited to 110,130 or 150 mph design wind speeds with one of the load tree configurations shown in Figure 1, and either single arm, single arm with luminaire, or double arms with arm orientations of 90° or 270° only.

Foundations and base plates for standard mast arm assemblies are pre-designed based on the following soil criteria:

Classification:	Cohesionless (Fine Sand)
Friction Angle:	30 Degrees
Unit Weight:	50 lbs./cubic foot (assumed submerged)

When the designer considers soil types at the specific site location to be of lesser strength properties than shown above, an analysis is required. Auger borings, SPT borings, or CPT soundings may be used as needed to verify the assumed soil properties, and at sites confirmed to be uniform, a single boring or sounding may cover several foundations. Borings in the area that were performed for other purposes may be used to confirm the assumed soil properties. Unique site circumstances may require the foundation variables to be modified from those shown on Index 17743. Accomplish this by completing the "Special Drilled Shaft Data" in the "Standard Mast Arm Assemblies Data Table". The Geotechnical Engineer must justify the differing foundation criteria to the District Structures Design Engineer during the design phase of the project.

To use standard mast arm assemblies:

1. Confirm that the information furnished by the signal designer in the "Mast Arm Tabulation Sheet" meets the geometric and load tree limitations shown in Figure 1.
2. Follow the procedure described in the design examples in the ***PPM***, Volume 2, Chapter 24, complete the necessary information required in the "Standard Mast Arm Assemblies Data Table" and include in the Traffic Plans.

Standard Mast Arm Assemblies for Site-Specific Loadings: Mast arms for unique loadings but which utilize all pre-designed components.

The FDOT Mast Arm Program will select component parts from those shown on Index 17743 for site specific load configurations differing from those shown in Figure 1.

In order to be eligible for utilization of pre-designed component parts, the mast arm assemblies must utilize only arms and poles from the components listed in the tables on Index 17743. As for standard mast arm assemblies, the foundation design is included with the pole selection and needs no further information.

Design and detail standard mast arm assemblies utilizing pre-designed component parts in the plans in the same manner as for standard mast arm assemblies by use of the "Standard Mast Arm Assemblies Data Table" cell. Similarly, because all pre-designed component parts are used, shop drawings are not required.

Plan Content Requirements

The signal designer completes the Mast Arm Tabulation Sheets, and the structures designer completes the Standard Mast Arm Assemblies Data Table, both of which will be included in the plans. These are the only plan sheets required for mast arm assemblies which meet the Department's Standard. The structures data table may be placed on a signal plan sheet, if space permits. Mast arm assemblies that do not meet the mast arm standard will require a special design (See Index 17745). See Introduction I.3 for more information regarding use of Data Tables.

The following instructions are for use with the Mast Arm Tabulation Sheets:

1. Each mast arm assembly is identified by a unique ID number.
2. Dimensions 1-5 are for signals and dimensions A-E are for signs. Record the distance from the edge of the pole, at ground level, to the center of the signal or sign.
3. Signals may be mounted vertically or horizontally. Indicate the mounting in the appropriate column in the table.
4. The entire line for arm #2 and the space for the angle between dual arms are left blank for single arm assemblies.
5. All arms and poles will be galvanized. If a color is required, indicate the color in the table, otherwise leave blank.
6. Starting at the pole, select the signals and/or signs that match the configuration you are tabulating. The spaces representing the signs or signals not used will be blank. Example 1: If no sign is located between the pole and signal 1, the spaces for Sign A would be blank. Example 2: A configuration for three signals and one sign between signal 1 and signal 2 - Only the spaces for signals 1, 2, 3 and sign B would be completed; the others will be blank.
7. Record the number of sections in each signal head in the space following the distance to that head.
8. Record the height and width of each sign in the space following the distance to the sign.
9. When double arm poles are used for a skewed intersection, the standard design should be used whenever possible. The standard orientation for arm #2 is 90 or 270 degrees measured in a counter clockwise direction from arm #1. The normal orientation of the mast arm is perpendicular to the roadway. Adjustments in mounting hardware can compensate for a skew angle of approximately 15 degrees or more from the normal, depending upon the attachment method. The designer should verify the mounting hardware capability before specifying an arm with a skew greater than 15 degrees.
10. The arm mounting height should be calculated to provide a minimum vertical clearance of 17'-6" from the roadway crown elevation to the lowest sign or signal. A standard signal section is approximately 14" square. Therefore the length of a 3-section head is about 42" and a 5-section is about 70". The use of back plates will add about 6" to each side of the signal head. Additionally, approximately 3" should be added to the end of the signal head to compensate for the attachment hardware. The

designer should coordinate with the maintaining agency to insure the signal assembly and all appropriate hardware has been considered in determining the vertical clearance. The maintaining agency can also provide guidance on the vertical or horizontal mounting of the signal assemblies. This information may be used to determine the arm mounting height.

11. The standard handhole location is 180 degrees from arm #1. Other handhole locations must be noted in the Special Instructions.
12. A free swinging internally illuminated street name sign may be attached to the Upright by an independent bracket arm if the sign area does not exceed 18 square feet and weigh more than 144 pounds. The Structures Design Engineer must review other signs attached to the pole or any size sign of this type attached to the signal mast arm.
13. The "Special Instructions" Table is used to tabulate pedestrian buttons and pedestrian signal locations and handhole locations when the handholes are not in the standard location. Tabulate the ID No. and the orientation of the pedestrian buttons and signals in degrees measured counter clockwise from arm #1. The handhole location should be left blank if the handhole is in the standard location (see note 11).
14. Arm #1 is the arm for a single arm assembly or the longer arm for a double arm assembly. If the arms are equal length, arm #1 is over the project roadway.

STANDARD MAST ARM ASSEMBLIES DATA TABLE

Table Date 01-01-12

STRUCTURE ID NUMBERS	ASSEMBLY NUMBERS (1)	FIRST ARM			SECOND ARM			UF (deg)	UL (deg)	POLE				SPECIAL DRILLED SHAFT (4)					
		ARM TYPE	FAA(2) (ft.)	FBA(2) (in.)	ARM TYPE	FAA(2) (ft.)	FBA(2) (in.)			POLE TYPE	UAA(3) (ft.)	UB (ft.)	UCA(3) (in.)	DA (ft.)	DB (ft.)	RA	RB	RC	RD (in.)

TABLE NOTES:

1. Assembly Number Legend

   Single Arm:
   Arm Type - Pole Type = D# - S#
   = E# - T#

   Double Arm:
   First Arm Type - Second Arm Type - Pole Type = D# - D# - S#
   = E# - E# - T#

2. If an entry appears in columns "FAA" and "FBA", a shorter arm is required. This is obtained by removing length from the arm tip. For those cases the mast arm length shall be shortened from "FA" to "FAA" and the tip diameter shall be increased from "FB" to "FBA".

3. If an entry appears in columns "UAA" and "UCA", a shorter pole is required. This is obtained by removing length from the pole tip. For these cases the pole height shall be shortened from "UA" to "UAA" and the pole tip diameter shall be increased from "UC" to "UCA".

4. The foundations for Standard Mast Arm Assemblies are pre-designed and are based upon the following conservative soil criteria which covers the great majority of soil types found in Florida. Only complete the "Special Drilled Shaft" data information if site conditions dictate drilled shafts with additional foundation capacity.

   Classification = Cohesionless (Fine Sand)
   Friction Angle = 30 Degrees (30°)
   Unit Weight = 50 lbs. / cu. ft. (assumed saturated)

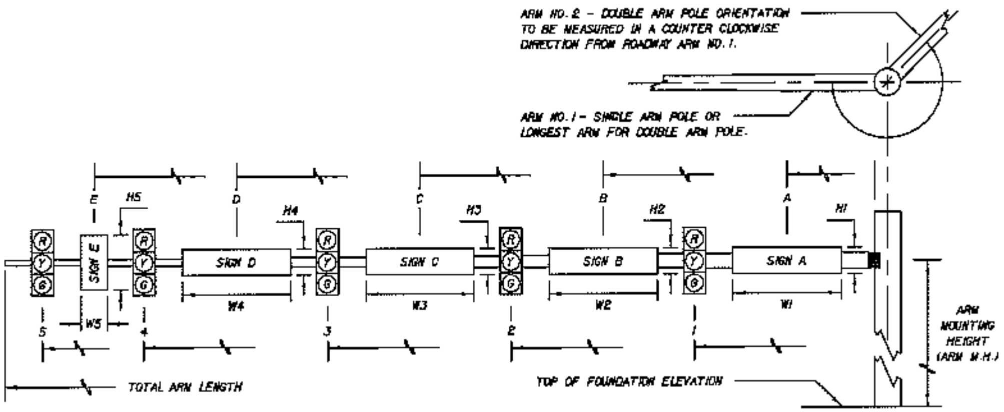
GENERAL NOTES:

1. Work this sheet with the Signal Designer's "Mast Arm Tabulation". See "Mast Arm Tabulation" for special instructions that include non standard Handhole location, paint color, terminal compartment requirement, and pedestrian features.

2. Work with Index Nos. 17743 and 17745.

Mast Arm Tabulation Sheet 1 of 2

SPECIAL INSTRUCTIONS					
ID NO.	PED. BUTTON		PED. SIGNALS		MANHOLE LOCATION



* DENOTES NUMBER OF SECTIONS IN SIGNAL HEAD ASSEMBLY

ID NO.	SHEET NO.	LOCATION BY STA.	TOP OF FOUNDATION ELEVATION	RDWY ARM NO.	CROWN ELEV.	SIGNAL DATA													TOTAL ARM LENGTH	ARM M.H.	∠ BETWEEN DUAL ARMS 90/270	SIGN DATA															PAINT COLOR
						SIGNAL Y/N	BACK PLATES Y/N	PED. SIGNAL Y/N	DISTANCE FROM POLE													DISTANCE FROM POLE / HEIGHT AND WIDTH OF SIGN															
									1	*	2	*	3	*	4	*	5	*				A	H1	W1	B	H2	W2	C	H3	W3	D	H4	W4	E	H5	W5	
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Mast Arm Tabulation Sheet 2 of 2

* DENOTES NUMBER OF SECTIONS IN SIGNAL HEAD ASSEMBLY

						SIGNAL DATA																SIGN DATA															
ID NO.	SHEET NO.	LOCATION OF STA.	TOP OF FOUNDATION ELEVATION	MAST ARM NO.	CROWN ELEV.	SIGNAL V/H	BACK PLATES Y/N	PED. SIGNAL Y/N	DISTANCE FROM POLE										TOTAL ARM LENGTH	ARM M.H.	∠ BETWEEN DUAL ARMS 90/270	DISTANCE FROM POLE / HEIGHT AND WIDTH OF SIGN															PAINT COLOR
									1	*	2	*	3	*	4	*	5	*				A	H1	W1	B	H2	W2	C	H3	W3	D	H4	W4	E	H5	W5	
				1																																	
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SPECIAL INSTRUCTIONS					
ID NO.	PED. BUTTON		PED. SIGNALS		HANDHOLE LOCATION

SPECIAL INSTRUCTIONS					
ID NO.	PED. BUTTON		PED. SIGNALS		HANDHOLE LOCATION

SPECIAL INSTRUCTIONS					
ID NO.	PED. BUTTON		PED. SIGNALS		HANDHOLE LOCATION

SPECIAL INSTRUCTIONS					
ID NO.	PED. BUTTON		PED. SIGNALS		HANDHOLE LOCATION

Payment

Item number	Item description	Unit Measure
649-3A-BCC	Steel Mast Arm Assembly	EA

Examples

Following are examples for use with the Standard Mast Arm Assemblies Data Table:

EXAMPLE 1

1. Select Arm Type.

   Investigate Arm E1. Compare attachment sizes and locations with design loading tree in Figure 1. All signals and signs are no further from the pole than shown in the Arm E1 design loading tree. Select Arm Type E1.

2. Select Pole Type.

   Use Pole Selection Tables in Index 17743 of the ***Design Standards***. Select Pole Type T1.

3. Determine Arm Mounting Height.

   UB + 10' = 12.5' + 17.5'min. + 2'
   UB = 22'min.   Use 22'

EXAMPLE 2

1. Select First Arm Type.

   Designate longest arm as First Arm. For 52' arm, investigate Arm D5. Compare attachment sizes and locations with design loading tree. All signals and signs are no larger than and are no further from the pole than shown in the Arm D5 design loading tree. Select Arm Type D5.

2. Specify shorter arm.

   Enter 28' under FAA.
   FAA + FE - Splice = 28' + 26' - 2' = 52'
   Determine actual tip diameter.
   FBA = FB + (60' - 52') x taper = 7.96" + 8' (0.14"/ft) = 9.08"

3. Select Second Arm Type.

   Select Arm Type D2.

4. Enter angle between arms.

   Angle UF is measured counter-clockwise from the First Arm and must be either 90° or 270°.

5. Select Pole Type.

   Use Pole Selection Tables. Select Pole Type S3.

6. Determine Arm Mounting Height.

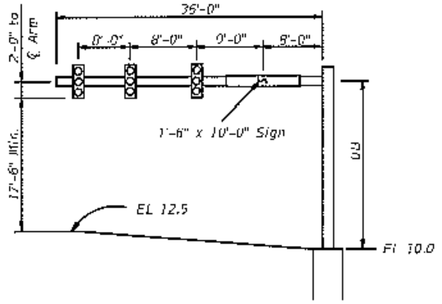
   UB + 10' = 9.5' + 17.5'min. + 2'
   UB = 19' min. Use 20'

7. Specify shorter pole.

   Enter 22' under UAA.
   Determine actual tip diameter.
   UCA = UC + (24' - 22') x taper = 17.64" + 2' (0.14"/ft) = 17.92"

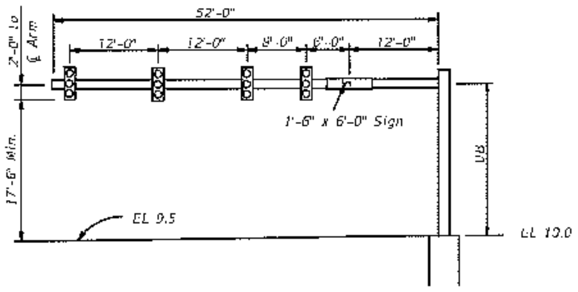
EXAMPLE 1

Single Arm Structure as shown,
110 mph Wind Speed with Signal Backplates.



EXAMPLE 2

First Arm Structure as shown, Second Arm same as Example 1
except 150 mph Wind Speed with Signal Backplates.



STANDARD MAST ARM ASSEMBLIES DATA TABLE

Table Date 01-01-12

STRUCTURE ID NUMBERS	ASSEMBLY NUMBERS (1)	FIRST ARM			SECOND ARM			UF (deg)	LL (deg)	POLE				SPECIAL DRILLED SHAFT (4)					
		ARM TYPE	FAA(2) (ft.)	FBA(2) (in.)	ARM TYPE	FAA(2) (ft.)	FBA(2) (in.)			POLE TYPE	UAA(3) (ft.)	UB (ft.)	UCA(3) (in.)	DA (ft.)	DB (ft.)	RA	RB	RC	RD (in.)
Example 1	E1 - T1	E1								T1		22							
Example 2	D5 - D2 - S3	D5	28	9.08	D2			270		S3	22	20	17.92						

TABLE NOTES:

1. Assembly Number Legend

Single Arm:
Arm Type - Pole Type = D# - S#
= E# - T#

Double Arm:
First Arm Type - Second Arm Type - Pole Type = D# - D# - S#
= E# - E# - T#

2. If an entry appears in columns "FAA" and "FBA", a shorter arm is required. This is obtained by removing length from the arm tip. For these cases the mast arm length shall be shortened from "FA" to "FAA" and the tip diameter shall be increased from "FB" to "FBA".

TABLE NOTES (CONT.):

3. If an entry appears in columns "UAA" and "UCA", a shorter pole is required. This is obtained by removing length from the pole tip. For these cases the pole height shall be shortened from "UA" to "UAA" and the pole tip diameter shall be increased from "UC" to "UCA".

4. The foundations for Standard Mast Arm Assemblies are pre designed and are based upon the following conservative soil criteria which covers the great majority of soil types found in Florida. Only complete the "Special Drilled Shaft" data information if site conditions dictate drilled shafts with additional foundation capacity.

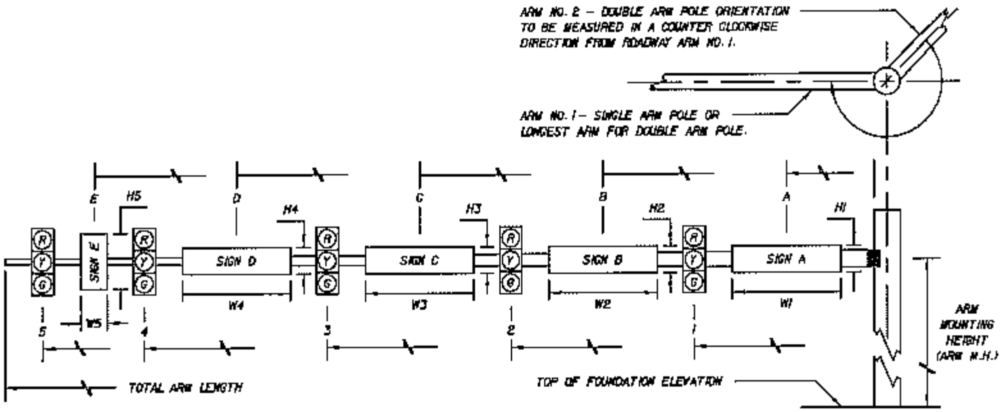
Classification= Cohesionless (Fine Sand)
Friction Angle= 30 Degrees (30°)
Unit Weight= 50 lbs. / cu. ft. (assumed saturated)

GENERAL NOTES:

1. Work this sheet with the Signal Designer's "Mast Arm Tabulation". See "Mast Arm Tabulation" for special instructions that include non-standard Handhole location, paint color, terminal compartment requirement, and pedestrian features.

2. Work with Index Nos. 17743 and 17745.

SPECIAL INSTRUCTIONS			
ID NO.	PED. BUTTON	PED. SIGNALS	HANDHOLE LOCATION



* DENOTES NUMBER OF SECTIONS IN SIGNAL HEAD ASSEMBLY

						SIGNAL DATA																	SIGN DATA														
									DISTANCE FROM POLE													DISTANCE FROM POLE / HEIGHT AND WIDTH OF SIGN															
ID NO.	SHEET NO.	LOCATION BY STA.	TOP OF FOUNDATION ELEVATION	RDWY ARM NO.	CROWN ELEV.	SIGNAL V/H	BACK PLATES Y/N	PED. SIGNAL Y/N	1	*	2	*	3	*	4	*	5	*	TOTAL ARM LENGTH	ARM M.H.	∠ BETWEEN DUAL ARMS 90/270	A	H1	W1	B	H2	W2	C	H3	W3	D	H4	W4	E	H5	W5	PAINT COLOR
1	T-4	EXAMPLE 1	10.0	1	12.5	V	Y		17.0	3	25.0	3	33.0	3					36.0	22.0		8.0	1.5	10.0													
				2																																	
2	T-5	EXAMPLE 2	10.0	1	9.5	V	Y		16.0	3	26.0	3	38.0	3	50.0	3			52.0	22.0	270	12.0	1.5	6.0													
				2	12.5	V	Y		17.0	3	25.0	3	33.0	3					36.0	22.0		8.0	1.5	10.0													
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Index 17745 Mast Arm Assemblies (Rev. 07/12)

Design Criteria

AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals, 5th Edition (LTS-5); ***Structures Manual*** Volume 9, FDOT Modifications to LTS-5; ***Structures Manual*** Introduction, I.6 References.

Design Assumptions and Limitations

See notes on the ***Design Standard*** and ***Structures Manual*** Volume 9.

See the ***PPM***, Volume 1, Chapter 29 for additional information.

Design all mast arm traffic signal assemblies with backplates in accordance with the ***PPM***, Volume 1, Chapter 7.

Custom Mast Arm Designs: Special Mast arms for unique loadings and/or geometric constraints that contain any component (arm or pole) that is outside the range of those in Index 17743.

The FDOT Mast Arm Program will provide the necessary variables to be shown in the "Special Mast Arm Assemblies Data Table" cell from the FDOT CADD Menu.

Plan Content Requirements

The signal designer completes the Mast Arm Tabulation Sheet, and the structures designer completes the Special Mast Arm Assemblies Data Table, both of which will be included in the plans. These are the only plan sheets required for mast arm assemblies which meet the Department's Standard. The structures data table may be placed on a signal plan sheet, if space permits. See Introduction I.3 for more information regarding use of Data Tables.

The following instructions are for use with the Mast Arm Tabulation Sheet:

1. Each mast arm assembly is identified by a unique ID number.
2. Dimensions 1-5 are for signals and dimensions A-E are for signs. Record the distance from the edge of the pole, at ground level, to the center of the signal or sign.
3. Signals may be mounted vertically or horizontally. Indicate the mounting in the appropriate column in the table.
4. The entire line for arm #2 and the space for the angle between dual arms are left blank for single arm assemblies.
5. All arms and poles will be galvanized. If a color is required, indicate the color in the table, otherwise leave blank.
6. Starting at the pole, select the signals and/or signs that match the configuration you are tabulating. The spaces representing the signs or signals not used will be blank.

Example 1: If no sign is located between the pole and signal 1, the spaces for Sign A would be blank. Example 2: A configuration for three signals and one sign between signal 1 and signal 2 - Only the spaces for signals 1, 2, 3 and sign B would be completed; the others will be blank.

7. Record the number of sections in each signal head in the space following the distance to that head.
8. Record the height and width of each sign in the space following the distance to the sign.
9. When double arm poles are used for a skewed intersection, the standard design should be used whenever possible. The standard orientation for arm #2 is 90 or 270 degrees measured in a counter clockwise direction from arm #1. The normal orientation of the mast arm is perpendicular to the roadway. Adjustments in mounting hardware can compensate for a skew angle of approximately 15 degrees or more from the normal, depending upon the attachment method. The designer should verify the mounting hardware capability before specifying an arm with a skew greater than 15 degrees.
10. The arm mounting height should be calculated to provide a minimum vertical clearance of 17'-6" from the roadway crown elevation to the lowest sign or signal. A standard signal section is approximately 14" square. Therefore the length of a 3-section head is about 42" and a 5-section is about 70". The use of back plates will add about 6" to each side of the signal head. Additionally, approximately 3" should be added to the end of the signal head to compensate for the attachment hardware. This information may be used to determine the arm mounting height. The designer should coordinate with the maintaining agency to insure the signal assembly and all appropriate hardware has been considered in determining the vertical clearance. The maintaining agency can also provide guidance on the vertical or horizontal mounting of the signal assemblies.
11. The standard handhole location is 180 degrees from arm #1. Other handhole locations must be noted in the Special Instructions.
12. A free swinging internally illuminated street name sign may be attached to the pole by an independent bracket arm if the sign area does not exceed 18 square feet and weigh more than 144 pounds. The Structures Design Engineer must review other signs attached to the pole or any size sign of this type attached to the signal mast arm.
13. The "Special Instructions" Table is used to tabulate pedestrian buttons and pedestrian signal locations and handhole locations when the handholes are not in the standard location. Tabulate the ID No. and the orientation of the pedestrian buttons and signals in degrees measured counter clockwise from arm #1. The handhole location should be left blank if the handhole is in the standard location (see note 11).
14. Arm #1 is the arm for a single arm assembly or the longer arm for a double arm assembly. If the arms are equal length, arm #1 is over the project roadway.

SPECIAL MAST ARM ASSEMBLIES DATA TABLE

Table Date 01-01-12

NUMBER OF LOCATIONS	STRUCTURE NUMBER	FIRST ARM				FIRST ARM EXTENSION				SECOND ARM				SECOND ARM EXTENSION				POLE						
		FA(ft)	FB(in)	FC(in)	FD(in)	FE(ft)	FF(in)	FG(in)	FH(in)	SA(ft)	SB(in)	SC(in)	SD(in)	SE(ft)	SF(in)	SG(in)	SH(in)	UA(ft)	UB(ft)	UC(in)	UD(in)	UE(in)	UF(deg)	UG(ft)

SPECIAL MAST ARM ASSEMBLIES DATA TABLE (CONT.)

Table Date 01-01-12

STRUCTURE NUMBER	FIRST ARM CONNECTION (in) First Arm Camber Angle = 2 Degrees											SECOND ARM CONNECTION (in) Second Arm Camber Angle = 2 Degrees										
	#Bolts	HT	FJ	FK	FL	FN	FO	FP	FR	FS	FT	#Bolts	HT	SJ	SK	SL	SN	SO	SP	SR	SS	ST

SPECIAL MAST ARM ASSEMBLIES DATA TABLE (CONT.)

Table Date 01-01-12

STRUCTURE NUMBER	POLE BASE CONNECTION (in)					SHAFT AND REINF.						LUMINAIRE AND LUMINAIRE CONNECTION										
	#Bolts	BA	BB	BC	BF	DA(ft)	DB(ft)	RA	RB	RC	RD(in)	LA(ft)	LB(ft)	LC(in)	LD(in)	LE	LF(ft)	LG(in)	LH(in)	LJ(in)	LK(in)	LL(deg)

NOTES:

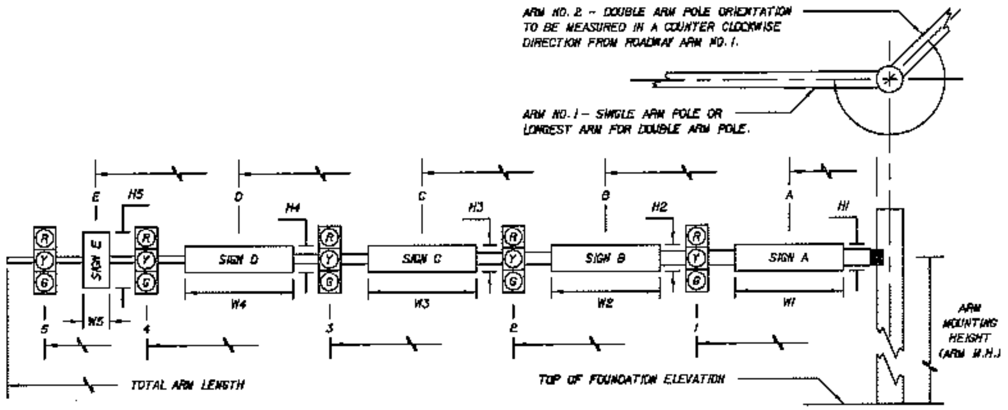
1 Work with Index 17745.
2 Design Wind Speed = mph
3 Contractor shall coordinate anchor bolt requirements with fabricator.
4 Contractor shall identify Structures Numbers and submit detailed shop drawings.

FOUNDATION NOTES:

1 Design based on Borings taken
sealed by
2. Assumptions and Values used in design:
Soil Type
Soil Layer Thickness = ft.
Soil Friction Angle = deg.
Soil Weight = pcf
Design Water Table is ft. below surface

Mast Arm Tabulation Sheet 1 of 2

SPECIAL INSTRUCTIONS			
ID NO.	PED. BUTTON	PED. SIGNALS	HANDHOLE LOCATION



* DENOTES NUMBER OF SECTIONS IN SIGNAL HEAD ASSEMBLY

						SIGNAL DATA																	SIGN DATA															
									DISTANCE FROM POLE														DISTANCE FROM POLE / HEIGHT AND WIDTH OF SIGN															
ID NO.	SHEET NO.	LOCATION BY STA.	TOP OF FOUNDATION ELEVATION	RDWY ARM NO.	CROWN ELEV.	SIGNAL V/H	BACK PLATES Y/N	PED. SIGNAL Y/N	1	*	2	*	3	*	4	*	5	*	TOTAL ARM LENGTH	ARM M.H.	∠ BETWEEN DUAL ARMS 90/270	A	H1	W1	B	H2	W2	C	H3	W3	D	H4	W4	E	H5	W5	PAINT COLOR
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Mast Arm Tabulation Sheet 2 of 2

* DENOTES NUMBER OF SECTIONS IN SIGNAL HEAD ASSEMBLY

						SIGNAL DATA																SIGN DATA															
ID NO.	SHEET NO.	LOCATION BY STA.	TOP OF FOUNDATION ELEVATION	MAST ARM NO.	CROWN ELEV.	SIGNAL Y/N	BACK PLATES Y/N	PED. SIGNAL Y/N	DISTANCE FROM POLE										TOTAL ARM LENGTH	ARM ø H.	∠ BETWEEN DUAL ARMS 90/270	DISTANCE FROM POLE / HEIGHT AND WIDTH OF SIGN															PAINT COLOR
									1	*	2	*	3	*	4	*	5	*				A	H1	W1	B	H2	W2	C	H3	W3	D	H4	W4	E	H5	W5	
				1																																	
■	■	■	■	2																	■																
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SPECIAL INSTRUCTIONS

ID NO.	PED. BUTTON	PED. SIGNALS	HANDHOLE LOCATION

SPECIAL INSTRUCTIONS

ID NO.	PED. BUTTON	PED. SIGNALS	HANDHOLE LOCATION

SPECIAL INSTRUCTIONS

ID NO.	PED. BUTTON	PED. SIGNALS	HANDHOLE LOCATION

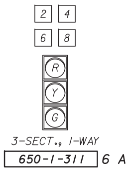
SPECIAL INSTRUCTIONS

ID NO.	PED. BUTTON	PED. SIGNALS	HANDHOLE LOCATION

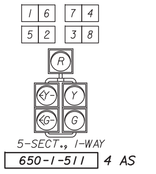
Payment

Item number	Item description	Unit Measure
649-3A-BCC	Steel Mast Arm Assembly	EA

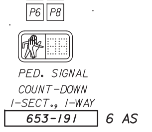
Section 3: Traffic Data



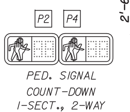
3-SECT., 1-WAY
650-1-311 6 AS



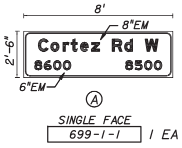
5-SECT., 1-WAY
650-1-511 4 AS



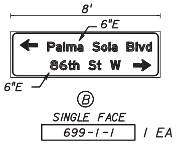
PED. SIGNAL
COUNT-DOWN
1-SECT., 1-WAY
653-191 6 AS



PED. SIGNAL
COUNT-DOWN
1-SECT., 2-WAY
653-192 1 AS



SINGLE FACE
699-1-1 1 EA



SINGLE FACE
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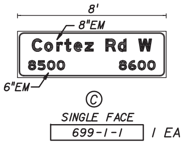
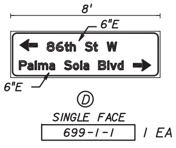
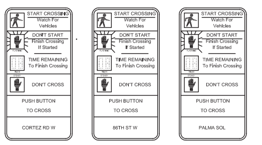


SINGLE FACE
699-1-1 1 EA



SINGLE FACE
699-1-1 1 EA

FTP-68B-06
9" X 18"



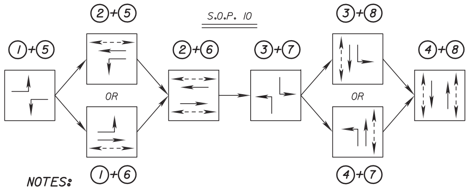
REMOVAL ITEMS:

690-10	8 EA
690-20	8 EA
690-34-2	(SEE PLAN SHEET FOR LOCATIONS)
690-50	1 EA
690-60	10 EA
690-70	8 EA
690-80	4 EA
690-90	1 PI
690-91	25 LF
690-100	1 PI
700-48-60	3 AS

CONTROLLER NOTES:

1. MAJOR STREET IS CORTEZ RD W. (MOVEMENTS 1, 2, 5 AND 6).
   MINOR STREET IS 86TH ST. W/PALMA SOLA RD (MOVEMENTS 3, 4, 7 AND 8).
2. THE CONTROLLER CABINET SHALL BE WIRED FOR SOP 10. THE CONTROLLER SHALL OPERATE AS INDICATED.
3. FLASHING OPERATION IS YELLOW FOR MOVEMENTS 2 AND 6 AND RED FOR ALL OTHER MOVEMENTS.
4. CONCURRENT/ ACTUATED PEDESTRIAN TIMING FOR MOVEMENTS P2, P4, P6 AND P8.
5. EACH PHASE/ MOVEMENT SHALL BE WIRED FROM THE SIGNAL DISPLAY TO THE CONTROLLER AS A SEPARATE PHASE/ MOVEMENT. THIS INCLUDES LEFT TURN MOVEMENTS. EACH LEFT TURN MOVEMENT SHALL HAVE CONDUCTORS AVAILABLE FOR PROTECTED AND PERMISSIVE OPERATION.
6. THE CONTRACTOR MUST PROGRAM PHASE RESTRICTIONS TO OMIT MOVEMENT 1 AND REDIRECT CALLS FROM MOVEMENT 1 TO MOVEMENT 6, WHEN MOVEMENT 2 IS GREEN AND TO OMIT MOVEMENT 5 AND REDIRECT CALLS FROM MOVEMENT 5 TO MOVEMENT 2, WHEN MOVEMENT 6 IS GREEN.

S.O.P. 10

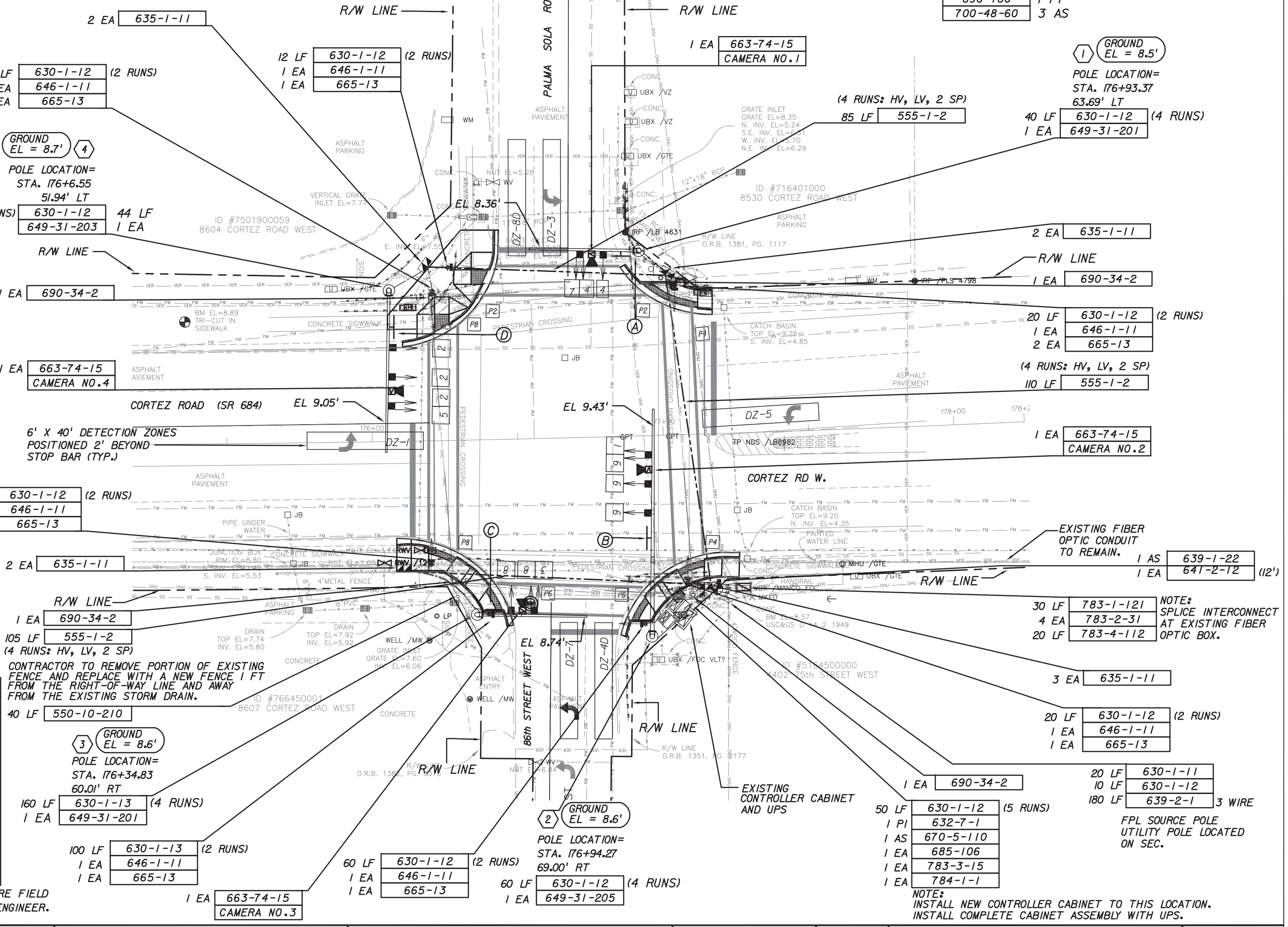


NOTES:

1. CONTRACTOR SHALL RUN CONDUCTORS FROM THE PROPOSED POWER SERVICE PEDESTAL UNDERGROUND TO THE FPL SOURCE POLE ON THE SEC AND THEN RUN THE CONDUCTORS UP THE FP&L SOURCE POLE WITH A 20 FT RISER RGS CONDUIT WITH WEATHERHEAD AND COIL 20 FT AT THE TOP TO BE CONNECTED BY FP&L.

2. CONTRACTOR SHALL USE THE EXISTING FIBER OPTIC SPLICE VAULT ENCLOSURE TO REROUTE AND CONNECT THE 12-COUNT DROP LINE TO THE PROPOSED CABINET.

3. ALL FPL OVERHEAD ELECTRICAL FACILITIES TO REMAIN ENERGIZED AND IN PLACE. TABLE A MINIMUM CLEARANCE DISTANCES SPEDIFIED IN SUBPART CC OF OSHA RULE 29 PART 1926 (AS THEY PERTAIN TO CRANE/DERRICK OPERATIONS), AND/OR THOSE MINIMUM DISTANCES SPECIFIED IN 29 CFR 1910.333(C)(3) FOR WORK IN PROXIMINTY TO POWER LINES NOT COVERED BY THIS SUBPART CC, MUST BE MAINTAINED.



CONTROLLER TIMINGS

	TIMING FUNCTION								
	MOVEMENT NUMBER	1	2	3	4	5	6	7	8
TIMING FUNCTION	MINIMUM GREEN	7	20	7	7	7	20	7	7
	EXTENSION	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
	MAXIMUM GREEN 1	12	50	12	18	12	50	12	18
	MAXIMUM GREEN 2								
	YELLOW CLEARANCE	4.5	4.5	3.0	3.5	4.5	4.5	3.5	3.5
	ALL RED	2.0	1.5	3.0	3.0	2.0	1.5	3.0	3.0
	PEDESTRIAN WALK		7		7		7		7
	PED. CLEARANCE		14		25		14		25
	RECALL		MIN				MIN		

TIMINGS ARE INITIAL AND MAY REQUIRE FIELD ADJUSTING AS DIRECTED BY PROJECT ENGINEER.

VIDEO DETECTOR ZONES

ZONE LOCATION NO.	VIDEO CAMERA NO.	NO. OF DETECTION ZONES	DELAY TIME (SEC)
DZ-1	2	1	0
DZ-2	4	2	0
DZ-3	3	1	3
DZ-4D	1	1	8
DZ-5	4	1	0
DZ-6	2	2	0
DZ-7	1	1	3
DZ-8D	3	1	8

DELAY TIME IS INITIAL AND MAY REQUIRE FIELD ADJUSTING AS DIRECTED BY PROJECT ENGINEER.

NO.	DESCRIPTION	BY	DATE

MANATEE COUNTY

CORTEZ RD. W. AT 86TH STREET IMPROVEMENTS
FP ID: 429867-1-58-01

Cardno TBE
12481 Telecom Drive, Tampa, FL 33637
www.cardnotbe.com - 813.221.0048
Certificate of Authorization No. 3843

UPIK Y. SUWARNO, PE
LIC. NO.: 62995
DATE

DESIGNED UYS
DRAWN UYS
Q.C. DJA
APPROVED

SIGNALIZATION PLAN

PROJECT NO: 00193-008-15
DATE: 01-25-2013
SHEET NO: T-6

SPECIAL NOTES:

A. EACH POLE AND MAST ARM SHALL BE IDENTIFIED WITH A PERMANENT ONE INCH (1") HIGH ENGRAVED OR IMPRESSED MARK WHICH BEARS THE POLE IDENTIFICATION NUMBER SHOWN ON THE PLANS.

B. ANCHOR BOLT COVERS (ORNAMENTAL, NON-ORNAMENTAL, AND/OR PAINTED) SHALL BE GALVANIZED STEEL OR CAST ALUMINUM AND SHALL BE SECURED BY A MINIMUM OF TWO (2) THREADED FASTENERS. THE BOLT COVERS SHALL BE OF SUFFICIENT SIZE SO THAT THERE IS NO GAP BETWEEN ITSELF AND THE POLE SHAFT.

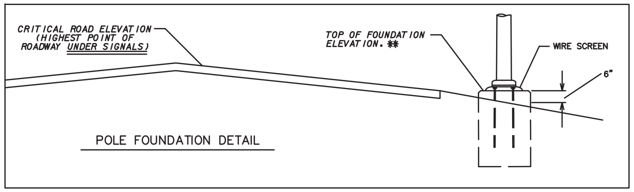
C. IT SHALL BE THE CONTRACTORS RESPONSIBILITY TO FIELD VERIFY ALL ELEVATIONS LISTED HEREIN.

D. INFORMATION BELOW IS FOR DESIGN PURPOSES ONLY. FIELD ADJUSTMENTS MAY BE REQUIRED.

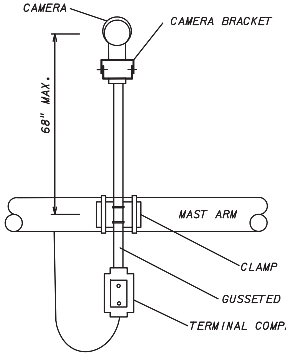
E. SEE APPROPRIATE PLAN SHEET FOR PROPOSED SIGNAL HEAD ALIGNMENTS AND SIGN CONFIGURATION/LOCATION.

F. BACKPLATES REQUIRED FOR ALL SIGNALS HEADS.

G. CONTRACTOR SHALL COORDINATE WITH MANATEE COUNTY FOR THE ACCEPTABLE AND COMPATIBLE VIDEO DETECTION BRACKET TO USE.

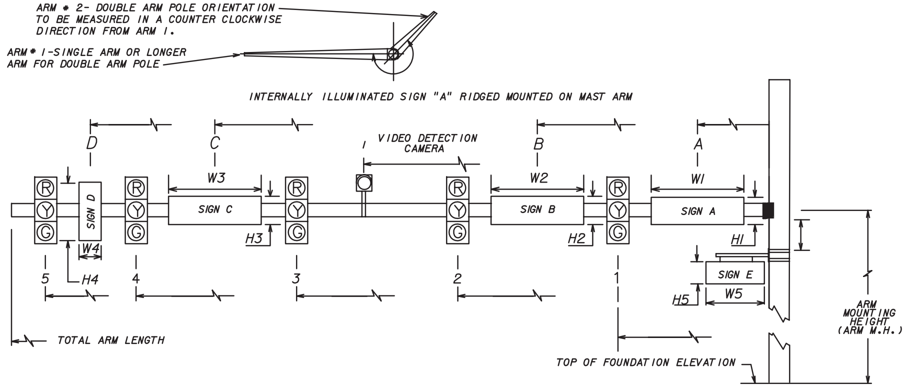


POLE FOUNDATION DETAIL



CAMERA MOUNTING DETAIL
(CONTACT MAINTAINING AGENCY
FOR MOUNTING PREFERENCES.)

SPECIAL INSTRUCTIONS					
ID NO.	PED. BUTTON		PED. SIGNALS		HANDHOLE LOCATION
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	



* DENOTES NUMBER OF SECTIONS IN SIGNAL HEAD ASSEMBLY

STRUCT. ID. NO.	POLE ID. NO.	SHEET NO.	LOCATION BY STA.	CRITICAL ROAD EL.	# FOUNDATION OUT OF GROUND	** TOP OF FOUNDATION ELEVATION	RDWY ARM NO.	SIGNAL DATA																			TOTAL ARM LENGTH	ARM M.H.	∠ BETWEEN DUAL ARMS 90/270	SIGN DATA															VIDEO DISTANCE FROM POLE		LUM	LUM ROTATION	LUM
								SIGNAL V/H	BACK PLATES Y/N	PED. SIGNAL Y/N	DISTANCE FROM POLE																			DISTANCE FROM POLE / HEIGHT AND WIDTH OF SIGN																			
											1	*	2	*	3	*	4	*	5	*	6	*	7	*	8	*				A	H1	W1	B	H2	W2	C	H3	W3	D	H4	W4	E	H5	W5	1	2	Y/N	(DEG)	WATTS
-	1	T-6	176+93.37, 63.69' LT	8.36'	0.5	9.0'	A	V	Y	N	10.5	3	18.5	5													36	20.0		4.5	2.5	8.0													14.5		N		
							B	V	Y	N																																							
-	2	T-6	176+94.27, 69.00' RT	9.43'	0.5	9.1'	A	V	Y	N	40.5	3	50.5	3	60.5	5											76	20.5		32.0	2.5	8.0													55.5		N		
							B	V	Y	N																																							
-	3	T-6	176+34.83, 60.01' RT	8.74'	0.0	8.6'	A	V	Y	N	10.5	3	18.5	5													36	20.5		4.0	2.5	8.0													14.0		N		
							B	V	Y	N																																							
-	4	T-6	176+6.55, 51.94' LT	9.05'	0.5	9.2'	A	V	Y	N	18.0	3	28.0	3	38.0	5											54	20.5		11.0	2.5	8.0													33.0		N		
							B	-	-	-																																							
-							A	V	Y	N																																							
							B	V	Y	N																																							
-							A	V	Y	N																																							
							B	-	-	-																																							
-					-	-	A	V	Y	N																																							
							B	V	Y	N																																							
					-	-	A	V	Y	N																																							
							B	V	Y	N																																							

NO.	DESCRIPTION	BY	DATE

MANATEE COUNTY

CORTEZ RD. W. AT 86TH STREET
IMPROVEMENTS
FP ID: 429867-1-58-01

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www.cardnotbe.com - 813.221.0048
Certificate of Authorization No. 3843

UPIK Y. SUWARNO, PE
LIC. NO.: 62995 DATE

DESIGNED UYS
DRAWN UYS
Q.C. DJA
APPROVED

MAST ARM TABULATION

PROJECT NO: 00193-008-15
DATE: 01-25-2013
SHEET NO: T-8

FILE: O:\JOB\0193\00193-008-15\ACAD\S6_MastTab.dwg LAST SAVED: Fri, 01/25/13-2:06p PLOTTED: Fri, 01/25/13-2:07p BY: Upik.Suwarno

SPECIAL NOTES:

A. EACH POLE AND MAST ARM SHALL BE IDENTIFIED WITH A PERMANENT ONE INCH (1") HIGH ENGRAVED OR IMPRESSED MARK WHICH BEARS THE POLE IDENTIFICATION NUMBER SHOWN ON THE PLANS.

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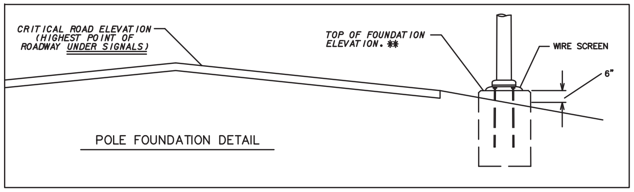
C. IT SHALL BE THE CONTRACTORS RESPONSIBILITY TO FIELD VERIFY ALL ELEVATIONS LISTED HEREIN.

D. INFORMATION BELOW IS FOR DESIGN PURPOSES ONLY. FIELD ADJUSTMENTS MAY BE REQUIRED.

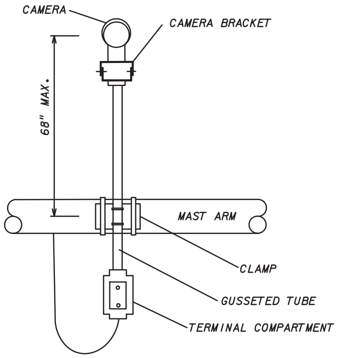
E. SEE APPROPRIATE PLAN SHEET FOR PROPOSED SIGNAL HEAD ALIGNMENTS AND SIGN CONFIGURATION/LOCATION.

F. BACKPLATES REQUIRED FOR ALL SIGNALS HEADS.

G. CONTRACTOR SHALL COORDINATE WITH MANATEE COUNTY FOR THE ACCEPTABLE AND COMPATIBLE VIDEO DETECTION BRACKET TO USE.



POLE FOUNDATION DETAIL



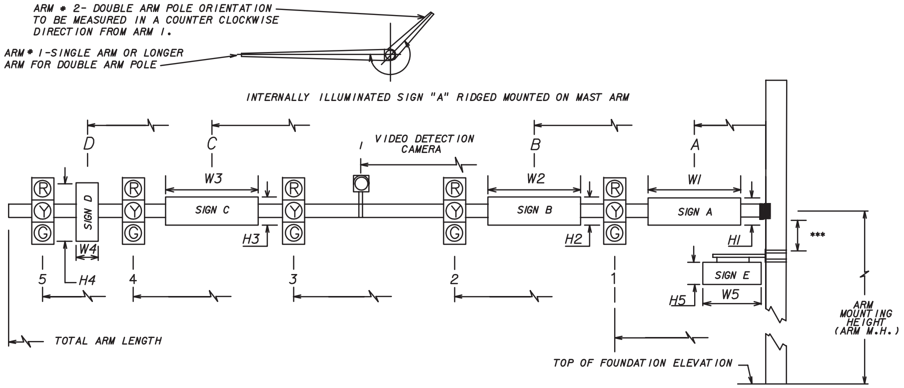
CAMERA MOUNTING DETAIL
(CONTACT MAINTAINING AGENCY
FOR MOUNTING PREFERENCES.)

SPECIAL INSTRUCTIONS					
ID NO.	PED. BUTTON		PED. SIGNALS		HANDHOLE LOCATION
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	
___	___	___	___	___	

ARM * 2- DOUBLE ARM POLE ORIENTATION TO BE MEASURED IN A COUNTER CLOCKWISE DIRECTION FROM ARM 1.

ARM * 1-SINGLE ARM OR LONGER ARM FOR DOUBLE ARM POLE

INTERNALLY ILLUMINATED SIGN "A" RIDGED MOUNTED ON MAST ARM



* DENOTES NUMBER OF SECTIONS IN SIGNAL HEAD ASSEMBLY

STRUCT. ID. NO.	POLE ID. NO.	SHEET NO.	LOCATION BY STA.	CRITICAL ROAD EL.	# FOUNDATION OUT OF GROUND	** TOP OF FOUNDATION ELEVATION	RDWY ARM NO.	SIGNAL DATA																			TOTAL ARM LENGTH	ARM M.H.	∠ BETWEEN DUAL ARMS 90/270
								SIGNAL V/H	BACK PLATES Y/N	PED. SIGNAL Y/N	DISTANCE FROM POLE																		
											1	*	2	*	3	*	4	*	5	*	6	*	7	*	8	*			
	1	T-6	176+93.37, 63.69' LT	8.36'	0.5	9.0'	A	V	Y	N	10.5	3	18.5	3	26.5	4											36	20.0	
							B	V	Y	N																			
	2	T-6	176+94.27, 69.00' RT	9.43'	0.5	9.1'	A	V	Y	N	40.5	3	52.5	3	66.5	4											76	20.5	
							B	V	Y	N																			
	3	T-6	176+34.83, 60.01' RT	8.74'	0.0	8.6'	A	V	Y	N	10.5	3	18.5	3	26.5	4											36	20.5	
							B	V	Y	N																			
	4	T-6	176+6.55, 51.94' LT	9.05'	0.5	9.2'	A	V	Y	N	18.0	3	32.0	3	44.0	4											54	20.5	
							B	V	Y	N																			
-					-	-	A	V	Y	N																			
							B	V	Y	N																			
-					-	-	A	V	Y	N																			
							B	V	Y	N																			
-					-	-	A	V	Y	N																			
							B	V	Y	N																			
-					-	-	A	V	Y	N																			
							B	V	Y	N																			

STRUCT. ID. NO.	POLE ID. NO.	RDWY ARM NO.	SIGN DATA															VIDEO DISTANCE FROM POLE		LUM	LUM ROTATION	LUM
			DISTANCE FROM POLE / HEIGHT AND WIDTH OF SIGN																			
			A	H1	W1	B	H2	W2	C	H3	W3	D	H4	W4	E	H5	W5	1	2	Y/N	(DEG)	WATTS
	1	A	4.5	2.5	8.0							31.0	3.0	3.0				17.0		N		
		B																				
	2	A	32.0	2.5	8.0							71.5	3.0	3.0				60.5		N		
		B																				
	3	A	4.5	2.5	8.0							31.0	3.0	3.0				22.0		N		
		B																				
	4	A	11.0	2.5	8.0							49.0	3.0	3.0				38.0		N		
		B																				
-		A																				
		B																				
-		A																				
		B																				
-		A																				
		B																				
-		A																				
		B																				

*** THIS SHEET IS FOR DESIGN PURPOSES ONLY! THE CONTRACTOR SHALL NOT USE THIS SHEET IN PLACEMENT OF THE SIGNALS AND/OR SIGNS. SEE THE "MAST ARM TABULATION" SHEET FOR ACTUAL SIGNAL INSTALLATION.

NO.	DESCRIPTION	BY	DATE

MANATEE COUNTY

CORTEZ RD. W. AT 86TH STREET
IMPROVEMENTS
FP ID: 429867-1-58-01

Cardno
TBE
12481 Telecom Drive, Tampa, FL 33637
www.cardnotbe.com - 813.221.0048
Certificate of Authorization No. 3843

UPIK Y. SUWARNO, PE
LIC. NO.: 62995 DATE

DESIGNED UYS
DRAWN UYS
Q.C. DJA
APPROVED

MAST ARM TABULATION (CALCULATION CONFIGURATION)

PROJECT NO: 00193-008-15
DATE: 01-25-2013
SHEET NO: T-9

FILE: O:\JOB\0193\00193-008-15\ACAD\S6_MastTab.dwg LAST SAVED: Fri, 01/25/13-2:06p PLOTTED: Fri, 01/25/13-2:07p BY: Upik.Suwarno

Section 4: Geotechnical Data

GEOTECHNICAL ENGINEERING SERVICES
CORTEZ ROAD & 86TH STREET WEST – MAST ARMS
MANATEE COUNTY, FLORIDA

Date: July 26, 2012

Prepared For:

Cardno TBE
22 Sarasota Center Boulevard
Sarasota, Florida 34240

Prepared By:

Dunkelberger Engineering and Testing, Inc.
8260 Vico Court, Unit B
Sarasota, Florida 34240

Project No.: SAR-12-1419

DUNKELBERGER
engineering & testing, inc.
www.dunkelberger-engineering.com

- Fort Lauderdale
- Port Saint Lucie
- Sarasota
- West Palm Beach

Cardno TBE
22 Sarasota Center Boulevard
Sarasota, Florida 34240

July 26, 2012
Project No.: SAR-12-1419

Attention: Mr. Larry Mau, P.E.
Branch Manager

Subject: **Geotechnical Engineering Services**
Cortez Road & 86th Street West – Mast Arms
Manatee County, Florida

Dear Mr. Mau:

INTRODUCTION

In accordance with Dunkelberger Engineering & Testing, Inc. (Dunkelberger) Proposal No. SAR-12-1439, dated March 13, 2012, which was authorized by issuance of a subconsultant agreement on April 12, 2012, we have completed our geotechnical engineering services in connection with the above referenced project.

PROJECT CONSIDERATIONS

We understand that four standard mast lighting assemblies are to be installed at the intersection of Cortez Road and 86th Street West in Manatee County, Florida. There will be one mast assembly installed at each corner of the intersection.

If actual conditions vary from our present understandings and assumptions, then we should be advised in order to re-evaluate our opinions, recommendations and conclusions presented in this report.

SURFICIAL SOIL CONDITIONS

The Soil Survey of Manatee County, issued April 1983, indicates that the site is mapped with Soil Unit 20. Unit 20, EauGallie fine sand, is comprised of nearly-level, poorly drained soil in broad areas of flatwoods. The typical soil profile consists of fine sand to a depth of 42 inches and underlain by loamy fine sand to a depth of 65 inches. Under natural (pre-development) conditions, the Seasonal High Groundwater Table (SHGWT) is reported to lie at a depth of less than 10 inches below the land surface (bls) for 2 to 4 months of the year.

SUBSURFACE CONDITIONS

Field Exploration

The subsurface conditions of the site were explored with two Standard Penetration Test (SPT) borings positioned in the northwest and southeast corners of the intersection and drilled to depths of 25 feet below the land surface (bls). The SPT borings were performed by a truck-mounted Central Mine Equipment Model 55 (CME 55) drill rig using mud rotary procedures and SPT methodology, per ASTM D-1586, for the collection of soil samples. Representative portions of the recovered soil samples were collected in labeled glass jars and transported to our laboratory for visual-manual classification by a geotechnical engineer.

The groundwater level was measured in each boring just prior to it being backfilled with cement grout.

The locations of the borings are indicated on the attached *Boring Location Plan* as Sheet 1.

SPT Boring Findings

In general, the SPT borings found very loose to medium dense fine sand with trace to slight amounts of silt and some shell (SP, SP-SM) to the borehole termination depth of 25 feet bls.

The boring results, including soil stratigraphy and classifications, SPT blowcount data (N-Values), groundwater levels, and results of laboratory testing can be seen on the *Subsurface Profiles* included as Sheet 1 of this report. This attachment should be consulted for details at each specific boring location.

Groundwater

Groundwater levels were measured during drilling and ranged from about 2 to 2 ½ feet bls. The groundwater measurements are influenced by the drilling process and ambient weather conditions which have been seasonably wet. In general terms, the groundwater level should be assumed as shallow for both design and construction purposes.

Laboratory Analyses

Soil samples collected from the borings were reviewed in our laboratory by a geotechnical engineer and assigned a visual-manual classification per the Unified Soil Classification System (U.S.C.S.). Also, four (4) samples were selected for testing to aid in the U.S.C.S classification. Four (4) moisture content tests and four (4) minus No. 200 sieve washes were performed. The results of the laboratory testing are shown on the on the *Subsurface Profiles* on the attached Sheet 1.

RECOMMENDATIONS

The table on Sheet 1 presents design parameters for the different soil strata encountered at the boring locations. It is our understanding that the pole foundations will be a drilled shaft system designed by others. The pole foundations should be designed using the soil parameters provided on Sheet 1.

LIMITATIONS OF STUDY

Dunkelberger warrants that the findings, recommendations, specifications, or professional advice contained herein have been made in accordance with generally accepted professional geotechnical engineering practices in the local area. No other warranties are implied or expressed.

The scope of services did not include an environmental assessment for determining the presence or absence of wetlands or hazardous or toxic materials in the soil, bedrock, surface water, groundwater, or air, on or below or around this site. Any statements in this report or on the boring profiles regarding odors, colors, unusual or suspicious items or conditions are strictly for the information of the client. Additionally our scope of services did not include any investigation into the potential for ground subsidence due to the presence of sinkhole activity.

The analysis and recommendations submitted in this report are based upon the data obtained from the soil borings performed at the locations indicated. If any subsoil variations become evident during the course of the project, a re-evaluation of the recommendations contained in this report will be necessary after we have had an opportunity to observe the characteristics of the conditions encountered. The applicability of the report should also be reviewed in the event significant changes occur in the design, nature or location of the assumed structures.

This report has been prepared for the exclusive use of Cardno TBE for the specific application to the new mast arms at the intersection of Cortez Road and 86th Street West in Manatee County, Florida.

___oOo___

We appreciate the opportunity to be of service during this phase of the project. If you have any questions, please contact the undersigned at 941-379-0621.

Sincerely,
DUNKELBERGER ENGINEERING & TESTING, INC.

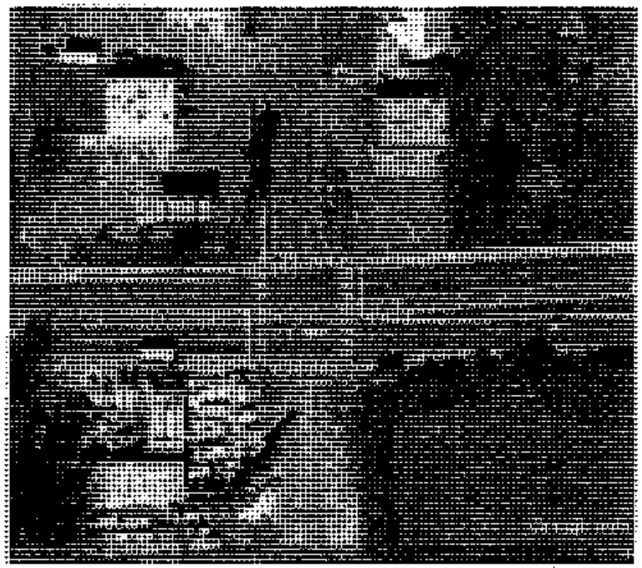
James Jackson

James M. Jackson, E.I.
Staff Engineer 7/26/12

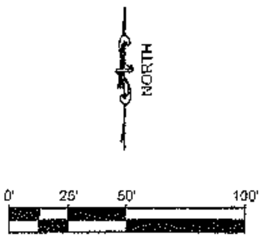
Scott Parrish

Scott N. Parrish, P.E.
Branch Manager 7/26/12
FL License No.: 69091

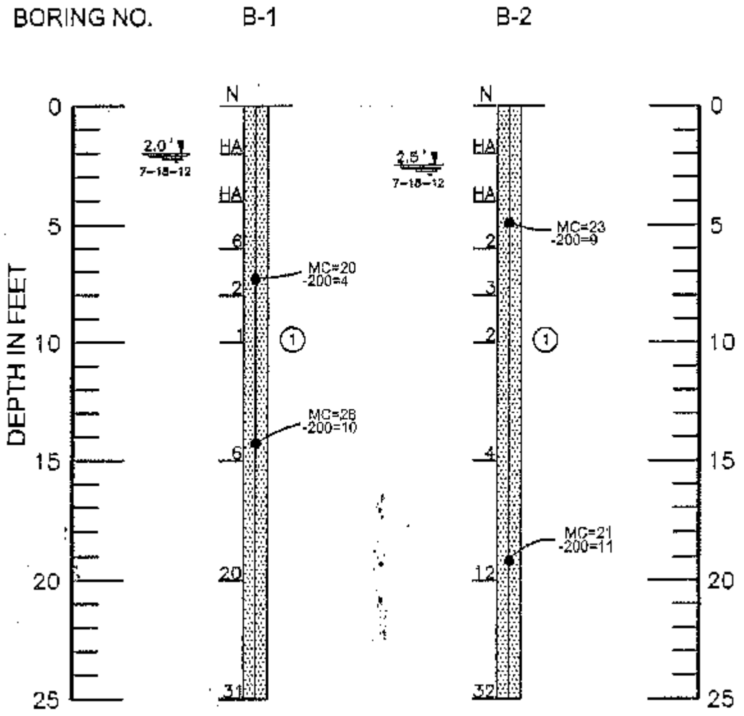
Attachments: Sheet 1 – Boring Location Plan & Subsurface Profiles



SOURCE: GOOGLE EARTH.COM



● STANDARD PENETRATION TEST
B-1 BORING LOCATION AND NUMBER



GENERAL LEGEND

▦ ① Gray to dark brown fine SAND with trace silt to slightly silty and some shell (SP, SP-SM)

N – Indicates the number of blows of a 140 pound hammer, freely falling a distance of 30 inches, required to drive a 2-inch diameter sampler 12 inches (ASTM D 1586)

-200 – Amount Passing U.S. Standard No. 200 Sieve (%)

MC – Moisture Content (%)

HA – Hand auger 4 feet in order to avoid possible conflict with underground utilities

B-1 – Standard Penetration Test (SPT) Boring and number

SP – Unified Soil Classification System Group Symbol (ASTM D 2487)

2.0' 7-18-12 – Depth of groundwater (feet) & date measured

NOTES

(1) Borings were drilled on July 18, 2012 using a Central Mine Equipment Model 55 (CME 55) drill rig.

(2) Strata boundaries are approximate and represent soil strata at each test hole location only. Soil transitions may be more gradual than implied.

(3) Groundwater depths shown on the subsurface profiles represent groundwater surfaces on the dates shown. Groundwater level fluctuations should be anticipated throughout the year.

STANDARD PENETRATION TEST DATA

SPOON INSIDE DIA.	1.375 inch
SPOON OUTSIDE DIA.	2.00 inches
AVG. HAMMER DROP	30 inches
HAMMER WEIGHT	140 pounds

SPT DENSITY CHART

GRANULAR MATERIALS- RELATIVE DENSITY	SPT (BLOWS/FOOT)
VERY LOOSE	LESS THAN 4
LOOSE	4 - 10
MEDIUM	10 - 30
DENSE	30 - 50
VERY DENSE	GREATER THAN 50

SUMMARY OF FOUNDATION DESIGN PARAMETERS

Boring No.	Depth (feet)	Range of SPT - N	Unit Weights (PCF)		Angle of Interval Friction (degrees)	Effective Cohesion (PSF)	Earth Pressure Coefficients	
			Moist	Submerged			Ka	Kp
TB-1 & TB-2	0-17	1-6	100	40	28	0	0.361	2.77
	17-25	12-32	110	50	30	0	0.333	3.00

DRAWN BY	JJ	7-30-12
CHECKED BY	SRP	7-30-12
APPROVED BY	SCOTT R. PARRISH, P.E.	

REVISIONS

SCOTT R. PARRISH, P.E.
FLORIDA LICENSE NO. 58097

FLORIDA ENGINEERING CERTIFICATE
OF AUTHORIZATION NO. 6870

DUNKELBERGER
engineering & testing, inc.

ROAD NO.	COUNTY	PROJECT No.
-	MANATEE	

REPORT OF CORE BORINGS
FOR SIGNAL POLES

PROJECT NAME: CORTEZ ROAD AND
86TH ST. WEST - MAST ARM
MANATEE COUNTY, FLORIDA

SHEET No.
1

DET Project No. 948-12-1419
Sheet 1

Section 5: Mast Arm Design

Project **Cortez and 86th st.**
TBE Project No. 00193008015
Subject **Determine AREA x DISTANCE values for project**

Calcs MAV *Date* **6-Dec-12**
Check ______ *Date* ______

DESIGN SHEETS USED FOR REFERENCE.
MAV

FDOT PPM
Vol. 1, Fig. 29.2
Loading Trees

SIGNAL DATA — *Area per Signal Section* 1.266 ft²

	Signal 1		Signal 2		Signal 3		Signal 4		Signal 5		Signal	SIGN DATA Sign 1			Sign 2			Sign	Total Area x	Arm
	Dist	# Sect	Dist	# Sect	Dist	# Sect	Dist	# Sect	Dist	# Sect	AxD	Dist	H	W	Dist	H	W	AxD	Distance	Length
	[ft]	[ea]	[ft]	[ea]	[ft]	[ea]	[ft]	[ea]	[ft]	[ea]	[ft² · ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft² · ft]	[ft² · ft]	[ft]
D1, D2, E1, E2, F1, F2	17.00	3	26.00	3	33.00	3					288.56	8.00	1.50	10.00				120.00	408.56	36.0
D3, D4, E3, E4, F3, F4	19.50	3	29.17	3	37.17	5					419.96	23.17	1.50	6.00	42.50	2.00	3.00	463.50	883.48	46.0
D5, E5, F5	21.00	3	29.00	3	40.00	3	52.00	5			670.78	35.00	1.50	6.00	44.00	2.00	2.50	535.00	1205.78	60.0
D6, E6, F6	20.00	3	32.00	3	44.25	3	56.25	3	67.33	3	834.68	38.08	1.50	6.00	62.25	2.00	2.50	654.00	1488.68	70.5
D7, E7, F7	38.00	3	53.00	3	68.00	3	76.00	3			892.27	29.00	1.50	10.00				435.00	1327.27	78.0

Mast Arms
for project 20

SIGNAL DATA — *Area per Signal Section* 1.266 ft²

				Signal 1		Signal 2		Signal 3		Signal 4		Signal 5		Signal 6		Signal
				Dist	# Sect	Dist	# Sect	Dist	# Sect	Dist	# Sect	Dist	# Sect	Dist	# Sect	AxD
ID No.	Location	Pole	Arm	[ft]	[ea]	[ft]	[ea]	[ft]	[ea]	[ft]	[ea]	[ft]	[ea]	[ft]	[ea]	[ft² · ft]
1	176+93.37	1	1	5.00	3	13.00	3	21.00	4							174.66
2	176+94.27	1	1	40.50	3	52.50	3	66.50	4							689.77
3	176+34.83	1	1	10.00	3	18.00	3	26.00	4							237.94
4	176+6.55	1	1	18.00	3	32.00	3	44.00	4							412.59

Mast Arms
for project

SIGN DATA

				Sign 1			Sign 2			Sign 3			Sign 4			Sign 5			Sign	Total Area x	Arm
				Dist	H	W	Dist	H	W	Dist	H	W	Dist	H	W	Dist	H	W	AxD	Distance	Length
ID No.	Location	Pole	Arm	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft]	[ft² · ft]	[ft² · ft]	[ft]
1	176+93.37	1	1	27.00	3.00	3.00				17.00	1.25	1.25	4.00	2.50	6.00				329.56	504.22	32.00
2	176+94.27	1	1	32.00	2.50	8.00	71.50	3.00	3.00	60.50	1.25	1.25							1378.03	2067.80	76.00
3	176+34.83	1	1	4.00	2.50	6.00	31.00	3.00	3.00	22.00	1.25	1.25							373.38	611.31	36.00
4	176+6.55	1	1	11.00	2.50	8.00	49.00	3.00	3.00	38.00	1.25	1.25							720.38	1132.97	54.00

Mast Arms

				Applied Area x Distance	Arm Length	FDOT Standard Arm Type	Area x Distance	Arm Length	Is Design > Applied AxD ?	% FDOT Capacity	Is Design >= Applied Length ?
ID No.	Location	Pole	Arm	[ft² · ft]	[ft]		[ft² · ft]	[ft]			
1	176+93.37	1	1	504.22	32.0	E1	408.56	36.00	FALSE	123.4%	TRUE
2	176+94.27	1	1	2067.80	76.0	E7	1327.27	78.00	FALSE	155.8%	TRUE
3	176+34.83	1	1	611.31	36.0	E1	408.56	36.00	FALSE	149.6%	TRUE
4	176+6.55	1	1	1132.97	54.0	E5	1205.78	60.00	TRUE	94.0%	TRUE

Notes :

1. "Area per Signal Section" is the projected area for a single signal section, and does not include backplates.
2. Assume video detection equipment will be added. Model equipment as an 1.25 x 1.25 foot sign 1 foot from the end of the pole.
3. If the "AreaxDistance" value exceeds the value computed for the standard loading tree, check the design using the MathCAD mast arm design templates.

LEGEND		
	33.00	Input
	550.55	Results

Project **Cortez and 86th st.**
TBE Project No. 00193008015

Calcs **MAV** *Date* 12/6/2012
Check ____________ *Date*

Subject **Determine arm mounting height for mast arms.**

Max. Vertical Clearance 19.50 ft
Min. Vertical Clearance 17.50 ft

Desired Vertical Clearance 18.25 ft

DATA

		ARM ONE						
LOCATION	***Struct ID***	*ELEV @ RDWY* CROWN	*ELEV @ TOP OF FOUNDATION*	*DIFFERENCE FOUNDATION TO CROWN*	*GROUT PAD*	*VERT. CLR.*	*O/S TO CL SIGNAL*	*ARM HEIGHT DIM "UB"*
176+93.37	1	8.36	9	-0.64	0.167	18.25	2.00	19.443
176+94.27	2	9.43	9.1	0.33	0.167	18.25	2.00	20.413
176+34.83	3	8.74	8.6	0.14	0.167	18.25	2.00	20.223
176+6.55	4	9.05	9.20	-0.15	0.167	18.25	2.00	19.933

RESULTS

LOCATION		*CALC'D HEIGHT (MAX)*	*USE HT. FOR DIM. "UB"*	*CHANGE IN HT.*	*VERT. CLR.*	*CHECK LIMITS*
176+93.37	1	19.443	20.000	0.557	18.81	OK
176+94.27	2	20.413	20.500	0.087	18.34	OK
176+34.83	3	20.223	20.500	0.277	18.53	OK
176+6.55	4	19.933	20.500	0.567	18.82	OK

Notes :

1. Refer to FDOT PPM §2.10 and Table 2.10.3 for minimum vertical clearance.
   Refer to 2002 FDOT Standard Index 17740 sheet 2 of 2 for maximum vertical clearance.

Project **Cortez and 86th st.**
TBE Project No. 00193008015

Calcs **MAV** *Date* **6-Dec-12**
Check ________ *Date* __________

Subject **Determine tip diameters for the arms and poles.**

from FDOT Standard Index 17743

standard taper rate -0.140 ft/ft

Mast Arm	*Arm L (ft)*	*FA(ft)*	*FC(in)*
D1	36	36	14
D2	36	36	14
D3	46	36.3	14
D4	46	36.3	14
D5	60	36	13
D6	70.5	39.4	15
D7	78	40	14
D99	*-999*	*-999*	*999*

Pole	*UA(ft)*	*UD(ft)*
S1	24	16
S2	24	18
S21	39	16
S22	39	18
S23	39	21
S24	39	26
S3	24	21
S4	24	26
S5	24	27
S6	24	25
S99	*-999*	*999*

Mast Arm	*Arm L (ft)*	*FA(ft)*	*FC(in)*
E1	36	36	11
E2	36	36	11
E3	46	36.3	12.14
E4	46	36.3	12.14
E5	60	36	11.14
E6	70.5	39.4	12.15
E7	78	40	13.04
E99	*-999*	*-999*	*999*

Pole	*UA(ft)*	*UD(ft)*
T1	24	14
T2	24	16
T21	39	14
T22	39	16
T23	39	19
T24	39	22
T3	24	19
T4	24	22
T5	24	22
T6	24	22
T99	*-999*	*999*

Mast Arm	*Arm L (ft)*	*FA(ft)*	*FC(in)*
F1	36	36	11
F2	36	36	11
F3	46	36.3	11
F4	46	36.3	11
F5	60	36	11
F6	70.5	39.4	11
F7	78	40	12
E99	*-999*	*-999*	*999*

Pole	*UA(ft)*	*UD(ft)*
W1	24	13
W2	24	15
W21	39	13
W22	39	15
W23	39	18
W24	39	21
W3	24	18
W4	24	21
W5	24	21
W6	24	21
T99	*-999*	*999*

Location **176+93.37**

first arm type	**E1**		**upright type**	**T1**	
new arm length	32.00	ft	mounting ht. UB	20.00	ft
std arm length	36.00	ft	new upright ht. UAA	21.50	ft
std base diametre	11.00	in	std upright height	24.00	ft
new arm len. FAA	**32.000**	ft	std base diametre	14	in
new tip diam. FBA	**6.52**	in	new tip diam. UCA	**10.990**	in

Location **176+94.27**

first arm type	**E7**		**upright type**	**T6**	
new arm length	76.00	ft	mounting ht. UB	20.50	ft
std arm length	78.00	ft	new upright ht. UAA	22.00	ft
std base diametre	13.04	in	std upright height	24.00	ft
new arm len. FAA	**38.000**	ft	std base diametre	22	in
new tip diam. FBA	**7.72**	in	new tip diam. UCA	**18.920**	in

Project **Cortez and 86th st.**
TBE Project No. 00193008015

Calcs **MAV** *Date* **6-Dec-12**
Check ________ *Date* ___________

Location **176+34.83**

first arm type	**E1**		**upright type**	**T1**	
new arm length	36.00	ft	mounting ht. UB	20.50	ft
std arm length	36.00	ft	new upright ht. UAA	22.00	ft
std base diametre	11.00	in	std upright height	24.00	ft
new arm len. FAA	**36.000**	ft	std base diametre	14	in
new tip diam. FBA	**5.96**	in	new tip diam. UCA	**10.920**	in

Location **176+6.55**

first arm type	**E5**		**upright type**	**T3**	
new arm length	54.00	ft	mounting ht. UB	20.50	ft
std arm length	60.00	ft	new upright ht. UAA	22.00	ft
std base diametre	11.14	in	std upright height	24.00	ft
new arm len. FAA	**30.000**	ft	std base diametre	19	in
new tip diam. FBA	**6.94**	in	new tip diam. UCA	**15.920**	in

I.D. No. 1: E1-T1

No Change.   Cortez & 86th St. Pole ID. 1

FDOT Mast Arm Analysis Program

1/22/13

Custom File Name (optional) ☐

The new custom file will be a copy of the last file called from the program. A ".dat" extension will be added to the file name.

Add file to file list [Refresh File List]

Select Data File (required)

- D6S4
- D7S6
- E1E1T1
- E1T1
- E1T21
- E3E1T2
- E3T2

All data files are in the same directory as the MastArm.xmcd file.

Path = "J:\00193\00193008.15\DOC\Calcs\ID_N0_1_MastarmV5.02\"

DataFile = "E1T1.dat"

Reference *Changes*

This program works in conjunction with Mastarm Design Standards 17743 and 17745.

References:
AASHTO Standard Specifications for Signs, Luminaires and Traffic Signals, 5th Edition (LTS).
FDOT Structures Manual Vol. 9 (SM V9).

For more information see Reference.xmcd and Changes.xmcd.

▶ Read In Data

General Information

DataFile = "E1T1.dat"

Current Values	New Values
Subject = "E1-T1 Mast Arm"	
ProjectNo = "00193008015"	"00193008015"
PoleLocation = "ID No.1"	ID No.1
Date = "12/4/2012"	12/4/2012
DesignedBy = "MAV"	MAV
CheckedBy = "FDOT"	

Use Control+F9 to recalculate the worksheet, once to write out data, twice to read in data

Wind Speed

DataFile = "E1T1.dat"

Current Value	New Value		
WindSpeed = 130·mph		*mph*	**SM V9 3.8.2**

Arm 1 Analysis

DataFile = "E1T1.dat"   WindSpeed = 130·mph

Arm 1 Loads

$$\text{SignalData}_{\text{arm1}} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 10.5 & 3 & \text{"yes"} \\ 2 & 18.5 & 3 & \text{"yes"} \\ 3 & 26.5 & 4 & \text{"yes"} \\ 4 & 0 & 0 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values   *"yes"or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	10.5	3	"yes"
2	18.5	3	"yes"
3	26.5	4	"yes"
4	0	0	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$\text{SignData}_{\text{arm1}} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 4.5 & 20 \\ 2 & 17 & 1.56 \\ 3 & 31 & 9 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	4.5	20
2	17	1.56
3	31	9
4	0	0
5	0	0

use X to zero out data
use 0 to keep current values

Arm 1 Loads

Arm 1 Properties

Current Values

New Values

$L_{total.arm1} = 36\,ft$ 36 *feet, 40 ft. max. for 1 piece arms*

$Diameter_{base.arm1} = 11\cdot in$ *inches, measured flat to flat (FG)*

$Dist_{splice.from.base.arm1} = 0\,ft$ *feet, splice distance, for 2 piece arms, length of piece closest to pole, use X to zero out (FE)*

set $Dist_{splice.from.base.arm1} = 0ft$ *for NO SPLICE*

$t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0 \end{pmatrix} \cdot in$

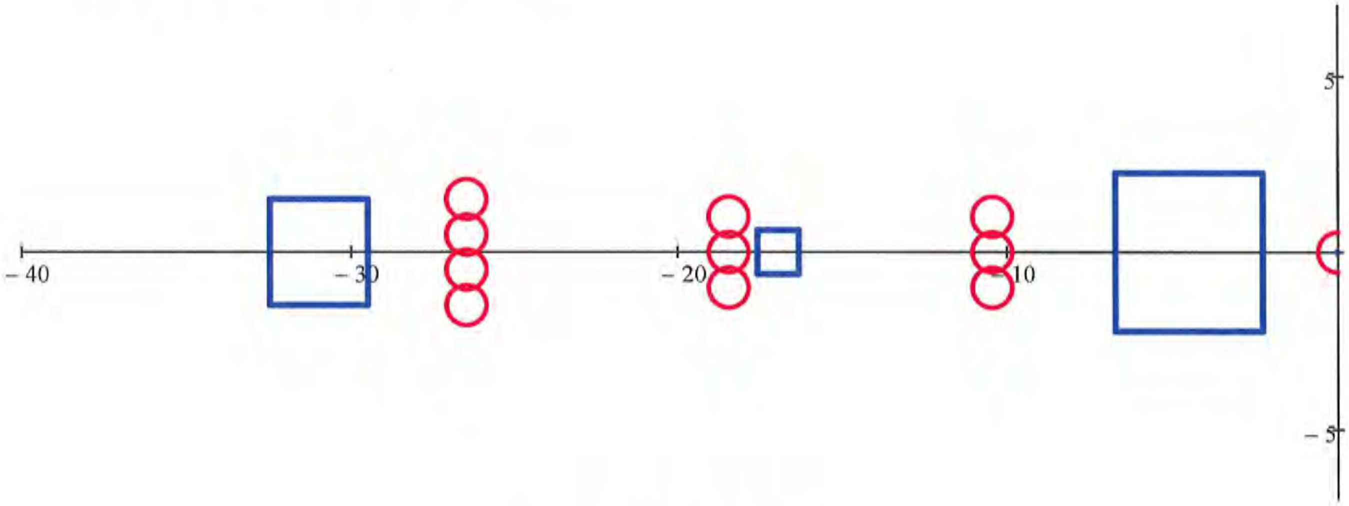
inches, this value is used for one piece arms (FD)

inches, for 2 piece arms, wall thickness of piece closest to the pole, use X to zero out (FH)

Arm 1 Properties

▶ Analyze Arm 1

Summary - Arm 1 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130\cdot mph$ $L_{total.arm1} = 36.00\,ft$

$Diameter_{tip.arm1} = \begin{pmatrix} 5.96 \\ 0 \end{pmatrix} \cdot in$ $Diameter_{base.arm1} = \begin{pmatrix} 11.00 \\ 0.00 \end{pmatrix} \cdot in$ $L_{arm1} = \begin{pmatrix} 36.00 \\ 0.00 \end{pmatrix} ft$ $t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0 \end{pmatrix} \cdot in$

$X_{signal.arm1_{i1}} =$

10.5	ft
18.5	
26.5	

$Sections_{signal.arm1_{i1}} =$

3
3
4

$X_{panel.arm1_{j1}} =$

4.5	ft
17	
31	

$Area_{panel.arm1_{j1}} =$

20	ft^2
1.56	
9	

Arm 1 Combined Stress Ratio and Deflection

$\max(\mathrm{CSR}_{\mathrm{arm1}}) = 0.953$ $\max(\Delta_{\mathrm{arm1}}) = 3.584\cdot\mathrm{in}$ $2\cdot\mathrm{deg}\cdot\sum(L_{\mathrm{arm1}} - L_{\mathrm{splice.provided}}) = 13.4\cdot\mathrm{in}$

Arm 2 Analysis

DataFile = "E1T1.dat" WindSpeed = 130·mph

Arm 2 Loads

$$\mathrm{SignalData}_{\mathrm{arm2}} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 0 & 0 & \text{"yes"} \\ 2 & 0 & 0 & \text{"yes"} \\ 3 & 0 & 0 & \text{"yes"} \\ 4 & 0 & 0 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values *"yes"or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	0	0	"yes"
2	0	0	"yes"
3	0	0	"yes"
4	0	0	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$\mathrm{SignData}_{\mathrm{arm2}} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 0 & 0 \\ 2 & 0 & 0 \\ 3 & 0 & 0 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0

use X to zero out
use 0 to keep current values

Arm 2 Loads

Arm 2 Properties

Current Values

New Values

$L_{total.arm2} = 0\ ft$

feet, 40 ft. max. for 1 piece arms, use X to zero out *set* $L_{total.arm2} = 0ft$ *for NO ARM2*

$Diameter_{base.arm2} = 0 \cdot in$

inches, measured flat to flat, use X to zero out (SG)

$Dist_{splice.from.base.arm2} = 0 \cdot ft$

feet, splice distance, for 2 piece arms,
length of piece closest to pole,
use X to zero out (SE)

set $Dist_{splice.from.base.arm2} = 0ft$
for NO SPLICE

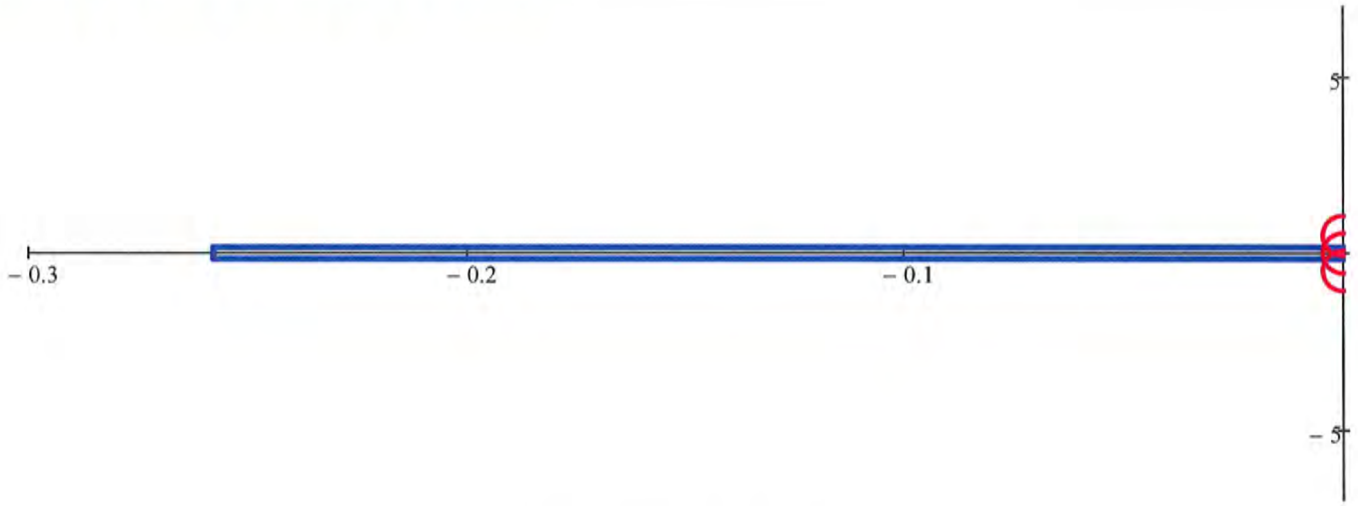
$t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

inches, use X to zero out (SD)

inches, for 2 piece arms, wall thickness of piece closest to the pole,
use X to zero out (SH)

Arm 2 Properties

Summary - Arm 2 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130 \cdot mph$ $L_{total.arm2} = 0.00\ ft$

$Diameter_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $Diameter_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} ft$ $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

$X_{signal.arm2_{i2}} =$	$Sections_{signal.arm2_{i2}} =$	$X_{panel.arm2_{j2}} =$	$Area_{panel.arm2_{j2}} =$
0 ft	0	0.1 ft	0.1 ft^2
0	0		

Arm 2 Combined Stress Ratio and Deflection

$\max(CSR_{arm2}) = 0$ $\max(\Delta_{arm2}) = 0\cdot in$ $2\cdot deg\cdot\sum(L_{arm2} - L_{splice.provided}) = -1.68\cdot in$

Luminaire Arm Analysis

DataFile = "E1T1.dat" WindSpeed = $130\cdot mph$

Luminaire Properties

See Design Standards 17743 and 17745 for input values.

Current Values

New Values

set $Y_{luminaire} = 0ft$ *for NO LUMINAIRE*

$Y_{luminaire} = 0\ ft$ ☐ *feet, use X to zero out (Standard LA = 40 feet)*

$X_{luminaire} = 10\cdot ft$ ☐ *feet, use X to zero out (Standard LB = 10 feet)*

$Diameter_{base.lumarm} = 3\cdot in$ ☐ *inches, use X to zero out (Standard LC = 3 inches)*

$t_{wall.lumarm} = 0.125\cdot in$ ☐ *inches, use X to zero out (Standard LD = 0.125 inches)*

$Slope_{lumarm} = 0.5$ ☐ *rise/run, use X to zero out (Standard LE = 0.5)*

$r_{lumarm} = 8\cdot ft$ ☐ *feet, use X to zero out (Standard LF = 8 feet)*

$d_{bolt.lum} = 0.5\cdot in$ ☐ *inches, use X to zero out (Standard LG = 0.5 inches)*

$t_{baseplate.lum} = 0.75\cdot in$ ☐ *inches, use X to zero out (Standard LH = 0.75 inches)*

Luminaire Properties

▶ Analyze Luminaire

Summary - Luminaire Arm Geometry

$Y_{luminaire} = 0\ ft$ $X_{luminaire} = 0\cdot ft$ $Diameter_{base.lumarm} = 0\cdot in$ $t_{wall.lumarm} = 0\cdot in$

$Slope_{lumarm} = 0$ $r_{lumarm} = 0\cdot ft$ $d_{bolt.lum} = 0\cdot in$ $t_{baseplate.lum} = 0\cdot in$

$w_{base.lum} = 0\cdot in$ $w_{channel.lum} = 0\cdot in$

Luminaire Arm Ratios

$CSR_{base.lumarm} = 0$ $PR_{bolt.lum} = 0$ $PR_{baseplate.lum} = 0$ $PR_{conn.plate.lum} = 0$

Upright Analysis

DataFile = "E1T1.dat"   WindSpeed = $130 \cdot mph$

Pole Properties

Current Values / New Values

$Y_{pole} = 21.5\ ft$	21.5	*feet (UA)*
$Y_{arm.conn} = 20\ ft$	20	*feet (UB)*
$Diameter_{base.pole} = 14 \cdot in$		*inches, measured flat to flat (UD)*
$t_{wall.pole} = 0.375 \cdot in$		*inches (UE)*
$Gap = \begin{pmatrix} 8.5 \\ 0 \end{pmatrix} \cdot in$		*inches, clear distance between connection plate and upright*
		inches, use X to zero out

Common wall thicknesses:
0.1793 in.
0.2391 in.
0.25 in.
0.313 in.
0.375 in.
0.5 in.

Pole Properties

Summary - Upright Geometry

$Y_{pole} = 21.5\ ft$ $Y_{arm.conn} = 20\ ft$ $\alpha = 0 \cdot deg$ $Gap = \begin{pmatrix} 8.5 \\ 0 \end{pmatrix} \cdot in$

$Diameter_{tip.pole} = 10.99 \cdot in$ $Diameter_{base.pole} = 14 \cdot in$ $t_{wall.pole} = 0.375 \cdot in$

Upright Combined Stress Ratio and Deflections

$\max(CSR_{pole}) = 0.71$ $\max(\Delta_{x.dl}) = 0.75 \cdot in$ $\max(\Delta_{z.dl}) = 0 \cdot in$

Mast Arm Connection(s) Analysis

DataFile = "E1T1.dat" WindSpeed = $130 \cdot \text{mph}$

Connection Properties

Current Values

$h_{conn.plate} = 22 \cdot \text{in}$

$t_{vertical.plate} = \begin{pmatrix} 0.5 \\ 0 \end{pmatrix} \cdot \text{in}$

$d_{bolt.conn} = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \cdot \text{in}$

$t_{baseplate.arm} = \begin{pmatrix} 2 \\ 0 \end{pmatrix} \cdot \text{in}$

Connection Properties

New Values

☐ *inches, for two arm Mast Arms both connection plate heights must be equal (HT)*

☐ *inches (FL)*

☐ *inches, use X to zero out (SL)*

☐ *inches (FP)*

☐ *inches, use X to zero out (SP)*

☐ *inches (FK)*

☐ *inches, use X to zero out (SK)*

Summary - Connection Geometry

$h_{conn.plate} = 22 \cdot in$ $Gap = \begin{pmatrix} 8.5 \\ 0 \end{pmatrix} \cdot in$ $Offset_{conn} = \begin{pmatrix} 14.1 \\ 0 \end{pmatrix} \cdot in$

$d_{bolt.conn} = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \cdot in$ $\#ConnBolts = \begin{pmatrix} 6 \\ 0 \end{pmatrix}$ $Spacing_{bolts.conn} = \begin{pmatrix} 9 \\ 0 \end{pmatrix} \cdot in$

$t_{conn.plate} = \begin{pmatrix} 1.625 \\ 0 \end{pmatrix} \cdot in$ $b_{conn.plate} = \begin{pmatrix} 21 \\ 0 \end{pmatrix} \cdot in$ $t_{vertical.plate} = \begin{pmatrix} 0.5 \\ 0 \end{pmatrix} \cdot in$ $t_{baseplate.arm} = \begin{pmatrix} 2 \\ 0 \end{pmatrix} \cdot in$

$w_{conn.plate} = \begin{pmatrix} 0.3125 \\ 0 \end{pmatrix} \cdot in$ $w_{vertical.plate} = \begin{pmatrix} 0.25 \\ 0 \end{pmatrix} \cdot in$

Connection Ratios

$PR_{bolt} = \begin{pmatrix} 0.496 \\ 0 \end{pmatrix}$ $CSR_{t.vert.plate} = \begin{pmatrix} 0.555 \\ 0 \end{pmatrix}$ $PR_{t.baseplate.arm} = \begin{pmatrix} 0.839 \\ 0 \end{pmatrix}$ $PR_{t.connplate.arm} = \begin{pmatrix} 0.924 \\ 0 \end{pmatrix}$

Base Plate Analysis

DataFile = "E1T1.dat" WindSpeed = $130 \cdot mph$

Base Plate Properties

Current Values

New Values

$\#AnchorRods = 6$ ☐ *use 6 bolts minimum*

$d_{bolt.pole} = 1.5 \cdot in$ ☐ *inches (BC)*

Base Plate Properties

Summary - Upright Base Plate Geometry

$\#AnchorRods = 6$ $d_{bolt.pole} = 1.5 \cdot in$ $t_{baseplate.pole} = 2.5 \cdot in$ $Diameter_{baseplate.pole} = 26 \cdot in$

Upright Base Plate Performance Ratios

$PR_{rod} = 0.734$ $PR_{plate.pole} = 1$

Foundation Analysis Cohesionless or Cohesive Soil

DataFile = "E1T1.dat"

Soil Properties

Current Values

New Values

○ Clay

SoilType = 1 ● Sand *0 - clay 1 - sand*

$\phi_{soil} = 28 \cdot deg$ 28 *degrees, soil friction angle (sand)*

$c_{soil} = 2000 \cdot psf$ ☐ *psf, soil shear strength (clay)*

$\gamma_{soil.dry} = 100 \cdot pcf$ 100 *pcf, dry soil weight*

$\gamma_{water} = 62.4 \cdot pcf$ ☐ *pcf, water weight (zero if no water)*

$\gamma_{soil} := \gamma_{soil.dry} - \gamma_{water}$ $\gamma_{soil} = 37.60 \cdot pcf$

Soil Properties

Analyze Foundation

Switch values, set values for DataOut, and Write Out Data to DataFile and Temp.dat

$out := out + 1$ $out = 35.00$

$SoilType := if(newSoilType = 0, 0, 1)$ $data_{out} := SoilType$ $data_{out} = 1.00$

$out := out + 1$ $out = 36.00$

$\phi_{soil} := fSwitchData(\phi_{soil}, new\phi_{soil}, deg)$ $data_{out} := \frac{\phi_{soil}}{deg}$ $data_{out} = 28$

$out := out + 1$ $out = 37.00$

$c_{soil} := fSwitchData(c_{soil}, newc_{soil}, psf)$ $data_{out} := \frac{c_{soil}}{psf}$ $data_{out} = 2000$

$out := out + 1$ $out = 38.00$

$\gamma_{soil.dry} := fSwitchData(\gamma_{soil.dry}, new\gamma_{soil.dry}, pcf)$ $data_{out} := \frac{\gamma_{soil.dry}}{pcf}$ $data_{out} = 100.00$

$out := out + 1$ $out = 39.00$

$\gamma_{water} := fSwitchData(\gamma_{water}, new\gamma_{water}, pcf)$ $data_{out} := \frac{\gamma_{water}}{pcf}$ $data_{out} = 62.40$

$out := out + 1$ $out = 40.00$

Subject := if(newSubject = 0, Subject, newSubject) $data_{out}$:= Subject

$data_{out}$ = "E1-T1 Mast Arm"

$out := out + 1$ $out = 41.00$

ProjectNo := if(**newProjectNumber** = 0 , **ProjectNo**, **newProjectNumber**)

data_{out} := **ProjectNo**

data_{out} = "00193008015"

out := out + 1   out = 42.00

PoleLocation := if(**newPoleLocation** = 0 , **PoleLocation**, **newPoleLocation**)

data_{out} := **PoleLocation**

data_{out} = "ID No.1"

out := out + 1   out = 43.00

Date := if(**newDate** = 0 , **Date**, **newDate**)

data_{out} := **Date**

data_{out} = "12/4/2012"

out := out + 1   out = 44.00

DesignedBy := if(**newDesignedBy** = 0 , **DesignedBy**, **newDesignedBy**)

data_{out} := **DesignedBy**

data_{out} = "MAV"

out := out + 1   out = 45.00

CheckedBy := if(**newCheckedBy** = 0 , **CheckedBy**, **newCheckedBy**)

data_{out} := **CheckedBy**

data_{out} = "FDOT"

WRITEPRN(DataFile) := data   WRITEPRN("temp.dat") := data

Foundation Design References

LRFD = AASHTO LRFD Bridge Design Specifications

SM V9 = FDOT Structures Manual Volume 9

SDG = FDOT Structures Design Guidelines

Spec = FDOT Standard Specifications

ACI = ACI 318 Structural Concrete Building Code

UF Report = FDOT/University of Florida Report BD545 RPWO #54

Applied Loads

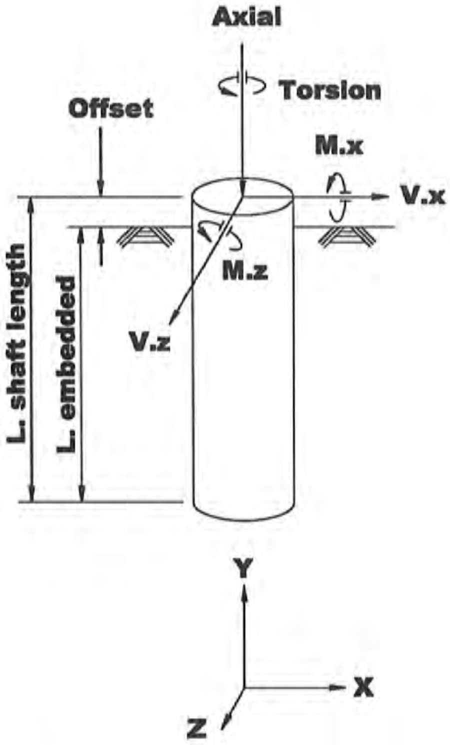
(From Arm1 Design)

WindSpeed = 130.00·mph

(from Base Plate Design)

#AnchorRods = 6.00 $d_{\text{bolt.pole}} = 1.50\cdot\text{in}$ $\text{Diameter}_{\text{boltcircle.pole}} = 20\cdot\text{in}$ $T_{\text{u.rod}} = 39.8\cdot\text{kip}$

(from Upright Design)



$M_{x.polebase} = \begin{pmatrix} 0 \\ 96.9 \\ 96.9 \end{pmatrix} \cdot kip \cdot ft$ $M_{y.polebase} = \begin{pmatrix} 77.2 \\ 0 \\ 77.2 \end{pmatrix} \cdot kip \cdot ft$ $M_{z.polebase} = \begin{pmatrix} 0 \\ 20.7 \\ 20.7 \end{pmatrix} \cdot kip \cdot ft$

LoadCaseT = 0.00
LoadCaseOT = 1.00
LoadCaseCSR = 2.00

$V_{x.polebase} = \begin{pmatrix} 0 \\ 0.2 \\ 0.2 \end{pmatrix} \cdot kip$ $AxialForce_{polebase} = \begin{pmatrix} 2.2 \\ 2.2 \\ 2.2 \end{pmatrix} \cdot kip$ $V_{z.polebase} = \begin{pmatrix} 0 \\ 5.2 \\ 5.2 \end{pmatrix} \cdot kip$

Foundation Diameter

$Diameter_{shaft} := Diameter_{boltcircle.pole} + 12 \cdot in + 12 \cdot in$ $Diameter_{shaft} = 3.67 \cdot ft$

round shaft diameter up to the nearest half foot dimension to accommodate available coring equipment

$Diameter_{shaft} := Ceil\left(Diameter_{shaft}, \frac{1}{2} \cdot ft\right)$ $Diameter_{shaft} = 4.00\ ft$

$b := Diameter_{shaft}$

Shaft Depth Required to Resist Overturning

$SF_{ot} := 2$ *Safety Factor against Overturning* *SM V9 13.6* $Offset := 1.0\cdot ft$ *vertical distance between top of foundation and groundline*

$$M_{total} := SF_{ot}\cdot\frac{\sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2}}{C_{a.pole}} \qquad M_{total} = 198.9\cdot kip\cdot ft$$

$$P_{total} := SF_{ot}\cdot\sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2} \qquad P_{total} = 10.4\cdot kip$$

short free-head pile in cohesionless soil using Broms method

$$K_p := \tan\left(45\cdot deg + \frac{\phi_{soil}}{2}\right)^2 \qquad e_{sand} := Offset$$

Guess value $L_{otSand} := 8\cdot ft$

Given $$\frac{\gamma_{soil}\cdot b\cdot L_{otSand}^{\ 3}\cdot K_p}{2} - P_{total}\cdot\left(e_{sand} + L_{otSand}\right) - M_{total} = 0\cdot kip\cdot ft$$

$Temp := Find\left(L_{otSand}\right)$ $L_{otSand} := Temp$ $L_{otSand} = 11.67\cdot ft$

(round up to next foot) $L_{otSand} := ceil\left(\frac{L_{otSand}}{ft}\right)\cdot ft$ $L_{otSand} = 12.00\,ft$

$$PR_{otSand} := \frac{M_{total} + P_{total}\cdot\left(e_{sand} + L_{otSand}\right)}{\frac{\gamma_{soil}\cdot b\cdot L_{otSand}^{\ 3}\cdot K_p}{2}} \qquad PR_{otSand} = 0.93$$

short free-head pile in cohesive soil using Modified Broms method for L < 3b (see reference file for derivation)

$$c_{soil} := if\left(c_{soil} = 0\cdot ksf, 0.1\cdot ksf, c_{soil}\right) \qquad Slope := 8\cdot\frac{c_{soil}}{3\cdot b} \qquad e_{clay} := \frac{M_{total}}{P_{total}} + Offset$$

$$nforce(M,N) := \left[Slope\cdot(2\cdot M + N) + 2\cdot c_{soil}\right]\cdot N\cdot\frac{b}{2} \qquad mforce(M) := \left(2\cdot c_{soil} + M\cdot Slope\right)\cdot M\cdot\frac{b}{2}$$

$$m\_arm(M) := e_{clay} + \frac{M}{3}\cdot\frac{2\cdot\left(M\cdot Slope + c_{soil}\right) + c_{soil}}{M\cdot Slope + 2\cdot c_{soil}}$$

$$n\_arm(M,N) := e_{clay} + M + \frac{N}{3}\cdot\frac{2\cdot\left(N\cdot Slope + M\cdot Slope + c_{soil}\right) + \left(M\cdot Slope + c_{soil}\right)}{Slope\cdot(2\cdot M + N) + 2\cdot c_{soil}}$$

Guess value $M := 4.0\cdot ft$ $N := 4.0\cdot ft$

Given $P_{total} + nforce(M,N) = mforce(M)$ $mforce(M)\cdot m\_arm(M) = nforce(M,N)\cdot n\_arm(M,N)$

$\begin{pmatrix} M \\ N \end{pmatrix} := \mathrm{Find}(M,N)$ $L_{ot1Clay.temp} := M + N$ $L_{ot1Clay.temp} = 6.68 \cdot ft$

(round up to next foot) $L_{ot1Clay} := \mathrm{ceil}\left(\frac{L_{ot1Clay.temp}}{ft}\right)\cdot ft$ $L_{ot1Clay} = 7.00 \cdot ft$

short free-head pile in cohesive soil using Regular Broms method for L > 3b

$f_{clay} := \frac{P_{total}}{9 \cdot c_{soil} \cdot b}$ $M_{maxtemp} := P_{total} \cdot (e_{clay} + 1.5 \cdot b + 0.5 \cdot f_{clay})$ $g := \sqrt{\frac{M_{maxtemp}}{2.25 \cdot c_{soil} \cdot b}}$

$L_{ot2Clay} := (1.5 \cdot b + f_{clay} + g)$ $L_{ot2Clay} = 10.04\,ft$

(round up to next foot) $L_{ot2Clay} := \mathrm{ceil}\left(\frac{L_{ot2Clay}}{ft}\right)\cdot ft$ $L_{ot2Clay} = 11.00 \cdot ft$

$L_{otClay} := \mathrm{if}(L_{ot1Clay} < 3 \cdot b, L_{ot1Clay}, L_{ot2Clay})$ $L_{otClay} = 7.00 \cdot ft$

(If $L_{ot} < 3b$, use Modified Broms method)

$$PR_{otClay} := \mathrm{if}\left(L_{otClay} < 3 \cdot b, \frac{L_{ot1Clay.temp}}{L_{ot1Clay}}, \frac{\sqrt{\frac{M_{maxtemp}}{2.25 \cdot c_{soil} \cdot b}} + \frac{P_{total}}{9 \cdot c_{soil} \cdot b}}{L_{ot2Clay} - 1.5 \cdot b}\right) \qquad PR_{otClay} = 0.95$$

$L_{reqdOT} := \mathrm{if}(\mathrm{SoilType} = 1, L_{otSand}, L_{otClay})$ $L_{reqdOT} = 12.00\,ft$

$PR_{ot} := \mathrm{if}(\mathrm{SoilType} = 1, PR_{otSand}, PR_{otClay})$ $PR_{ot} = 0.93$

Shaft Depth Required to Resist Torsion

$SF_{tor} := \mathbf{1.0}$ *Safety Factor against Torsion*
1.0 for Mast Arm signal structures

SM V9 13.6

NOTE: ω_{fdot} and μ are based upon CONCRETE and soil interaction. ***This torsion methodology is not to be used with permanent casing.***

$N_{blows} := 15$ *Number of blows per foot. If N< 5, contact the district geotech Engineer*

$\omega_{fdot} := \mathrm{if}\left(N_{blows} < 5, 0, \mathrm{if}\left(N_{blows} \ge 15, 1.5, 1.5 \cdot \frac{N_{blows}}{15}\right)\right) = 1.50$ *load transfer ratio*

$\mu := \tan(\phi_{soil}) = 0.53$ *coefficient of friction between concrete shaft and soil*

$\gamma_{concrete} := 150 \cdot pcf$ $\gamma_{concrete} := \gamma_{concrete} - \gamma_{water}$ $\gamma_{concrete} = 87.60 \cdot pcf$

$\text{CohesionFactor} := 0.55$ $f_{se} := \text{CohesionFactor} \cdot c_{soil}$

$\text{Torsion} := SF_{tor} \cdot {M_{y.polebase}}_{LoadCaseT}$ $\text{Torsion} = 77.2 \cdot \text{kip} \cdot \text{ft}$

short free-head pile in cohesionless soil

Guess value $L_{torSand} := L_{reqdOT}$

Given

$$\text{Torsion} = \frac{\left[\pi \cdot b \cdot (L_{torSand}) \cdot \gamma_{soil} \cdot \left(\frac{L_{torSand}}{2}\right) \cdot (\omega_{fdot}) \cdot \frac{b}{2} + \pi \cdot \left(\frac{b}{2}\right)^2 \cdot L_{torSand} \cdot (\gamma_{concrete}) \cdot \frac{b}{3} \cdot \mu\right]}{SF_{tor}}$$

$\text{Temp} := \text{Find}(L_{torSand})$ $L_{torSand} := \text{Temp}$ $L_{torSand} = 9.9\,\text{ft}$

(round up to next foot) $L_{torSand} := \text{ceil}\left(\frac{L_{torSand}}{\text{ft}}\right) \cdot \text{ft}$ $L_{torSand} = 10.00\,\text{ft}$

$$PR_{torSand} := \frac{\text{Torsion} \cdot SF_{tor}}{\pi \cdot b \cdot (L_{torSand}) \cdot \gamma_{soil} \cdot \left(\frac{L_{torSand}}{2}\right) \cdot (\omega_{fdot}) \cdot \frac{b}{2} + \pi \cdot \left(\frac{b}{2}\right)^2 \cdot L_{torSand} \cdot (\gamma_{concrete}) \cdot \frac{b}{3} \cdot \mu}$$ $PR_{torSand} = 0.98$

short free-head pile in cohesive soil

Guess value $L_{torClay} := L_{reqdOT}$

Given $\left[f_{se} \cdot (\pi \cdot b) \cdot (L_{torClay} - 1.5 \cdot \text{ft}) \cdot \frac{b}{2}\right] + \left[f_{se} \cdot \pi \cdot \left(\frac{b}{2}\right)^2 \cdot \left(\frac{b}{3}\right)\right] = \text{Torsion} \cdot SF_{tor}$

$\text{Temp} := \text{Find}(L_{torClay})$ $L_{torClay} := \text{Temp}$ $L_{torClay} = 3.63\,\text{ft}$

(round up to next foot) $L_{torClay} := \text{ceil}\left(\frac{L_{torClay}}{\text{ft}}\right) \cdot \text{ft}$ $L_{torClay} = 4.00\,\text{ft}$

$$PR_{torClay} := \frac{\text{Torsion} \cdot SF_{tor}}{\left[f_{se} \cdot (\pi \cdot b) \cdot (L_{torClay} - 1.5 \cdot \text{ft}) \cdot \frac{b}{2}\right] + \left[f_{se} \cdot \pi \cdot \left(\frac{b}{2}\right)^2 \cdot \left(\frac{b}{3}\right)\right]}$$ $PR_{torClay} = 0.88$

$L_{reqdTor} := \text{if}(\text{SoilType} = 1, L_{torSand}, L_{torClay})$ $L_{reqdTor} = 10.00\,\text{ft}$

$PR_{tor} := \text{if}(\text{SoilType} = 1, PR_{torSand}, PR_{torClay})$ $PR_{tor} = 0.98$

$L_{embedded} := \text{if}(L_{reqdTor} > L_{reqdOT}, L_{reqdTor}, L_{reqdOT})$ $L_{embedded} = 12.00\,\text{ft}$

$L_{shaft} := L_{embedded} + Offset$ $L_{shaft} = 13.00\,ft$

$PR_{foundation} := if(L_{reqdTor} > L_{reqdOT}, PR_{tor}, PR_{ot})$ $PR_{foundation} = 0.93$

Unfactored Maximum Moment in Shaft

short free-head pile in cohesionless soil using Broms method

$$f_{sand} := \sqrt{\frac{2 \cdot \frac{P_{total}}{SF_{ot}}}{3 \cdot \gamma_{soil} \cdot b \cdot K_p}} \qquad f_{sand} = 2.89\,ft$$

$$M_{maxSand} := \frac{P_{total}}{SF_{ot}} \cdot (e_{sand} + f_{sand}) - \frac{\frac{P_{total}}{SF_{ot}} \cdot f_{sand}}{3} + \frac{M_{total}}{SF_{ot}} \qquad M_{maxSand} = 114.7 \cdot kip \cdot ft$$

short free-head pile in cohesive soil using Modified Broms method for L < 3b (see reference file for derivation)

Guess value $f_{mod} := 4.0 \cdot ft$

Given $$\frac{P_{total}}{SF_{ot}} = \frac{f_{mod} \cdot b}{2} \cdot (2 \cdot c_{soil} + f_{mod} \cdot Slope)$$

$f_{mod} := Find(f_{mod})$ $f_{mod} = 0.55\,ft$

$$M_{modBroms} := \frac{P_{total}}{SF_{ot}} \cdot (e_{clay} + f_{mod}) - \frac{c_{soil} \cdot b \cdot f_{mod}^{2}}{2} - \frac{b \cdot f_{mod}^{3} \cdot Slope}{6} \qquad M_{modBroms} = 106.2 \cdot kip \cdot ft$$

short free-head pile in cohesive soil using Regular Broms method for L > 3b

$$M_{Broms} := \frac{P_{total}}{SF_{ot}} \cdot (e_{clay} + 1.5 \cdot b + 0.5 \cdot f_{clay}) \qquad M_{Broms} = 136.3 \cdot kip \cdot ft$$

$M_{maxClay} := if(L_{ot1Clay} < 3 \cdot b, M_{modBroms}, M_{Broms})$ $M_{maxClay} = 106.2 \cdot kip \cdot ft$

(If $L_{ot} < 3b$, use Modified Broms method)

$M_{max} := if(SoilType = 1, M_{maxSand}, M_{maxClay})$ *(this is a Service moment)* $M_{max} = 114.7 \cdot kip \cdot ft$

Minimum Reinforcing and Spacing

$F_{y.rebar} :=$ **60**$\cdot ksi$ *reinforcing yield strength*

$f_c :=$ **4.0**$\cdot ksi$ *concrete strength* *Spec 346-3*

$\text{cover} := \mathbf{6} \cdot \text{in}$ *cover* ***SDG Table 1.4.2-1***

$A_{bar} := \mathbf{1.56} \cdot \text{in}^2$ *longitudinal bar area*

$d_{bar} := \mathbf{1.41} \cdot \text{in}$ *longitudinal bar diameter*

$A_{v.bar} := \mathbf{0.31} \cdot \text{in}^2$ *stirrup area* ***SM V9 13.6.2***

$d_{v.bar} := \mathbf{0.625} \cdot \text{in}$ *stirrup diameter*

$s_{v1} := \mathbf{4} \cdot \text{in}$ *stirrup spacing, depth = 0 ft-2 ft* ***SM V9 13.6.2***

$s_{v2} := \mathbf{12} \cdot \text{in}$ *stirrup spacing, depth = 2 ft-depth.stir*

$s_{v3} := \mathbf{12} \cdot \text{in}$ *stirrup spacing, depth > depth.stir*

$\text{depth}_{stir} := 9.0 \cdot \text{ft}$ *stirrup depth, see s.v2 and s.v3 above*

$b = 4.00\ \text{ft}$ *shaft diameter*

$\text{BarsProv}_1 := \frac{0.01}{A_{bar}} \cdot \frac{\pi \cdot b^2}{4}$ $\text{BarsProv}_1 = 11.60$ ***LRFD 5.7.4.2***

$\text{BarsProv}_2 := \frac{0.135}{A_{bar} \cdot F_{y.rebar}} \cdot \left(\frac{\pi \cdot b^2}{4} \cdot f_c \right)$ $\text{BarsProv}_2 = 10.44$

$\text{BarsProv} := \text{ceil}\left(\max\left(\text{BarsProv}_1, \text{BarsProv}_2\right)\right)$ $\text{BarsProv} = 12.00$ *number of longitudinal bars*

$\text{NumSpaces}_{v.bar} := \text{round}\left(\frac{\text{depth}_{stir} - 2 \cdot \text{ft}}{s_{v2}} \right)$ $\text{NumSpaces}_{v.bar} = 7.00$

$\text{ReinfClearSpacing} := \left[b - 2 \cdot \left(\text{cover} + d_{v.bar} + \frac{d_{bar}}{2} \right) \right] \cdot \frac{\pi}{\text{BarsProv}} - d_{bar}$ $\text{ReinfClearSpacing} = 7.32 \cdot \text{in}$

CheckReinfClearSpacing := if(ReinfClearSpacing ≥ 6in, "OK" , "No Good") CheckReinfClearSpacing = "OK"

SDG 3.6.10

Check Shear and Torsion

$LF_{shr} := \mathbf{1.3}$ *Shear Load Factor* *1.3 is a reasonable Load Factor for combined WL + DL on sign*

$LF_{tor} := \mathbf{1.3}$ *Torsion Load Factor* *and signal structures*

$\phi_{shr} := \mathbf{0.90}$ *Shear Resistance Factor* ***LRFD 5.5.4.2.1***

$\phi_{tor} := \mathbf{0.90}$ *Torsion Resistance Factor* ***LRFD 5.5.4.2.1***

$$V_u := LF_{shr} \cdot \sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2} \qquad V_u = 6.8 \cdot kip$$

$$T_u := LF_{tor} \cdot Torsion \qquad T_u = 100.41 \cdot kip \cdot ft$$

Area and perimeter of concrete cross-section

$$A_{cp} := \pi \cdot \left(\frac{b}{2}\right)^2 \qquad A_{cp} = 1809.6 \cdot in^2$$

$$p_{cp} := 2 \cdot \pi \cdot \left(\frac{b}{2}\right) \qquad p_{cp} = 150.8 \cdot in$$

Diameter, perimeter and area enclosed by the centerline of the outermost closed transverse torsion reinforcement

$$d_{oh} := b - 2 \cdot \left(cover + \frac{d_{v.bar}}{2}\right) \qquad d_{oh} = 35.4 \cdot in$$

$$p_h := \pi \cdot d_{oh} \qquad p_h = 111.1 \cdot in$$

$$A_{oh} := \pi \left(\frac{d_{oh}}{2}\right)^2 \qquad A_{oh} = 982.8 \cdot in^2$$

$$A_o := 0.85 \cdot A_{oh} \qquad A_o = 835.4 \cdot in^2$$

LRFD C5.8.2.1

Effective shear depth

$$D_r := b - 2 \cdot \left(cover + d_{v.bar} + \frac{d_{bar}}{2}\right) \qquad d_e := \frac{b}{2} + \frac{D_r}{\pi} = 2.88\,ft$$

$$d_v := \max\left(0.9 \cdot d_e, 0.72 \cdot b\right) = 2.88\,ft$$

LRFD C5.8.2.1

Check Shear Strength

$$V_c := 0.0316 \cdot (2.0) \cdot \sqrt{\frac{f_c}{ksi}} \cdot \left(\frac{d_v}{in}\right) \cdot \left(\frac{b}{in}\right) \cdot kip \qquad V_c = 209.7 \cdot kip$$

LRFD Eqn 5.8.3.3-3

LRFD 5.8.3.4.1

ACI 11.3.3

$$V_s := \frac{A_{v.bar} \cdot F_{y.rebar} \cdot \left(d_v\right)}{\max\left(s_{v1}, s_{v2}, s_{v3}\right)} \qquad V_s = 53.6 \cdot kip$$

LRFD Eqn 5.8.3.3-4

$$\phi_{shr} = 0.90 \qquad V_u = 6.8 \cdot kip$$

$$ShearRatio := \frac{V_u - \phi_{shr} \cdot V_c}{\phi_{shr} \cdot V_s} \qquad ShearRatio = -3.77$$

$\text{ShearRatio} := \text{if}(\text{ShearRatio} \le 0, 0, \text{ShearRatio})$ $\text{ShearRatio} = 0.00$

Check Torsion Strength

$$T_{n1} := \frac{2 \cdot A_o \cdot A_{v.bar} \cdot F_{y.rebar}}{s_{v1}} \qquad T_{n1} = 647.4 \cdot \text{kip} \cdot \text{ft}$$

LRFD Eqn 5.8.3.6.2-1

LRFD 5.8.3.4.1

$$T_{n2} := \frac{2 \cdot A_o \cdot A_{v.bar} \cdot F_{y.rebar}}{s_{v2}} \qquad T_{n2} = 215.8 \cdot \text{kip} \cdot \text{ft}$$

$$T_{n3} := \frac{2 \cdot A_o \cdot A_{v.bar} \cdot F_{y.rebar}}{s_{v3}} \qquad T_{n3} = 215.8 \cdot \text{kip} \cdot \text{ft}$$

$\phi_{tor} = 0.90$ $\qquad T_u = 100.41 \cdot \text{kip} \cdot \text{ft}$ $\qquad L_{reqdTor} = 10.00\,\text{ft}$

$$\text{Tor2}_{sand} := T_u - \max\left[\left[\pi \cdot b \cdot (2 \cdot \text{ft} - \text{Offset}) \cdot \gamma_{soil} \cdot \left(\frac{2 \cdot \text{ft} - \text{Offset}}{2}\right) \cdot (\omega_{fdot}) \cdot \frac{b}{2}\right], 0 \cdot \text{kip} \cdot \text{ft}\right] \qquad \text{Tor2}_{sand} = 99.7 \cdot \text{kip} \cdot \text{ft}$$

$$\text{Tor3}_{sand} := T_u - \max\left[\left[\pi \cdot b \cdot (\text{depth}_{stir} - \text{Offset}) \cdot \gamma_{soil} \cdot \left(\frac{\text{depth}_{stir} - \text{Offset}}{2}\right) \cdot (\omega_{fdot}) \cdot \frac{b}{2}\right], 0 \cdot \text{kip} \cdot \text{ft}\right] \qquad \text{Tor3}_{sand} = 55.1 \cdot \text{kip} \cdot \text{ft}$$

$$\text{Tor2}_{clay} := T_u - \max\left[\left[f_{se} \cdot (\pi \cdot b) \cdot (2.0 \cdot \text{ft} - \text{Offset} - 1.5 \cdot \text{ft}) \cdot \frac{b}{2}\right], 0 \cdot \text{kip} \cdot \text{ft}\right] \qquad \text{Tor2}_{clay} = 100.41 \cdot \text{kip} \cdot \text{ft}$$

$$\text{Tor3}_{clay} := T_u - \max\left[\left[f_{se} \cdot (\pi \cdot b) \cdot (\text{depth}_{stir} - \text{Offset} - 1.5 \cdot \text{ft}) \cdot \frac{b}{2}\right], 0 \cdot \text{kip} \cdot \text{ft}\right] \qquad \text{Tor3}_{clay} = -79.29 \cdot \text{kip} \cdot \text{ft}$$

$$\text{Tor2} := \text{if}(\text{SoilType} = 1, \text{Tor2}_{sand}, \text{Tor2}_{clay}) \qquad \text{Tor2} = 99.70 \cdot \text{kip} \cdot \text{ft}$$

$$\text{Tor3} := \text{if}(\text{SoilType} = 1, \text{Tor3}_{sand}, \text{Tor3}_{clay}) \qquad \text{Tor3} = 55.05 \cdot \text{kip} \cdot \text{ft}$$

$$\text{TorsionRatio}_{n1} := \frac{T_u}{\phi_{tor} \cdot T_{n1}} \qquad \text{TorsionRatio}_{n1} = 0.17$$

$$\text{TorsionRatio}_{n2} := \frac{\text{Tor2}}{\phi_{tor} \cdot T_{n2}} \qquad \text{TorsionRatio}_{n2} = 0.51$$

$$\text{TorsionRatio}_{n3} := \frac{\text{Tor3}}{\phi_{tor} \cdot T_{n3}} \qquad \text{TorsionRatio}_{n3} = 0.28$$

$$\text{TorsionRatio} := \max(\text{TorsionRatio}_{n1}, \text{TorsionRatio}_{n2}, \text{TorsionRatio}_{n3}) \qquad \text{TorsionRatio} = 0.51$$

$$T_{cr} := 0.125\sqrt{\frac{f_c}{\text{ksi}}} \cdot \left(\frac{A_{cp}^{\;2}}{p_{cp} \cdot \text{in}^3}\right) \cdot \text{kip} \cdot \text{in} \qquad T_{cr} = 452.4 \cdot \text{kip} \cdot \text{ft}$$

LRFD Eqn 5.8.2.1-4

$\text{TorsionRatio} := \text{if}\left(T_u \le 0.25 \cdot \phi_{tor} \cdot T_{cr}, 0, \text{TorsionRatio}\right)$ $\text{TorsionRatio} = 0.00$ ***LRFD Eqn 5.8.2.1-3***

$\text{ShearRatio} = 0.00$

$\text{CheckShearTorsion} := \text{if}(\text{ShearRatio} + \text{TorsionRatio} \le 1, \text{"OK"}, \text{"No Good"})$ $\text{CheckShearTorsion} = \text{"OK"}$

Check Maximum Spacing Transverse Reinforcement

$$vu := \frac{V_u}{\phi_{shr} \cdot b \cdot (0.8 \cdot b)}$$

$vu = 0.004087 \cdot \text{ksi}$ ***LRFD Eqn 5.8.2.9-1***

$0.125 \cdot f_c = 0.50 \cdot \text{ksi}$

$s_{max1} := \text{if}\left(0.8 \cdot d_v < 24 \cdot \text{in}, 0.8 \cdot d_v, 24 \cdot \text{in}\right)$ $s_{max1} = 24 \cdot \text{in}$ ***LRFD Eqn 5.8.2.7-1***

$s_{max2} := \text{if}\left(0.4 \cdot d_v < 12 \cdot \text{in}, 0.4 \cdot d_v, 12 \cdot \text{in}\right)$ $s_{max2} = 12 \cdot \text{in}$ ***LRFD Eqn 5.8.2.7-2***

$s_{max} := \text{if}\left(vu < 0.125 \cdot f_c, s_{max1}, s_{max2}\right)$ $s_{max} = 24 \cdot \text{in}$

$\max\left(s_{v1}, s_{v2}, s_{v3}\right) = 12.00 \cdot \text{in}$

$\text{CheckMaxSpacingTransvReinf} := \text{if}\left(\max\left(s_{v1}, s_{v2}, s_{v3}\right) \le s_{max}, \text{"OK"}, \text{"No Good"}\right)$ $\text{CheckMaxSpacingTransvReinf} = \text{"OK"}$

Check Longitudinal Reinforcement for Combined Shear and Torsion   ***LRFD Eqn 5.8.3.6.3-1***

LRFD 5.8.3.4.1

$$M_u := LF_{tor} \cdot \sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2}$$

$M_u = 128.8 \cdot \text{kip} \cdot \text{ft}$

$$V_{temp} := \text{if}\left(\frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s > 0 \cdot \text{kip}, \frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s, 0 \cdot \text{kip}\right)$$

$V_{temp} = 0 \cdot \text{kip}$

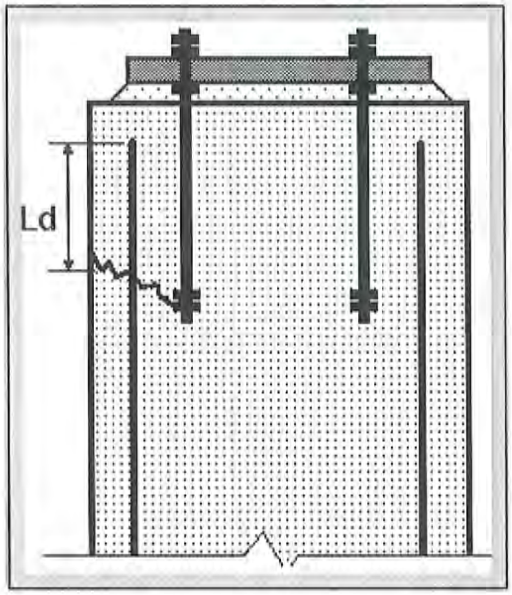
$$\text{LongReinf}_{shr.tor} := \frac{\dfrac{M_u}{\phi_{tor} \cdot (0.8 \cdot b)} + \sqrt{\left(\dfrac{V_{temp}}{\text{kip}}\right)^2 + \left(\dfrac{0.45 \cdot p_h \cdot T_u}{2 \cdot A_o \cdot \phi_{tor} \cdot \text{kip}}\right)^2} \cdot \text{kip}}{F_{y.rebar}}$$

$\text{LongReinf}_{shr.tor} = 1.41 \cdot \text{in}^2$

$\text{BarsProv} \cdot A_{bar} = 18.72 \cdot \text{in}^2$

$\text{CheckLongReinf}_{shr.tor} := \text{if}\left(\text{BarsProv} \cdot A_{bar} \ge \text{LongReinf}_{shr.tor}, \text{"OK"}, \text{"No Good"}\right)$ $\text{CheckLongReinf}_{shr.tor} = \text{"OK"}$

Anchor Bolt Embedment



$$\mathrm{Gap_{shaft}} := \frac{b - 2\cdot \mathrm{cover} - 2\cdot d_{v.bar} - \mathrm{Diameter_{boltcircle.pole}} - d_{bar}}{2}$$

$\mathrm{Gap_{shaft}} = 6.67\cdot \mathrm{in}$

$\mathrm{Diameter_{rebar.circle}} := b - 2\cdot \mathrm{cover} - d_{bar} - 2\cdot d_{v.bar}$

$\mathrm{Diameter_{rebar.circle}} = 33.3\cdot \mathrm{in}$

$\mathrm{\#BarsProvided} := \mathrm{BarsProv}$ $\mathrm{\#BarsProvided} = 12.00$

$$\mathrm{\#BarsProvidedPerRod} := \min\left(\begin{pmatrix} \dfrac{\mathrm{\#BarsProvided}}{\mathrm{\#AnchorRods}} \\ 3 \end{pmatrix}\right)$$

Use a maximum of three rebar per anchor bolt (conservative)

$\mathrm{\#BarsProvidedPerRod} = 2.00$

$$\phi := 0.9 \qquad \mathrm{\#BarsReqdPerRod} := \frac{T_{u.rod}}{A_{bar}\cdot(\phi\cdot F_{y.rebar})}\cdot\frac{\mathrm{Diameter_{boltcircle.pole}}}{\mathrm{Diameter_{rebar.circle}}}$$

$\mathrm{\#BarsReqdPerRod} = 0.28$

$$\mathrm{AreaRatio} := \frac{\mathrm{\#BarsReqdPerRod}}{\mathrm{\#BarsProvidedPerRod}}$$

$\mathrm{AreaRatio} = 0.14$

$\mathrm{AreaRatio} := \mathrm{if}(\mathrm{AreaRatio} < 1, \mathrm{AreaRatio}, 1)$ $\mathrm{AreaRatio} = 0.14$

$$L_{d.bar} := \max\left[\begin{bmatrix} \dfrac{1.25\cdot(A_{bar})\cdot F_{y.rebar}}{\sqrt{f_c\cdot \mathrm{ksi}}\cdot \mathrm{in}} \\ \dfrac{0.4\cdot(d_{bar})\cdot F_{y.rebar}}{\mathrm{ksi}} \end{bmatrix}\right]$$

development length of bar ***LRFD 5.11.2.1.1***

$$L_{d.bar} := \mathrm{if}\left(A_{bar} = 2.25\cdot \mathrm{in}^2, \frac{2.70\cdot \mathrm{in}^2\cdot F_{y.rebar}}{\sqrt{f_c\cdot \mathrm{ksi}}\cdot \mathrm{in}}, L_{d.bar}\right)$$

$L_{d.bar} = 58.5\cdot \mathrm{in}$

$$\mathrm{SpacingFactor} := \max\left(\begin{pmatrix} \mathrm{\#BarsProvidedPerRod}\cdot 0.5 - 0.5 \\ 0.5 \end{pmatrix}\right)$$

$\mathrm{SpacingFactor} = 0.50$

$$L_{embedment.added} := \sqrt{(\mathrm{ReinfClearSpacing}\cdot \mathrm{SpacingFactor})^2 + \mathrm{Gap_{shaft}}^2}$$

$L_{embedment.added} = 7.6\cdot \mathrm{in}$

$$L_{embedment.rod} := \max\left[\begin{bmatrix} L_{d.bar}\cdot(\mathrm{AreaRatio}) + 12\cdot \mathrm{in} + L_{embedment.added} \\ 20\cdot d_{bolt.pole} \end{bmatrix}\right]$$

$L_{embedment.rod} := \mathrm{Ceil}(L_{embedment.rod}, in)$ $\quad L_{embedment.rod} = 30 \cdot in$

$L_{anchor.rod} := \mathrm{Ceil}[(L_{embedment.rod} + 8 \cdot in), in]$ $\quad L_{anchor.rod} = 38 \cdot in$

Anchor Bolt Shear Break-Out Strength

References:
ACI 318-05 Appendix D.
FDOT/University of Florida Report BD545 RPWO #54,
Anchor Embedment Requirements for Signal/Sign Structures, July 2007.

$\#AnchorRods = 6.00$ *number of anchor bolts*

$d_{bolt.pole} = 1.50 \cdot in$ *anchor bolt diameter*

$Diameter_{boltcircle.pole} = 20.00 \cdot in$ *anchor bolt circle diameter*

$L_{embedment.rod} = 30.00 \cdot in$ *anchor bolt embedment*

$b = 48.00 \cdot in$ *shaft diameter*

$r_b := \dfrac{Diameter_{boltcircle.pole}}{2}$ $\quad r_b = 10.00 \cdot in$

$r := \dfrac{b}{2}$ $\quad r = 24.00 \cdot in$

$c_{a1} := \dfrac{\sqrt{{r_b}^2 + 3.25 \cdot \left(r^2 - {r_b}^2\right)} - r_b}{3.25}$ $\quad c_{a1} = 9.41 \cdot in$ *adjusted cover*

UF Report Eqn 3-2

$L_e := \min(8 \cdot d_{bolt.pole}, L_{embedment.rod})$ $\quad L_e = 12.00 \cdot in$ *load bearing length of anchor for shear*

ACI D.6.2.2

$V_b := 13 \cdot \left(\dfrac{L_e}{d_{bolt.pole}}\right)^{0.2} \cdot \sqrt{\dfrac{d_{bolt.pole}}{in}} \cdot \sqrt{\dfrac{f_c}{psi}} \left(\dfrac{c_{a1}}{in}\right)^{1.5} \cdot lbf$ *shear break-out strength (single anchor)*

UF Report Eqn 2-11

$V_b = 44.1 \cdot kip$

$A := \dfrac{(360 \cdot deg)}{\#AnchorRods}$ $\quad A = 60 \cdot deg$ ***UF Report Fig 3-7***

$\text{alpha} := 2\,\text{asin}\left[\frac{(1.5\cdot c_{a1})}{r}\right]$ $\text{alpha} = 72.1\cdot\text{deg}$

OverlapTest := if(A ≤ alpha, "Overlap of Failure Cones" , "No Overlap of Failure Cones")

OverlapTest = "Overlap of Failure Cones"

$\text{chord} := 2\cdot r\cdot \sin\left(\frac{A}{2}\right)$ $\text{chord} = 24\cdot\text{in}$ ***UF Report Fig 3-7***

$A_{Vco} := 4.5\cdot {c_{a1}}^2$ $A_{Vco} = 398.5\cdot\text{in}^2$ *projected concrete failure area (single anchor)*
ACI Eqn D-23

$A_{Vc} := \text{chord}\cdot 1.5\cdot c_{a1}$ $A_{Vc} = 338.8\cdot\text{in}^2$ *projected concrete failure area (group)*
ACI D.6.2.1

$A_{Vc} := \text{if}\left(A_{Vc} > A_{Vco}, A_{Vco}, A_{Vc}\right)$ $A_{Vc} = 338.8\cdot\text{in}^2$

$\psi_{ecV} := \mathbf{1.0}$ *eccentric load modifier* ***ACI D.6.2.5***

$\psi_{edV} := \mathbf{1.0}$ *edge effect modifier* ***ACI D.6.2.6***

$\psi_{cV} := \mathbf{1.4}$ *cracked section modifier* ***ACI D.6.2.7*** *(stirrup spacing <= 4)'*

$\psi_{hV} := \mathbf{1.0}$ *member thickness modifier* ***ACI D.6.2.8***

$\phi_{breakout} := \mathbf{0.75}$ *strength reduction factor* ***ACI D.4.4.c.i*** *(shear breakout, condition A)*

$V_{cbg} := \#\text{AnchorRods}\cdot\left(\frac{A_{Vc}}{A_{Vco}}\right)\cdot\left(\psi_{ecV}\cdot\psi_{edV}\cdot\psi_{cV}\cdot\psi_{hV}\right)\cdot V_b$ $V_{cbg} = 314.6\cdot\text{kip}$ *concrete breakout strength - shear*
ACI Eqn D-22 *Shear force ⊥ to edge*

$V_{cbg\_parallel} := 2\cdot V_{cbg}$ $V_{cbg\_parallel} = 629.3\cdot\text{kip}$ ***ACI D.6.2.1.c*** *Shear force || to edge*

$T_{n.breakout} := V_{cbg\_parallel}\cdot r_b$ $T_{n.breakout} = 524.4\cdot\text{kip}\cdot\text{ft}$ *concrete breakout strength - torsion*

$\phi_{breakout}\cdot T_{n.breakout} = 393.3\cdot\text{kip}\cdot\text{ft}$

$T_u = 100.4\cdot\text{kip}\cdot\text{ft}$

BreakoutTest := if($\phi_{breakout}\cdot T_{n.breakout} \geq T_u$, "OK" , "No Good") BreakoutTest = "OK"

OverlapDesign := if(A ≤ α, "Based on Overlap of Failure Cones" , "Based on No Overlap of Failure Cones")

OverlapDesign = "Based on No Overlap of Failure Cones"

$M_{x.polebase} = \begin{pmatrix} 0.0 \\ 96.9 \\ 96.9 \end{pmatrix} \cdot kip \cdot$ $M_{y.polebase} = \begin{pmatrix} 77.2 \\ 0.0 \\ 77.2 \end{pmatrix} \cdot kip \cdot ft$ $M_{z.polebase} = \begin{pmatrix} 0.0 \\ 20.7 \\ 20.7 \end{pmatrix} \cdot kip \cdot ft$

maximum torsion (Mx & Mz not used)
maximum overturning (My not used)
maximum CSR

☐ Analyze Foundation

Summary - Soil Properties and Drilled Shaft Geometry

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

$\phi_{soil} = 28 \cdot deg$

$c_{soil} = 2000 \cdot psf$

$\gamma_{soil} = 37.6 \cdot pcf$

$Diameter_{shaft} = 4\ ft$

$L_{shaft} = 13\ ft$

$L_{embedment.rod} = 30 \cdot in$

$L_{anchor.rod} = 38.00 \cdot in$

#BarsProvided = 12

$d_{bar} = 1.41 \cdot in$

Foundation Performance Ratios

$PR_{foundation} = 0.929$

Fatigue Analysis

DataFile = "E1T1.dat"

WindSpeed = 130·mph

Use the member cross section adjacent to the weld toe to compute the nominal stress range. ***LTS 11.9***

FatigueCategory := 2 ***SM V9 11.6***

☐ Analyze Structure for Fatigue

Fatigue Importance Factors

LTS Table 11-1

Galloping: $I_{F.g}$:= if(FatigueCategory = 1, 1.0, if(FatigueCategory = 2, 0.65, 0.3)) = 0.65

Natural Wind Gusts: $I_{F.nw}$:= if(FatigueCategory = 1, 1.0, if(FatigueCategory = 2, 0.80, 0.55)) = 0.80

Vortex Shedding: No check. ***LTS Table 11-1***

Truck Gust: No check. ***LTS 11.7.4***

Constant Amplitude Fatigue Threshold

LTS Table 11-3

$CAFT_A := 24 \cdot ksi$

$CAFT_B := 16 \cdot ksi \quad CAFT_{B'} := 12 \cdot ksi$

$CAFT_C := 10 \cdot ksi$

$CAFT_D := 7 \cdot ksi$

$CAFT_E := 4.5 \cdot ksi \quad CAFT_{E'} := 2.6 \cdot ksi$

$CAFT_{ET} := 1.2 \cdot ksi$

$CAFT_{K2} := 1.0 \cdot ksi$

Galloping

LTS 11.7.1

Pressure: $Pressure_{galloping} := (21 \cdot psf) \cdot I_{F.g} = 13.65 \cdot psf$

Natural Wind Gust

LTS 11.7.3

$C_{d.nwg.tube} := 1.2$

Pressure: coefficient of drag will be added with each component $Pressure_{natural.wind.gust} := (5.2 \cdot psf) \cdot I_{F.nw} = 4.16 \cdot psf$

Arm and Pole Welds

*NOTE: *LTS = proposed for 2012*

****LTS 11.9.3.1***

$$^{**}\, b_{conn.plate} = \begin{pmatrix} 21.00 \\ 0.00 \end{pmatrix} \cdot in$$

***NOTE: For Standard Mastarms check Design Standard 17743 for arm plate width FJ.*

$D_{BC.arm1} := b_{conn.plate_0} - 4 \cdot d_{bolt.conn_0} = 17.00 \cdot in \quad D_{OP.arm1} := \max(Diameter_{base.arm1}) - 4 \cdot in = 7.00 \cdot in$

$D_{T.arm1} := \max(Diameter_{base.arm1}) = 11.00 \cdot in$

$D_{BC.arm2} := b_{conn.plate_1} - 4 \cdot d_{bolt.conn_1} = 0.00 \cdot in \quad D_{OP.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 10 \cdot in, \max(Diameter_{base.arm2}) - 4 \cdot in\right] = 10.00 \cdot in$

$D_{T.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 14 \cdot in, \max(Diameter_{base.arm2})\right] = 14.00 \cdot in$

$D_{BC.pole} := Diameter_{boltcircle.pole} = 20.00 \cdot in \quad D_{OP.pole} := Diameter_{base.pole} - 4 \cdot in = 10.00 \cdot in \quad D_{T.pole} := Diameter_{base.pole} = 14.00 \cdot in$

$$C_{BC.arm1} := \frac{D_{BC.arm1}}{D_{T.arm1}} = 1.55 \qquad C_{OP.arm1} := \frac{D_{OP.arm1}}{D_{T.arm1}} = 0.64 \qquad t_{T.arm1} := \max(t_{wall.arm1}) = 0.25 \cdot in$$

$$t_{TP.arm1} := t_{baseplate.arm_0} + t_{conn.plate_0} = 3.625 \cdot in$$

$$C_{BC.arm2} := \frac{D_{BC.arm2}}{D_{T.arm2}} = 0.00 \qquad C_{OP.arm2} := \frac{D_{OP.arm2}}{D_{T.arm2}} = 0.71 \qquad t_{T.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 0.1 \cdot in, \max(t_{wall.arm2})\right] = 0.1 \cdot in$$

$$t_{TP.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 0.1 \cdot in, t_{baseplate.arm_1} + t_{conn.plate_1}\right] = 0.1 \cdot in$$

$C_{BC.pole} := \frac{D_{BC.pole}}{D_{T.pole}} = 1.43$ $\quad C_{OP.pole} := \frac{D_{OP.pole}}{D_{T.pole}} = 0.71$ $\quad t_{T.pole} := t_{wall.pole} = 0.375\cdot in$ $\quad t_{TP.pole} := t_{baseplate.pole} = 2.5\cdot in$

*LTS Table 11-3, Eqn 11-13

$$K_{F.arm1} := 1.35 + 16\cdot\left(15\cdot\frac{t_{T.arm1}}{in}+1\right)\cdot\left(\frac{D_{T.arm1}}{in}-5\right)\cdot\left(\frac{C_{BC.arm1}{}^{0.02}-1}{4\cdot C_{OP.arm1}{}^{-0.7}-3}\right)\cdot\left(\frac{t_{TP.arm1}}{in}\right)^{-2} = 1.47$$

$$K_{F.arm2} := 1.35 + 16\cdot\left(15\cdot\frac{t_{T.arm2}}{in}+1\right)\cdot\left(\frac{D_{T.arm2}}{in}-5\right)\cdot\left(\frac{C_{BC.arm2}{}^{0.02}-1}{4\cdot C_{OP.arm2}{}^{-0.7}-3}\right)\cdot\left(\frac{t_{TP.arm2}}{in}\right)^{-2} = -1.75\times 10^{4}$$

valid for:

$0.179\cdot in \le t_T \le 0.625\cdot in$

$8\cdot in \le D_T \le 50\cdot in$

$2\cdot in \le t_{TP} \le 4\cdot in$

$\le C_{BC} \le 2.5$

$0.3 \le C_{OP} \le 0.9$

$$K_{F.pole} := 1.35 + 16\cdot\left(15\cdot\frac{t_{T.pole}}{in}+1\right)\cdot\left(\frac{D_{T.pole}}{in}-5\right)\cdot\left(\frac{C_{BC.pole}{}^{0.02}-1}{4\cdot C_{OP.pole}{}^{-0.7}-3}\right)\cdot\left(\frac{t_{TP.pole}}{in}\right)^{-2} = 1.88$$

$$K_{I.arm1} := \left[\left(1.76 + 1.83\cdot\frac{t_{T.arm1}}{in}\right) - 4.76\cdot 0.22^{K_{F.arm1}}\right]\cdot K_{F.arm1} = 2.51$$

$$K_{I.arm2} := \text{if}\left[\left(L_{total.arm2} = 0\cdot ft\right), 100, \left[\left(1.76 + 1.83\cdot\frac{t_{T.arm2}}{in}\right) - 4.76\cdot 0.22^{K_{F.arm2}}\right]\cdot K_{F.arm2}\right] = 100.00$$

$$K_{I.pole} := \left[\left(1.76 + 1.83\cdot\frac{t_{T.pole}}{in}\right) - 4.76\cdot 0.22^{K_{F.pole}}\right]\cdot K_{F.pole} = 4.08$$

*LTS Table 11-2, Detail 4.5

$$CAFT_{fullpengroove.weld.arm1} := \text{if}\left(K_{I.arm1} < 3.0, 10.0\cdot ksi, \text{if}\left(K_{I.arm1} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 10.00\cdot ksi$$

$$CAFT_{fullpengroove.weld.arm2} := \text{if}\left(K_{I.arm2} < 3.0, 10.0\cdot ksi, \text{if}\left(K_{I.arm2} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 4.50\cdot ksi$$

$$CAFT_{fullpengroove.weld.pole} := \text{if}\left(K_{I.pole} < 3.0, 10.0\cdot ksi, \text{if}\left(K_{I.pole} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 4.50\cdot ksi$$

Galloping Moment: $\quad base1 = 20 \quad base2 = 20 \quad polebase = 10$

$$M_{galloping.arm1.base} := \left(\frac{M_{wl.signal.arm1}{}_{base1}}{C_{d.signal}} + \frac{M_{wl.panel.arm1}{}_{base1}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 13.88\cdot kip\cdot ft$$

$$M_{galloping.arm2.base} := \left(\frac{M_{wl.signal.arm2}{}_{base2}}{C_{d.signal}} + \frac{M_{wl.panel.arm2}{}_{base2}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 0.00\cdot kip\cdot ft$$

$$M_{galloping.pole.base} := \max\left(M_{galloping.arm1.base}, M_{galloping.arm2.base}\right) = 13.88 \cdot kip \cdot ft$$

Galloping Shear:

$$V_{galloping.arm1.base} := \left(\frac{V_{wl.signal.arm1_{base1}}}{C_{d.signal}} + \frac{V_{wl.panel.arm1_{base1}}}{C_{d.panel}}\right) \cdot \left(\frac{Pressure_{galloping}}{Pressure \cdot K_{z.arm}}\right) = 0.86 \cdot kip$$

$$V_{galloping.arm2.base} := \left(\frac{V_{wl.signal.arm2_{base2}}}{C_{d.signal}} + \frac{V_{wl.panel.arm2_{base2}}}{C_{d.panel}}\right) \cdot \left(\frac{Pressure_{galloping}}{Pressure \cdot K_{z.arm}}\right) = 0 \cdot kip$$

Galloping Bending Stress

$$\phi := \frac{180 \cdot deg}{Sides} = 15.00 \cdot deg$$

$$f_{b.galloping.arm1.base} := \frac{M_{galloping.arm1.base} \cdot \left(\frac{a_{od.arm1_{base1}}}{2 \cdot \sin(\phi)}\right)}{I_{arm1_{base1}}} = 7.43 \cdot ksi$$

$$f_{b.galloping.arm2.base} := if\left[I_{arm2_{base2}} > 0 \cdot in^4, \frac{M_{galloping.arm2.base} \cdot \left(\frac{a_{od.arm2_{base2}}}{2 \cdot \sin(\phi)}\right)}{I_{arm2_{base2}}}, 0 \cdot ksi\right] = 0.00 \cdot ksi$$

$$f_{b.galloping.pole.base} := \frac{M_{galloping.pole.base} \cdot \left(\frac{a_{od.pole_{polebase}}}{2 \cdot \sin(\phi)}\right)}{I_{pole_{polebase}}} = 3.09 \cdot ksi$$

Galloping Shear Stress:

$$f_{v.galloping.arm1.base} := 2.025 \cdot \frac{V_{galloping.arm1.base}}{A_{arm1_{base1}}} = 0.20 \cdot ksi$$

$$f_{v.galloping.arm2.base} := if\left(A_{arm2_{base2}} > 0 \cdot in^2, 2.025 \cdot \frac{V_{galloping.arm2.base}}{A_{arm2_{base2}}}, 0 \cdot ksi\right) = 0.00 \cdot ksi$$

Check Galloping Stress:

$$f_{galloping.arm1} := \sqrt{f_{b.galloping.arm1.base}^{\;2} + f_{v.galloping.arm1.base}^{\;2}} = 7.43 \cdot ksi \qquad CAFT_{fullpengroove.weld.arm1} = 10.00 \cdot ksi$$

$$Check_{galloping.arm1} := if\left(CAFT_{fullpengroove.weld.arm1} \geq f_{galloping.arm1}, \text{"OK"}, \text{"No Good"}\right) \qquad Check_{galloping.arm1} = \text{"OK"}$$

$$f_{galloping.arm2} := \sqrt{f_{b.galloping.arm2.base}^{\;2} + f_{v.galloping.arm2.base}^{\;2}} = 0.00 \cdot ksi \qquad CAFT_{fullpengroove.weld.arm2} = 4.50 \cdot ksi$$

$$f_{galloping.arm2} := \text{if}\left(L_{total.arm2} = 0\cdot ft, 0\cdot ksi, f_{galloping.arm2}\right) = 0.00\cdot ksi$$

$$Check_{galloping.arm2} := \text{if}\left(CAFT_{fullpengroove.weld.arm2} \ge f_{galloping.arm2}, \text{"OK"}, \text{"No Good"}\right)$$

$$Check_{galloping.arm2} := \text{if}\left(L_{total.arm2} = 0\cdot ft, \text{"NA"}, Check_{galloping.arm2}\right)$$

$$Check_{galloping.arm2} = \text{"NA"}$$

$$f_{galloping.pole} := f_{b.galloping.pole.base} = 3.09\cdot ksi$$

$$CAFT_{fullpengroove.weld.pole} = 4.50\cdot ksi$$

$$Check_{galloping.pole} := \text{if}\left(CAFT_{fullpengroove.weld.pole} \ge f_{galloping.pole}, \text{"OK"}, \text{"No Good"}\right)$$

$$Check_{galloping.pole} = \text{"OK"}$$

Natural Wind Gust Moment: $base1 = 20$ $base2 = 20$ $polebase = 10$

$$M_{nwg.arm1.base} := \left(M_{wl.signal.arm1_{base1}} + M_{wl.panel.arm1_{base1}} + M_{wl.tube.arm1_{base1}} \cdot \frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}} = 7.2\cdot kip\cdot ft$$

$$M_{nwg.arm2.base} := \left(M_{wl.signal.arm2_{base2}} + M_{wl.panel.arm2_{base2}} + M_{wl.tube.arm2_{base2}} \cdot \frac{C_{d.nwg.tube}}{C_{d.segment.arm2_{base2}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}} = 0\cdot kip\cdot ft$$

$$M_{nwg.pole.base} := \max(M_x) \cdot \left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}} = 14.27\cdot kip\cdot ft$$

$$M_{x.connect_{\beta}} := M_{x_{\beta,0}}$$

$$M_{nwg.pole.connect} := \max(M_{x.connect}) \cdot \left(\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}} = 5.02 \times 10^{-3}\cdot kip\cdot ft$$

$$M_{nwg.pole.torsion} := \max(M_y) \cdot \left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}} = 11.37\cdot kip\cdot ft$$

Natural Wind Gust Shear:

$$V_{nwg.arm1.base} := \left(V_{wl.signal.arm1_{base1}} + V_{wl.panel.arm1_{base1}} + V_{wl.tube.arm1_{base1}} \cdot \frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right) \cdot \left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 0.44\cdot kip$$

$$V_{nwg.arm2.base} := \left(V_{wl.signal.arm2_{base2}} + V_{wl.panel.arm2_{base2}} + V_{wl.tube.arm2_{base2}} \cdot \frac{C_{d.nwg.tube}}{C_{d.segment.arm2_{base2}}}\right) \cdot \left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 4.99 \times 10$$

$$V_{nwg.pole.base} := \max(V_z) \cdot \left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right) \cdot \left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}}\right) = 0.77\cdot kip$$

$$V_{x.connect_{\beta}} := V_{x_{\beta,0}}$$

$$V_{nwg.pole.connect} := \max\left(V_{x.connect}\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 1.34\times 10^{-3}\cdot kip$$

Natural Wind Gust Bending Stress:

$$f_{b.nwg.arm1.base} := \frac{M_{nwg.arm1.base}\cdot\left(\frac{a_{od.arm1_{base1}}}{2\cdot\sin(\phi)}\right)}{I_{arm1_{base1}}} = 3.84\cdot ksi$$

$$f_{b.nwg.arm2.base} := \mathrm{if}\left[I_{arm2_{base2}} > 0\cdot in^{4}, \frac{M_{nwg.arm2.base}\cdot\left(\frac{a_{od.arm2_{base2}}}{2\cdot\sin(\phi)}\right)}{I_{arm2_{base2}}}, 0\cdot ksi\right] = 0.00\cdot ksi$$

$$f_{b.nwg.pole.base} := \frac{M_{nwg.pole.base}\cdot\left(\frac{a_{od.pole_{polebase}}}{2\cdot\sin(\phi)}\right)}{I_{pole_{polebase}}} = 3.18\cdot ksi$$

$$f_{b.nwg.pole.connect} := \frac{M_{nwg.pole.connect}\cdot\left(\frac{a_{od.pole_{0}}}{2\cdot\sin(\phi)}\right)}{I_{pole_{0}}} = 1.79\times 10^{-3}\cdot ksi$$

Natural Wind Gust Shear Stress:

$$f_{v.nwg.arm1.base} := 2.025\cdot\frac{V_{nwg.arm1.base}}{A_{arm1_{base1}}} = 0.10\cdot ksi$$

$$f_{v.nwg.arm2.base} := \mathrm{if}\left(A_{arm2_{base2}} > 0\cdot in^{2}, 2.025\cdot\frac{V_{nwg.arm2.base}}{A_{arm2_{base2}}}, 0\cdot ksi\right) = 0.00\cdot ksi$$

$$f_{v.nwg.pole.base.shear} := 2.025\cdot\frac{V_{nwg.pole.base}}{A_{pole_{polebase}}} = 0.09\cdot ksi$$

$$f_{v.nwg.pole.connect.shear} := 2.025\cdot\frac{V_{nwg.pole.connect}}{A_{pole_{0}}} = 2.08\times 10^{-4}\cdot ksi$$

$$f_{v.nwg.pole.base.torsion} := \frac{M_{nwg.pole.torsion} \cdot k_{t_{polebase}}}{6.43 \cdot \left(R_{b_{polebase}}\right)^2 \cdot t_{pole}} = 1.26 \cdot ksi$$

$$f_{v.nwg.pole.connect.torsion} := \frac{M_{nwg.pole.torsion} \cdot k_{t_0}}{6.43 \cdot \left(R_{b_0}\right)^2 \cdot t_{pole}} = 1.97 \cdot ksi$$

$$f_{v.nwg.pole.base} := \sqrt{f_{v.nwg.pole.base.shear}^{\ \ 2} + f_{v.nwg.pole.base.torsion}^{\ \ 2}} = 1.27 \cdot ksi$$

$$f_{v.nwg.pole.connect} := \sqrt{f_{v.nwg.pole.connect.shear}^{\ \ 2} + f_{v.nwg.pole.connect.torsion}^{\ \ 2}} = 1.97 \cdot ksi$$

Check Natural Wind Gust Stress:

$$f_{nwg.arm1} := \sqrt{f_{b.nwg.arm1.base}^{\ \ 2} + f_{v.nwg.arm1.base}^{\ \ 2}} = 3.84 \cdot ksi$$

$$CAFT_{fullpengroove.weld.arm1} = 10.00 \cdot ksi$$

$$Check_{nwg.arm1} := if\left(CAFT_{fullpengroove.weld.arm1} \geq f_{nwg.arm1}, \text{"OK"}, \text{"No Good"}\right)$$

$$Check_{nwg.arm1} = \text{"OK"}$$

$$f_{nwg.arm2} := \sqrt{f_{b.nwg.arm2.base}^{\ \ 2} + f_{v.nwg.arm2.base}^{\ \ 2}} = 0.00 \cdot ksi$$

$$CAFT_{fullpengroove.weld.arm2} = 4.50 \cdot ksi$$

$$f_{nwg.arm2} := if\left(L_{total.arm2} = 0 \cdot ft, 0 \cdot ksi, f_{nwg.arm2}\right) = 0.00 \cdot ksi$$

$$Check_{nwg.arm2} := if\left(CAFT_{fullpengroove.weld.arm2} \geq f_{nwg.arm2}, \text{"OK"}, \text{"No Good"}\right)$$

$$Check_{nwg.arm2} := if\left(L_{total.arm2} = 0 \cdot ft, \text{"NA"}, Check_{nwg.arm2}\right)$$

$$Check_{nwg.arm2} = \text{"NA"}$$

$$f_{nwg.pole.base} := \sqrt{f_{b.nwg.pole.base}^{\ \ 2} + f_{v.nwg.pole.base}^{\ \ 2}} = 3.42 \cdot ksi$$

$$f_{nwg.pole.connect} := \sqrt{f_{b.nwg.pole.connect}^{\ \ 2} + f_{v.nwg.pole.connect}^{\ \ 2}} = 1.97 \cdot ksi$$

$$f_{nwg.pole} := if\left(f_{nwg.pole.connect} > f_{nwg.pole.base}, f_{nwg.pole.connect}, f_{nwg.pole.base}\right) = 3.42 \cdot ksi$$

$$CAFT_{fullpengroove.weld.pole} = 4.50 \cdot ksi$$

$$Check_{nwg.pole} := if\left(CAFT_{fullpengroove.weld.pole} \geq f_{nwg.pole}, \text{"OK"}, \text{"No Good"}\right)$$

$$Check_{nwg.pole} = \text{"OK"}$$

A325 Connection Bolts

$CAFT_{conn.bolt} := CAFT_B = 16.00\cdot ksi$ ***LTS Table 11-2, Detail 3***

Galloping

$M_{galloping.arms_0} := M_{galloping.arm1.base}$

$M_{galloping.arms_1} := M_{galloping.arm2.base}$

$$T_{g.conn_j} := \frac{M_{galloping.arms_j}}{RC_j + CompForceOffset_j + t_{arm_j}} \qquad T_{g.conn} = \begin{pmatrix} 8.6 \\ 2.7\times 10^{-4} \end{pmatrix}\cdot kip$$

$$T_{g.bolt.max_j} := \text{if}\left[\#ConnBolts_j = 0, 0\cdot ksi, \frac{T_{g.conn_j}}{0.5\cdot\#ConnBolts_j} + \frac{DistA_j\cdot\tan\left(\theta_j\right)\cdot T_{g.conn_j}\cdot\left(\#ConnBolts_j\cdot 0.25 - 0.5\right)\cdot Spacing_{bolts.conn_j}}{\displaystyle\sum_{n=0}^{floor\left(0.25\cdot\#ConnBolts_j\right)}\left[\frac{\left[\left(\#ConnBolts_j\cdot 0.5\right) - 1\right] - 2\cdot n}{2}\cdot Spacing_{bolts.conn_j}\right]}\right.$$

$$T_{g.bolt.max} = \begin{pmatrix} 3.8 \\ 0.0 \end{pmatrix}\cdot kip$$

$$f_{t.g.bolt_j} := \frac{T_{g.bolt.max_j}}{A_{gross.bolt_j}} \qquad f_{t.g.bolt} = \begin{pmatrix} 4.8 \\ 0.0 \end{pmatrix}\cdot ksi$$

Bolt Tensile Stress

$$Check_{g.conn.bolt_j} := \text{if}\left(CAFT_{conn.bolt} \ge f_{t.g.bolt_j}, \text{"OK"}, \text{"No Good"}\right) \qquad Check_{g.conn.bolt} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$$

Natural wind gust

$M_{nwg.arms_0} := M_{nwg.arm1.base}$

$M_{nwg.arms_1} := M_{nwg.arm2.base}$

$$T_{nwg.conn_j} := \frac{M_{nwg.arms_j}}{RC_j + CompForceOffset_j + t_{arm_j}} \qquad T_{nwg.conn} = \begin{pmatrix} 4.5 \\ 10.0\times 10^{-5} \end{pmatrix}\cdot kip$$

$$T_{nwg.bolt.max_j} := \text{if}\left[\#ConnBolts_j = 0, 0\cdot ksi, \frac{T_{nwg.conn_j}}{0.5\cdot\#ConnBolts_j} + \frac{DistA_j\cdot\tan\left(\theta_j\right)\cdot T_{nwg.conn_j}\cdot\left(\#ConnBolts_j\cdot 0.25 - 0.5\right)\cdot Spacing_{bolts.co}}{\displaystyle\sum_{n=0}^{floor\left(0.25\cdot\#ConnBolts_j\right)}\left[\frac{\left[\left(\#ConnBolts_j\cdot 0.5\right) - 1\right] - 2\cdot n}{2}\cdot Spacing_{bolts.co}\right]}\right.$$

$$T_{nwg.bolt.max} = \begin{pmatrix} 2.0 \\ 0.0 \end{pmatrix}\cdot kip$$

$$f_{t.nwg.bolt_j} := \frac{T_{nwg.bolt.max_j}}{A_{gross.bolt_j}} \qquad f_{t.nwg.bolt} = \begin{pmatrix} 2.5 \\ 0.0 \end{pmatrix}\cdot ksi$$

Bolt Tensile Stress

$\text{Check}_{\text{nwg.conn.bolt}_j} := \text{if}\left(\text{CAFT}_{\text{conn.bolt}} \geq f_{\text{t.nwg.bolt}_j}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{\text{nwg.conn.bolt}} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

Anchor Bolts

$\text{CAFT}_{\text{anchor.rods}} := \text{CAFT}_D = 7.00 \cdot \text{ksi}$ ***LTS Table 11-2, Detail 5***

Galloping

$T_{\text{g.rod}} := \dfrac{M_{\text{galloping.arm1.base}}}{S_{\text{rod.group}}}$ $T_{\text{g.rod}} = 5.6 \cdot \text{kip}$

$f_{\text{t.g.rod}} := \dfrac{T_{\text{g.rod}}}{A_{\text{net.rod}}}$ $f_{\text{t.g.rod}} = 4.48 \cdot \text{ksi}$

$\text{Check}_{\text{g.rod}} := \text{if}\left(\text{CAFT}_{\text{anchor.rods}} \geq f_{\text{t.g.rod}}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{\text{g.rod}} = \text{"OK"}$

Natural Wind Gust

$T_{\text{nwg.rod}} := \dfrac{M_{\text{nwg.pole.base}}}{S_{\text{rod.group}}}$ $T_{\text{nwg.rod}} = 5.7 \cdot \text{kip}$

$f_{\text{t.nwg.rod}} := \dfrac{T_{\text{nwg.rod}}}{A_{\text{net.rod}}}$ $f_{\text{t.nwg.rod}} = 4.60 \cdot \text{ksi}$

$\text{Check}_{\text{nwg.rod}} := \text{if}\left(\text{CAFT}_{\text{anchor.rods}} \geq f_{\text{t.nwg.rod}}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{\text{nwg.rod}} = \text{"OK"}$

Longitudinal Seam Weld on Arm and Upright Tubes

$\text{CAFT}_{\text{seam.weld}} := \text{CAFT}_{B'} = 12.00 \cdot \text{ksi}$ ***LTS Table 11-2, Detail 8***

$\text{CAFT}_{\text{seam.weld}}$ > galloping or natural wind gust stress. No check.

Arm Telescopic Splice

$\text{CAFT}_{\text{splice}} := \text{CAFT}_B = 16.00 \cdot \text{ksi}$ ***LTS Table 11-2, Detail 2***

$\text{CAFT}_{\text{splice}}$ > galloping or natural wind gust stress. No check.

Reinforced Handhole

$\text{CAFT}_{\text{handhole}} := 7 \cdot \text{ksi}$ ****LTS Table 11-2, Detail 3.2***

$\text{CAFT}_{\text{handhole}}$ > galloping or natural wind gust stress. No check.

$\text{CAFT}_{\text{fullpengroove.weld.arm2}} := \text{if}\left(L_{\text{total.arm2}} = 0 \cdot \text{ft}, \text{"NA"}, \text{CAFT}_{\text{fullpengroove.weld.arm2}}\right)$

▲ Analyze Structure for Fatigue

Arm and Pole Welds

$f_{galloping.arm1} = 7.43 \cdot ksi$ $CAFT_{fullpengroove.weld.arm1} = 10.00 \cdot ksi$ $Check_{galloping.arm1} = "OK"$

$f_{galloping.arm2} = 0.00 \cdot ksi$ $CAFT_{fullpengroove.weld.arm2} = "NA" \cdot ksi$ $Check_{galloping.arm2} = "NA"$

$f_{galloping.pole} = 3.09 \cdot ksi$ $CAFT_{fullpengroove.weld.pole} = 4.50 \cdot ksi$ $Check_{galloping.pole} = "OK"$

$f_{nwg.arm1} = 3.84 \cdot ksi$ $Check_{nwg.arm1} = "OK"$

$f_{nwg.arm2} = 0.00 \cdot ksi$ $Check_{nwg.arm2} = "NA"$

$f_{nwg.pole} = 3.42 \cdot ksi$ $Check_{nwg.pole} = "OK"$

A325 Connection Bolts

$f_{t.g.bolt} = \begin{pmatrix} 4.8 \\ 0.0 \end{pmatrix} \cdot ksi$ $CAFT_{conn.bolt} = 16.00 \cdot ksi$ $Check_{g.conn.bolt} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$

$f_{t.nwg.bolt} = \begin{pmatrix} 2.5 \\ 0.0 \end{pmatrix} \cdot ksi$ $Check_{nwg.conn.bolt} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$

Anchor Bolts

$f_{t.g.rod} = 4.48 \cdot ksi$ $CAFT_{anchor.rods} = 7.00 \cdot ksi$ $Check_{g.rod} = "OK"$

$f_{t.nwg.rod} = 4.60 \cdot ksi$ $Check_{nwg.rod} = "OK"$

▶ Summary

Mast Arm Design and Analysis Summary

DataFile = "E1T1.dat" WindSpeed = 130·mph

Subject = "E1-T1 Mast Arm" **DesignedBy** = "MAV" **PoleLocation** = "ID No.1"

ProjectNo = "00193008015" **CheckedBy** = "FDOT" **Date** = "12/4/2012"

SUMMARY

1st Mast Arm

$\#\mathrm{Signals}_{arm1} = 3$

$\#\mathrm{Panels}_{arm1} = 3$

$X_{signal.arm1} = \begin{pmatrix} 10.5 \\ 18.5 \\ 26.5 \end{pmatrix} \mathrm{ft}$ $\mathrm{Sections}_{signal.arm1} = \begin{pmatrix} 3 \\ 3 \\ 4 \end{pmatrix}$ $\mathrm{Backplate}_{signal.arm1} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$

$X_{panel.arm1} = \begin{pmatrix} 4.5 \\ 17 \\ 31 \end{pmatrix} \mathrm{ft}$ $\mathrm{Area}_{panel.arm1} = \begin{pmatrix} 20 \\ 1.56 \\ 9 \end{pmatrix} \mathrm{ft}^2$

$L_{total.arm1} = 36\,\mathrm{ft}$ $L_{splice.provided.arm1} = 24 \cdot \mathrm{in}$

'FA'=
'FE'= $L_{arm1} = \begin{pmatrix} 36 \\ 0 \end{pmatrix} \cdot \mathrm{ft}$ ✓

'FB'=
'FF'= $\mathrm{Diameter}_{tip.arm1} = \begin{pmatrix} 5.96 \\ 0 \end{pmatrix} \cdot \mathrm{in}$ ✓

'FC'=
'FG'= $\mathrm{Diameter}_{base.arm1} = \begin{pmatrix} 11 \\ 0 \end{pmatrix} \cdot \mathrm{in}$ ✓

'FD'=
'FH'= $t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0 \end{pmatrix} \cdot \mathrm{in}$ ✓

$\max(\Delta_{arm1}) = 3.58 \cdot \mathrm{in}$

$\max(\mathrm{CSR}_{arm1}) = 0.953$ ✓

2nd Mast Arm

$\#\mathrm{Signals}_{arm2} = 0$

$\#\mathrm{Panels}_{arm2} = 1$

$X_{signal.arm2} = (0)\,\mathrm{ft}$ $\mathrm{Sections}_{signal.arm2} = (0)$ $\mathrm{Backplate}_{signal.arm2} = (0)$

$X_{panel.arm2} = (0.1)\,\mathrm{ft}$ $\mathrm{Area}_{panel.arm2} = (0.1)\,\mathrm{ft}^2$

$L_{total.arm2} = 0\,\mathrm{ft}$ $L_{splice.provided.arm2} = 24 \cdot \mathrm{in}$

'UF'= $\alpha = 0 \cdot \mathrm{deg}$ **(Angle Between Arms)**

'SA'=
'SE'= $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot \mathrm{ft}$

'SB'=
'SF'= $\mathrm{Diameter}_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot \mathrm{in}$

'SC'=
'SG'= $\mathrm{Diameter}_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot \mathrm{in}$

'SD'=
'SH'= $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot \mathrm{in}$

$\max(\Delta_{arm2}) = 0 \cdot \mathrm{in}$

$\max(\mathrm{CSR}_{arm2}) = 0$

Luminaire Arm and Connection

DataFile = "E1T1.dat"

WindSpeed = 130·mph

(use MC10x33.6 channel for connection)

'LA'= $Y_{luminaire} = 0\,\mathrm{ft}$

'LB'= $X_{luminaire} = 0\,\mathrm{ft}$

'LC'= $\mathrm{Diameter}_{base.lumarm} = 0 \cdot \mathrm{in}$

'LD'= $t_{wall.lumarm} = 0 \cdot in$ 'LE'= $Slope_{lumarm} = 0$ 'LF'= $r_{lumarm} = 0\ ft$

'LG'= $d_{bolt.lum} = 0 \cdot in$ 'LH'= $t_{baseplate.lum} = 0 \cdot in$

'LJ'= $w_{base.lum} = 0 \cdot in$ 'LK'= $w_{channel.lum} = 0 \cdot in$

$CSR_{base.lumarm} = 0$ $PR_{bolt.lum} = 0$ $PR_{baseplate.lum} = 0$ $PR_{conn.plate.lum} = 0$

Upright

'UA'= $Y_{pole} = 21.5 \cdot ft$ ✓ 'UB'= $Y_{arm.conn} = 20 \cdot ft$ ✓ 'UC'= $Diameter_{tip.pole} = 10.99 \cdot in$ ✓

'UD'= $Diameter_{base.pole} = 14 \cdot in$ ✓ 'UE'= $t_{wall.pole} = 0.375 \cdot in$ ✓ 'UF'= $\alpha = 0 \cdot deg$ ✓

'UG'= $Y_{lum.conn} = 0\ ft$

$\Delta_{x.dl} = 0.75 \cdot in$ $Slope_x = 0.4 \cdot deg$

$\Delta_{z.dl} = 0 \cdot in$

$Slope_z = 0 \cdot deg$ $C_{a.pole} = 0.996$

$\max(CSR_{pole}) = 0.71$ ✓

1st Arm/Upright Connection

$\#ConnBolts_0 = 6$ 'HT'= $h_{conn.plate} = 22 \cdot in$ ✓ 'FJ'= $b_{conn.plate_0} = 21.00 \cdot in$ ✓ <1

'FK'= $t_{baseplate.arm_0} = 2 \cdot in$ ✓ 'FL'= $t_{vertical.plate_0} = 0.5 \cdot in$ ✓

'FN'= $w_{vertical.plate_0} = 0.25 \cdot in$ < ✓ 'FO'= $Offset_{conn_0} = 14.1 \cdot in$ ✓ ±

'FP'= $d_{bolt.conn_0} = 1 \cdot in$ ✓ 'FR'= $t_{conn.plate_0} = 1.625 \cdot in$ <1 ✓

'FS'= $Spacing_{bolts.conn_0} = 9 \cdot in$ ✓ 'FT'= $w_{conn.plate_0} = 0.3125 \cdot in$ <1 ✓

$$\begin{pmatrix} PR_{bolt_0} \\ PR_{t.baseplate.arm_0} \\ PR_{t.connplate.arm_0} \\ CSR_{t.vert.plate_0} \end{pmatrix} = \begin{pmatrix} 0.496 \\ 0.839 \\ 0.924 \\ 0.555 \end{pmatrix}$$ ✓ ✓ ✓ ✓

2nd Arm/Upright Connection

$\#ConnBolts_1 = 0$ 'HT'= $h_{conn.plate} = 22 \cdot in$ 'SJ'= $b_{conn.plate_1} = 0.00 \cdot in$

'SK'= $t_{baseplate.arm_1} = 0 \cdot in$ 'SL'= $t_{vertical.plate_1} = 0 \cdot in$

'SN'= $w_{vertical.plate_1} = 0\cdot in$ 'SO'= $Offset_{conn_1} = 0\cdot in$

'SP'= $d_{bolt.conn_1} = 0\cdot in$ 'SR'= $t_{conn.plate_1} = 0\cdot in$

'SS'= $Spacing_{bolts.conn_1} = 0\cdot in$ 'ST'= $w_{conn.plate_1} = 0\cdot in$

$$\begin{pmatrix} PR_{bolt_1} \\ PR_{t.baseplate.arm_1} \\ PR_{t.connplate.arm_1} \\ CSR_{t.vert.plate_1} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Pole Baseplate

DataFile = "E1T1.dat" WindSpeed = $130\cdot mph$

#AnchorRods = 6 ✓ 'BA'= $Diameter_{baseplate.pole} = 26\cdot in$ ✓ 'BB'= $t_{baseplate.pole} = 2.5\cdot in$ ✓

'BC'= $d_{bolt.pole} = 1.50\cdot in$ ✓ 'BF'= $L_{embedment.rod} = 30\cdot in$ ↳ ✓

$Diameter_{boltcircle.pole} = 20\cdot in$

$PR_{rod} = 0.734$ ✓

$PR_{plate.pole} = 1$ ✓

Foundation

'DA'= $L_{shaft} = 13\cdot ft$ > 11', special 'DB'= $Diameter_{shaft} = 4\cdot ft$ ✓ $d_{bar} = 1.41\cdot in$ ✓

'RA'= $round\left(\frac{d_{bar}}{0.125in}\right) = 11$ ✓ 'RB'= #BarsProvided = 12 <14 ✓ $Diameter_{rebar.circle} = 2.7783\ ft$

'RC'= $NumSpaces_{v.bar} = 7$ 'RD'= $s_{v2} = 12\cdot in$ $PR_{foundation} = 0.929$ ✓

▶ WRITEPRN to Line 1-2-3

Mast Arm Tip Deflection

Compare Mast Arm deflection of each arm to a proposed camber

$Camber_{arm1} := \mathbf{2}\cdot deg$ $Camber_{arm2} := \mathbf{2}\cdot deg$

$L_{arm1} := \sum L_{arm1} - if\left[\left(L_{arm1_1} = 0\cdot ft\right), 0\cdot ft, 2\cdot ft\right]$ $L_{arm2} := \sum L_{arm2} - if\left[\left(L_{arm2_1} = 0\cdot ft\right), 0\cdot ft, 2\cdot ft\right]$

$Deflection_{arm1} := Slope_x\cdot L_{arm1} + max(\Delta_{arm1})$ $Deflection_{arm1} = 6.63\cdot in$

$CamberArm1_{upward} := sin(Camber_{arm1})\cdot L_{arm1}$ $CamberArm1_{upward} = 15.08\cdot in$

$Deflection_{arm2} := \left[Slope_z\cdot L_{arm2}\cdot(sin(\alpha))\right] + Slope_x\cdot L_{arm2}\cdot cos(\alpha) + max(\Delta_{arm2})$ $Deflection_{arm2} = 0\cdot in$

$CamberArm2_{upward} := sin(Camber_{arm2})\cdot L_{arm2}$ $CamberArm2_{upward} = 0\cdot in$

Check Clearance Between Connection Plates *(for Two Arm Structures only)*

$\alpha = 0.00\cdot deg$ $\alpha := if[(\alpha > 180\cdot deg), (360\cdot deg - \alpha), \alpha]$

$Offset_{conn_0} = 14.10\cdot in$ $b_{conn.plate_0} = 21.00\cdot in$ $h_{conn.plate} = 22.00\cdot in$ $\alpha = 0.00\cdot deg$

$Offset_{conn_1} = 0.00\cdot in$ $b_{conn.plate_1} = 0.00\cdot in$

$x_1 := \mathrm{Offset}_{\mathrm{conn}_0} - t_{\mathrm{conn.plate}_0} - h_{\mathrm{conn.plate}} \cdot \frac{\sin(\mathrm{Camber}_{\mathrm{arm1}})}{2}$ $\quad y_1 := \frac{b_{\mathrm{conn.plate}_0}}{2}$ $\quad x_1 = 12.09 \cdot \mathrm{in} \quad y_1 = 10.5 \cdot \mathrm{in}$

$x_2 := \left(\mathrm{Offset}_{\mathrm{conn}_1} - t_{\mathrm{conn.plate}_1} - h_{\mathrm{conn.plate}} \cdot \frac{\sin(\mathrm{Camber}_{\mathrm{arm2}})}{2}\right) \cdot \cos(\alpha) + \frac{b_{\mathrm{conn.plate}_1}}{2} \cdot \sin(\alpha)$

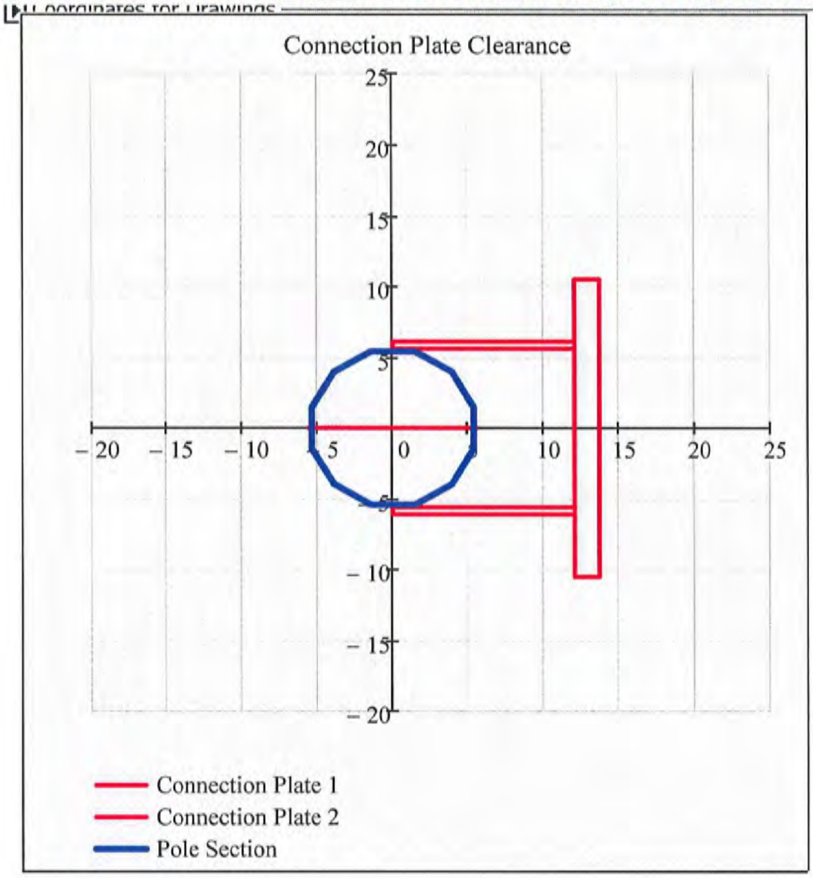
$y_2 := \left(\mathrm{Offset}_{\mathrm{conn}_1} - t_{\mathrm{conn.plate}_1} - h_{\mathrm{conn.plate}} \cdot \frac{\sin(\mathrm{Camber}_{\mathrm{arm2}})}{2}\right) \cdot \sin(\alpha) - \frac{b_{\mathrm{conn.plate}_1}}{2} \cdot \cos(\alpha)$ $\quad x_2 = -0.38 \cdot \mathrm{in} \; y_2 = 0 \cdot \mathrm{in}$

$\mathrm{Clearance} := \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ $\quad \mathrm{Clearance} := \mathrm{if}\left[(y_2 \le y_1), \mathrm{if}\left[(x_1 > x_2), \mathrm{Clearance}, 0 \cdot \mathrm{in}\right], \mathrm{Clearance}\right]$ $\quad \mathrm{Clearance} = 16.31 \cdot \mathrm{in}$

(if Clearance equals 0, then Connection Plates intersect and redesign is required.

Plan View - Connection Plate Clearance for Two Arm Connections

Coordinates for Drawings



$\text{Clearance} = 16.31 \cdot \text{in}$

$\text{Diameter}_{\text{conn.pole}} = 11.2 \cdot \text{in}$

$t_{\text{conn.plate}_0} = 1.625 \cdot \text{in}$

$b_{\text{conn.plate}_0} = 21 \cdot \text{in}$

$t_{\text{vertical.plate}_0} = 0.5 \cdot \text{in}$

$\text{Offset}_{\text{conn}_0} = 14.1 \cdot \text{in}$

$\text{Gap}_0 = 8.5 \cdot \text{in}$

$t_{\text{conn.plate}_1} = 0 \cdot \text{in}$

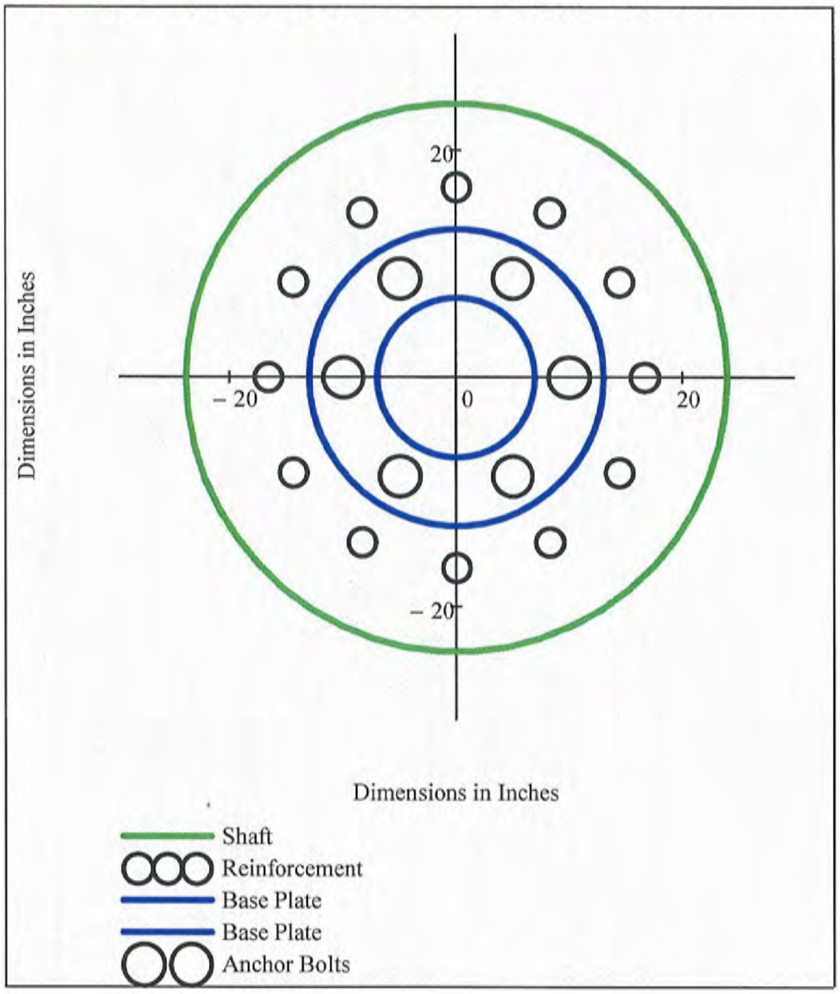
$b_{\text{conn.plate}_1} = 0 \cdot \text{in}$

$t_{\text{vertical.plate}_1} = 0 \cdot \text{in}$

$\text{Offset}_{\text{conn}_1} = 0 \cdot \text{in}$

$\text{Gap}_1 = 0 \cdot \text{in}$

Plan View - Drilled Shaft, Base Plate, Anchor Bolts, & Reinforcing Steel



$\text{Diameter}_{\text{base.pole}} = 14 \cdot \text{in}$

$\text{Diameter}_{\text{baseplate.pole}} = 26 \cdot \text{in}$

$\text{Diameter}_{\text{shaft}} = 48 \cdot \text{in}$

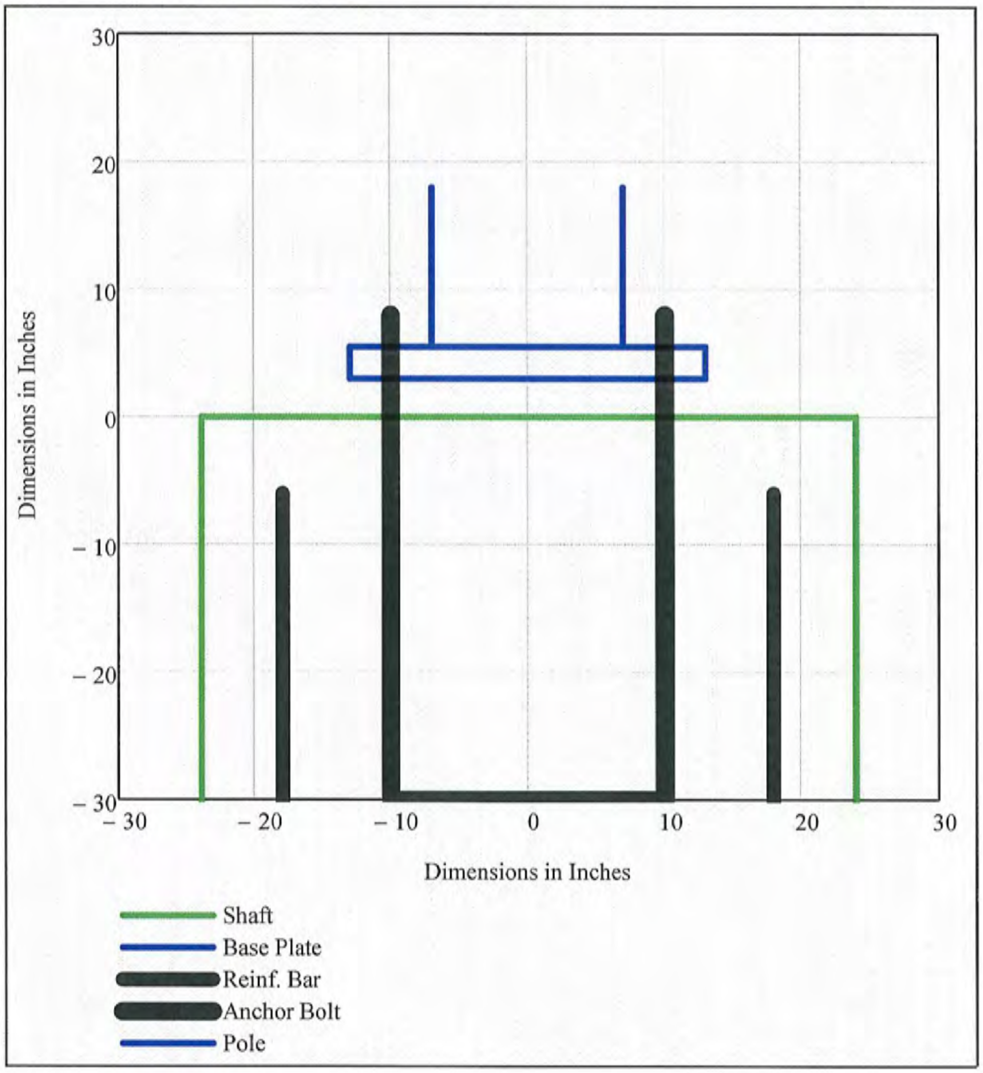
$\text{Diameter}_{\text{boltcircle.pole}} = 20 \cdot \text{in}$

$\text{Diameter}_{\text{rebar.circle}} = 33.34 \cdot \text{in}$

#AnchorRods = 6

#BarsProvided = 12

Elevation View - Drilled Shaft, Base Plate, Anchor Bolts, & Reinforcing Steel



$\text{Diameter}_{\text{base.pole}} = 14.00\cdot\text{in}$

$\text{Diameter}_{\text{baseplate.pole}} = 26.00\cdot\text{in}$

$t_{\text{baseplate.pole}} = 2.50\cdot\text{in}$

$\text{Diameter}_{\text{shaft}} = 4.00\cdot\text{ft}$

$\text{Diameter}_{\text{boltcircle.pole}} = 20.00\cdot\text{in}$

$\text{Diameter}_{\text{rebar.circle}} = 33.3\cdot\text{in}$

ID No. 2: E7-T6

ID. No. 2: E7-T6

12/5/12

FDOT Mast Arm Analysis Program

Custom File Name (optional) ☐

The new custom file will be a copy of the last file called from the program. A ".dat" extension will be added to the file name.

Add file to file list [Refresh File List]

Select Data File (required)

- E6E4T4
- E6E5T4
- E6E6T5
- E6T24
- E6T4
- **E7T6**
- ENGDIC

All data files are in the same directory as the MastArm.xmcd file.

Path = "J:\00193\00193008.15\DOC\Calcs\ID_N0_2_MastarmV5.02\"

DataFile = "E7T6.dat"

Reference *Changes*

This program works in conjunction with Mastarm Design Standards 17743 and 17745.

References:
AASHTO Standard Specifications for Signs, Luminaires and Traffic Signals, 5th Edition (LTS).
FDOT Structures Manual Vol. 9 (SM V9).

For more information see Reference.xmcd and Changes.xmcd.

▶ Read In Data

General Information DataFile = "E7T6.dat"

Current Values	New Values
Subject = "E7-T6 Mast Arm"	
ProjectNo = "00193008015"	"00193008015"
PoleLocation = "ID No.2"	ID No.2
Date = "12/5/2012"	12/5/2012
DesignedBy = "MAV"	MAV
CheckedBy = "FDOT"	

Use Control+F9 to recalculate the worksheet, once to write out data, twice to read in data

Wind Speed DataFile = "E7T6.dat"

Current Value	New Value		
WindSpeed = 130·mph		*mph*	**SM V9 3.8.2**

Arm 1 Analysis

DataFile = "E7T6.dat"   WindSpeed = 130·mph

Arm 1 Loads

$$\text{SignalData}_{\text{arm1}} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 40.5 & 3 & \text{"yes"} \\ 2 & 52.5 & 3 & \text{"yes"} \\ 3 & 66.5 & 4 & \text{"yes"} \\ 4 & 0 & 0 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values   *"yes"or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	40.5	3	"yes"
2	52.5	3	"yes"
3	66.5	4	"yes"
4	"X"	"X"	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$\text{SignData}_{\text{arm1}} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 32 & 20 \\ 2 & 71.5 & 9 \\ 3 & 60.5 & 1.56 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	32	20
2	71.5	9
3	60.5	1.56
4	0	0
5	0	0

use X to zero out data
use 0 to keep current values

Arm 1 Loads

Arm 1 Properties

Current Values

New Values

$L_{total.arm1} = 76\,ft$ | 76 | *feet, 40 ft. max. for 1 piece arms*

$Diameter_{base.arm1} = 18 \cdot in$ | | *inches, measured flat to flat (FG)*

$Dist_{splice.from.base.arm1} = 40\,ft$ | | *feet, splice distance, for 2 piece arms, length of piece closest to pole, use X to zero out (FE)*

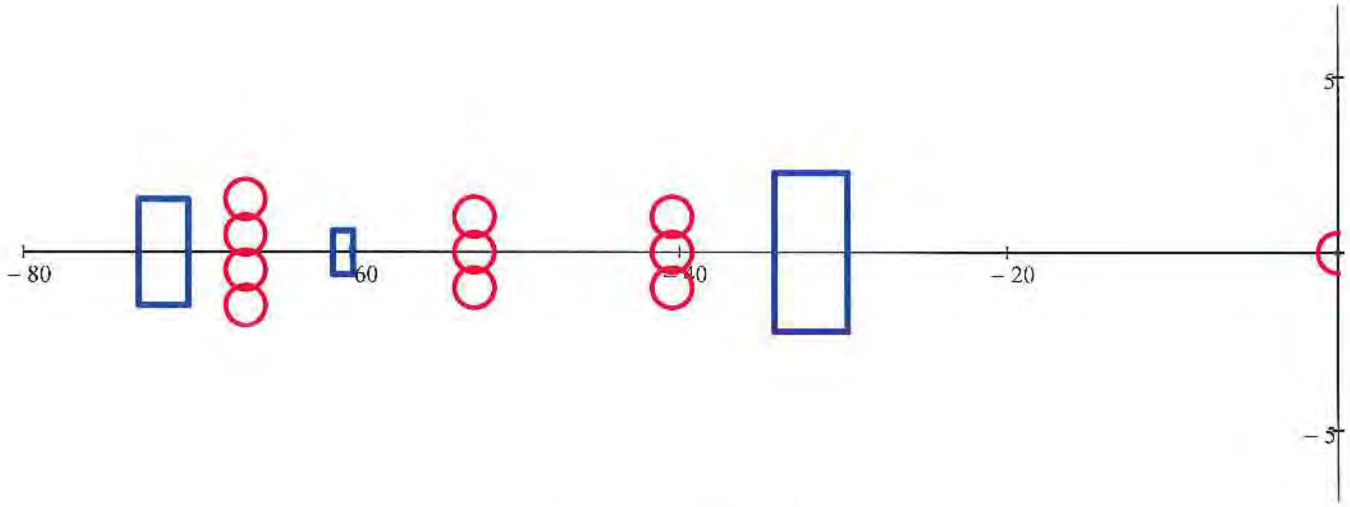
set $Dist_{splice.from.base.arm1} = 0\,ft$ *for NO SPLICE*

$t_{wall.arm1} = \begin{pmatrix} 0.1793 \\ 0.375 \end{pmatrix} \cdot in$ | | *inches, this value is used for one piece arms (FD)* | | *inches, for 2 piece arms, wall thickness of piece closest to the pole, use X to zero out (FH)*

Arm 1 Properties

▶ Analyze Arm 1

Summary - Arm 1 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130 \cdot mph$ $L_{total.arm1} = 76.00\,ft$

$Diameter_{tip.arm1} = \begin{pmatrix} 7.72 \\ 12.4 \end{pmatrix} \cdot in$ $Diameter_{base.arm1} = \begin{pmatrix} 13.04 \\ 18.00 \end{pmatrix} \cdot in$ $L_{arm1} = \begin{pmatrix} 38.00 \\ 40.00 \end{pmatrix} ft$ $t_{wall.arm1} = \begin{pmatrix} 0.1793 \\ 0.375 \end{pmatrix} \cdot in$

$X_{signal.arm1_{i1}} =$	$Sections_{signal.arm1_{i1}} =$	$X_{panel.arm1_{j1}} =$	$Area_{panel.arm1_{j1}} =$
40.5 ft	3	32 ft	20 ft^2
52.5	3	71.5	9
66.5	4	60.5	1.56

Arm 1 Combined Stress Ratio and Deflection

$\max(CSR_{arm1}) = 0.932$ $\max(\Delta_{arm1}) = 15.438 \cdot in$ $2 \cdot deg \cdot \sum (L_{arm1} - L_{splice.provided}) = 31 \cdot in$

Arm 2 Analysis

DataFile = "E7T6.dat" WindSpeed = 130·mph

Arm 2 Loads

$$\mathrm{SignalData}_{arm2} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 0 & 0 & \text{"yes"} \\ 2 & 0 & 0 & \text{"yes"} \\ 3 & 0 & 0 & \text{"yes"} \\ 4 & 0 & 0 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values *"yes" or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	0	0	"yes"
2	0	0	"yes"
3	0	0	"yes"
4	0	0	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$\mathrm{SignData}_{arm2} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 0 & 0 \\ 2 & 0 & 0 \\ 3 & 0 & 0 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0

use X to zero out
use 0 to keep current values

Arm 2 Loads

Arm 2 Properties

Current Values

New Values

$L_{total.arm2} = 0\ ft$ ☐ *feet, 40 ft. max. for 1 piece arms, use X to zero out set* $L_{total.arm2} = 0ft$ *for NO ARM2*

$Diameter_{base.arm2} = 0 \cdot in$ ☐ *inches, measured flat to flat, use X to zero out (SG)*

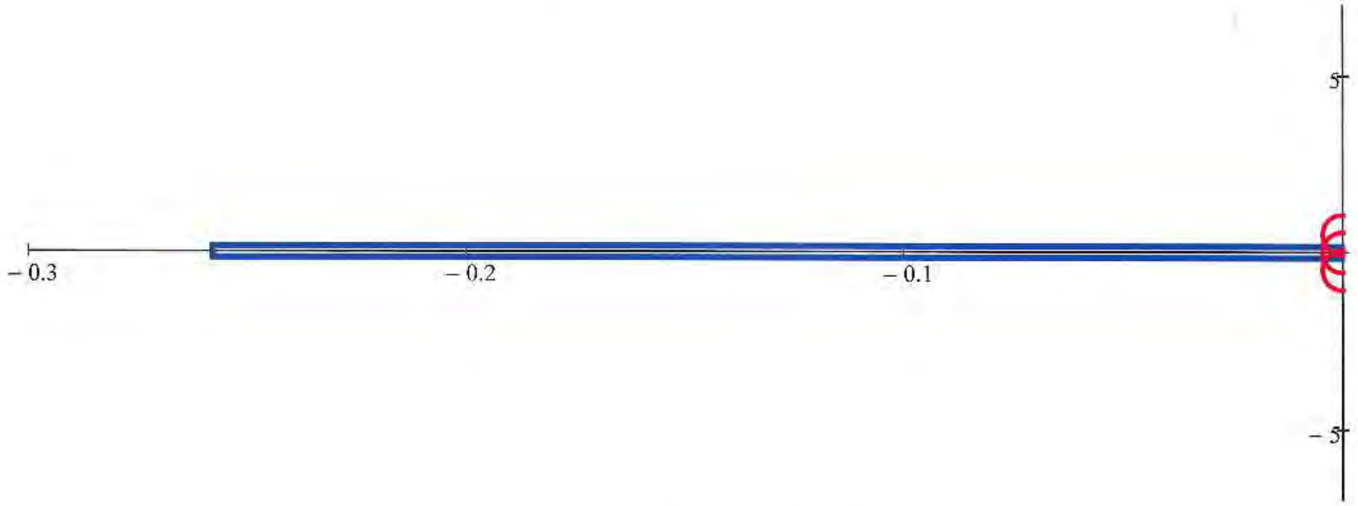
$Dist_{splice.from.base.arm2} = 0 \cdot ft$ ☐ *feet, splice distance, for 2 piece arms, length of piece closest to pole, use X to zero out (SE)* *set* $Dist_{splice.from.base.arm2} = 0ft$ *for NO SPLICE*

$t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ ☐ *inches, use X to zero out (SD)*

☐ *inches, for 2 piece arms, wall thickness of piece closest to the pole, use X to zero out (SH)*

Arm 2 Properties

Summary - Arm 2 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130 \cdot mph$ $L_{total.arm2} = 0.00\ ft$

$Diameter_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $Diameter_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} ft$ $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

$X_{signal.arm2_{i2}} =$	$Sections_{signal.arm2_{i2}} =$	$X_{panel.arm2_{j2}} =$	$Area_{panel.arm2_{j2}} =$
0 ft	0	0.1 ft	0.1 ft^2
0	0		

Arm 2 Combined Stress Ratio and Deflection

$\max(CSR_{arm2}) = 0$ $\max(\Delta_{arm2}) = 0 \cdot in$ $2 \cdot deg \cdot \sum (L_{arm2} - L_{splice.provided}) = -1.68 \cdot in$

Luminaire Arm Analysis DataFile = "E7T6.dat" WindSpeed = 130·mph

Luminaire Properties

See Design Standards 17743 and 17745 for input values.

Current Values	New Values	*set* $Y_{luminaire} = 0\text{ft}$ *for NO LUMINAIRE*
$Y_{luminaire} = 0\ \text{ft}$	☐	*feet, use X to zero out (Standard LA = 40 feet)*
$X_{luminaire} = 10 \cdot \text{ft}$	☐	*feet, use X to zero out (Standard LB = 10 feet)*
$Diameter_{base.lumarm} = 3 \cdot \text{in}$	☐	*inches, use X to zero out (Standard LC = 3 inches)*
$t_{wall.lumarm} = 0.125 \cdot \text{in}$	☐	*inches, use X to zero out (Standard LD = 0.125 inches)*
$Slope_{lumarm} = 0.5$	☐	*rise/run, use X to zero out (Standard LE = 0.5)*
$r_{lumarm} = 8 \cdot \text{ft}$	☐	*feet, use X to zero out (Standard LF = 8 feet)*
$d_{bolt.lum} = 0.5 \cdot \text{in}$	☐	*inches, use X to zero out (Standard LG = 0.5 inches)*
$t_{baseplate.lum} = 0.75 \cdot \text{in}$	☐	*inches, use X to zero out (Standard LH = 0.75 inches)*

Luminaire Properties

▶ Analyze Luminaire

Summary - Luminaire Arm Geometry

$Y_{luminaire} = 0\ \text{ft}$ $X_{luminaire} = 0 \cdot \text{ft}$ $Diameter_{base.lumarm} = 0 \cdot \text{in}$ $t_{wall.lumarm} = 0 \cdot \text{in}$

$Slope_{lumarm} = 0$ $r_{lumarm} = 0 \cdot \text{ft}$ $d_{bolt.lum} = 0 \cdot \text{in}$ $t_{baseplate.lum} = 0 \cdot \text{in}$

$w_{base.lum} = 0 \cdot \text{in}$ $w_{channel.lum} = 0 \cdot \text{in}$

Luminaire Arm Ratios

$CSR_{base.lumarm} = 0$ $PR_{bolt.lum} = 0$ $PR_{baseplate.lum} = 0$ $PR_{conn.plate.lum} = 0$

Upright Analysis DataFile = "E7T6.dat" WindSpeed = 130·mph

Pole Properties

Current Values	New Values		
$Y_{pole} = 22\ ft$	22	*feet (UA)*	
$Y_{arm.conn} = 20.5\ ft$	20.5	*feet (UB)*	
$Diameter_{base.pole} = 22\cdot in$		*inches, measured flat to flat (UD)*	
$t_{wall.pole} = 0.375\cdot in$		*inches (UE)*	
$Gap = \begin{pmatrix} 5.5 \\ 0 \end{pmatrix}\cdot in$		*inches, clear distance between connection plate and upright*	
		inches, use X to zero out	

Common wall thicknesses:
0.1793 in.
0.2391 in.
0.25 in.
0.313 in.
0.375 in.
0.5 in.

Pole Properties

Summary - Upright Geometry

$Y_{pole} = 22\ ft$ $Y_{arm.conn} = 20.5\ ft$ $\alpha = 0\cdot deg$ $Gap = \begin{pmatrix} 5.5 \\ 0 \end{pmatrix}\cdot in$

$Diameter_{tip.pole} = 18.92\cdot in$ $Diameter_{base.pole} = 22\cdot in$ $t_{wall.pole} = 0.375\cdot in$

Upright Combined Stress Ratio and Deflections

$\max(CSR_{pole}) = 0.899$ $\max(\Delta_{x.dl}) = 1.03\cdot in$ $\max(\Delta_{z.dl}) = 0\cdot in$

Mast Arm Connection(s) Analysis

DataFile = "E7T6.dat"   WindSpeed = 130·mph

Connection Properties

Current Values

New Values

$h_{conn.plate} = 30 \cdot in$

☐ *inches, for two arm Mast Arms both connection plate heights must be equal (HT)*

$t_{vertical.plate} = \begin{pmatrix} 0.75 \\ 0 \end{pmatrix} \cdot in$

☐ *inches (FL)*

☐ *inches, use X to zero out (SL)*

$d_{bolt.conn} = \begin{pmatrix} 1.25 \\ 0 \end{pmatrix} \cdot in$

☐ *inches (FP)*

☐ *inches, use X to zero out (SP)*

$t_{baseplate.arm} = \begin{pmatrix} 2.5 \\ 0 \end{pmatrix} \cdot in$

☐ *inches (FK)*

☐ *inches, use X to zero out (SK)*

Connection Properties

Analyze Connection

Switch values, set values for DataOut

$out := out + 1 \quad out = 29.00$

$h_{conn.plate} := fSwitchData(h_{conn.plate}, newh_{conn.plate}, in)$ $data_{out} := \frac{h_{conn.plate}}{in}$ $data_{out} = 30.00$

$out := out + 1 \quad out = 30.00$

$t_{vertical.plate} := fSwitchData3(t_{vertical.plate}, newt_{vertical.plate}, in)$ $data_{out} := \frac{t_{vertical.plate}}{in}$ $data_{out} = \begin{pmatrix} 0.75 \\ 0.00 \end{pmatrix}$

$t_{vertical.plate_1} := if(L_{total.arm2} = 0 \cdot ft, 0 \cdot in, t_{vertical.plate_1})$

$out := out + 1 \quad out = 31.00$

$d_{bolt.conn} := fSwitchData3(d_{bolt.conn}, newd_{bolt.conn}, in)$ $data_{out} := \frac{d_{bolt.conn}}{in}$ $data_{out} = \begin{pmatrix} 1.25 \\ 0.00 \end{pmatrix}$

$d_{bolt.conn_1} := if(L_{total.arm2} = 0 \cdot ft, 0 \cdot in, d_{bolt.conn_1})$

$out := out + 1 \quad out = 32.00$

$t_{baseplate.arm} := fSwitchData3(t_{baseplate.arm}, newt_{baseplate.arm}, in)$ $data_{out} := \frac{t_{baseplate.arm}}{in}$ $data_{out} = \begin{pmatrix} 2.50 \\ 0.00 \end{pmatrix}$

$t_{baseplate.arm_1} := if(L_{total.arm2} = 0 \cdot ft, 0 \cdot in, t_{baseplate.arm_1})$

Design Parameters

Trial Plate Thicknesses and Bolt Diameter $j := 0..1$

Design Criteria:

$PR_{bolt} < 1$ *(performance ratio of bolt),* $PR_{t.baseplate.arm} < 1$ *(performance ratio of arm base plate),*

& $CSR_{t.vert.plate} < 1$ (combined stress ratio of vertical plate).

$\#ConnBolts_j := \begin{bmatrix} 6 \\ 6 \end{bmatrix}$

$F_{y.baseplate} := 36 \cdot ksi$ *(for the base plate)*

Applied Loads

From Mast Arm Design

$M_{dl} = \begin{pmatrix} 104.3 \\ 0.0 \end{pmatrix} \cdot kip \cdot ft$ $V_{dl.arm} = \begin{pmatrix} 3.5 \\ 0.0 \end{pmatrix} \cdot kip$ $t_{arm} = \begin{pmatrix} 0.375 \\ 0 \end{pmatrix} \cdot in$ $d_{base.arm} = \begin{pmatrix} 18.00 \\ 0.00 \end{pmatrix} \cdot in$

$M_{wl} = \begin{pmatrix} 275.8 \\ 0.0 \end{pmatrix} \cdot kip \cdot ft$ $V_{wl.arm} = \begin{pmatrix} 6.6 \\ 0.0 \end{pmatrix} \cdot kip$ $Gap = \begin{pmatrix} 5.50 \\ 0.00 \end{pmatrix} \cdot in$

Note: Gap is the distance between the upright and the Arm Base Plate. (5.5 inches is a suggested minimum for two arm poles)

$Diameter_{conn.pole} = 19.13 \cdot in$ *From Upright Design (at arm connection)*

$$Offset_{conn} := Gap + \frac{Diameter_{conn.pole}}{2}$$

$Offset_{conn} = \begin{pmatrix} 15.06 \\ 9.56 \end{pmatrix} \cdot in$ *(FO)* *(SO)*

Total Factored Moment and Shear

AISC LRFD, Vol 1, 6-A4 Specs, 2nd Ed.

$$M_{u.conn_j} := \sqrt{\left(1.2 \cdot M_{dl_j}\right)^2 + \left(1.3 \cdot M_{wl_j}\right)^2}$$

$M_{u.conn} = \begin{pmatrix} 379.7 \\ 0.0 \end{pmatrix} \cdot kip \cdot ft$

$$V_{u.conn_j} := \sqrt{\left(1.2 \cdot V_{dl.arm_j}\right)^2 + \left(1.3 \cdot V_{wl.arm_j}\right)^2}$$

$V_{u.conn} = \begin{pmatrix} 9.5 \\ 0.0 \end{pmatrix} \cdot kip$

Arm Base Plate Dimensions

Control dimensions

$$Distance_{bolt.edge_j} := Ceil\left(2 \cdot d_{bolt.conn_j}, \frac{1}{4} in\right)$$

rounded up to the next 1/4 inch dimension

$Distance_{bolt.edge} = \begin{pmatrix} 2.50 \\ 0.00 \end{pmatrix} \cdot ir$

$$ControlDim_j := if\left[\left(d_{base.arm_j} > Diameter_{conn.pole}\right), Ceil\left(d_{base.arm_j}, \frac{1}{2} \cdot in\right), Ceil\left(Diameter_{conn.pole}, \frac{1}{2} \cdot in\right)\right]$$

$ControlDim = \begin{pmatrix} 19.5 \\ 19.5 \end{pmatrix} \cdot in$

Minimum Mast Arm base plate height $t_{vertical.plate_1} := if\left(t_{vertical.plate_1} = 0 \cdot in, .1 \cdot in, t_{vertical.plate_1}\right)$

$$h_{min.conn.plate_j} := \max\left[\left[\sqrt[3]{\dfrac{d_{base.arm_j} + 3\cdot in}{\pi\cdot\left(\dfrac{d_{base.arm_j}}{2}\right)^{3}\cdot t_{arm_j}\cdot\left(\dfrac{12}{t_{vertical.plate_j}}\right)}}\right]\right] \qquad h_{min.conn.plate} = \begin{pmatrix}24.0\\3.0\end{pmatrix}\cdot in$$

$$h_{conn.plate} = 30.00\cdot in$$

Mast Arm base plate height, rounded up to next 1 inch dimension if necessary

$$h_{conn.plate} := if\left[\left(h_{conn.plate} > \max\left(h_{min.conn.plate}\right)\right), h_{conn.plate}, Ceil\left(\max\left(h_{min.conn.plate}\right), in\right)\right] \qquad h_{conn.plate} = 30.00\cdot in$$

Mast Arm base plate width

$$b_{conn.plate_j} := \left(ControlDim_j + 2\cdot Distance_{bolt.edge_j} + 4\cdot d_{bolt.conn_j} + 2\cdot t_{vertical.plate_j}\right) \qquad b_{conn.plate} = \begin{pmatrix}31\\19.7\end{pmatrix}\cdot in$$

Mast Arm base plate width round up to next 1 inch dimension

$$b_{conn.plate_j} := if\left[\left(t_{vertical.plate_j} = 0\cdot in\right), 0\cdot in, Ceil\left(b_{conn.plate_j}, in\right)\right] \qquad b_{conn.plate} = \begin{pmatrix}31.00\\20.00\end{pmatrix}\cdot in \begin{matrix}(FJ)\\(SJ)\end{matrix}$$

Bolt spacing

$$Spacing_{bolts.conn_j} := if\left[\left(t_{vertical.plate_j} = 0\cdot in\right), 0\cdot in, \frac{h_{conn.plate} - \left(2\cdot Distance_{bolt.edge_j}\right)}{0.5\cdot \#ConnBolts_j - 1}\right] \qquad Spacing_{bolts.conn} = \begin{pmatrix}12.5\\15\end{pmatrix}\cdot in \begin{matrix}(FS)\\(SS)\end{matrix}$$

D. Calculate Bolt Loads

Calculate Capacities of Connection Elements Based on the AISC LRFD Code, 2nd Edition

(Research Report 1126-4F by the Bureau of Engineering Research at the Univ. of Texas at Austin)
(Design of bolts and plates based on Design Guide for Steel to Concrete Connections by Cook, Doerr & Klingner)

$$Fy_{bolt_j} := if\left[\left(d_{bolt.conn_j} \le 1.0\cdot in\right), 92\cdot ksi, 81\cdot ksi\right] \qquad Fy_{bolt} = \begin{pmatrix}81\\92\end{pmatrix}\cdot ksi$$

min. yield stress
for A325 bolts

$$A_{A325bolts} = \begin{pmatrix}0.5 & 0.625 & 0.75 & 0.875 & 1 & 1.125 & 1.25 & 1.375 & 1.5 & 0 & 1.75\\0.142 & 0.226 & 0.334 & 0.462 & 0.606 & 0.763 & 0.969 & 1.16 & 1.41 & 0 & 1.9\end{pmatrix}$$

ıolt diameter
net tensile area

$$A_{net.bolt_j} := hlookup\left(\frac{d_{bolt.conn_j}}{in}, A_{A325bolts}, 1\right)_0\cdot in^2 \qquad A_{net.bolt} = \begin{pmatrix}0.97\\0.00\end{pmatrix}\cdot in^2$$

$$T_{n.bolts_j} := \left[\left(A_{net.bolt_j}\right)\cdot\left(Fy_{bolt_j}\right)\right]\cdot\frac{\#ConnBolts_j}{2} \qquad T_{n.bolts} = \begin{pmatrix}235.5\\0.0\end{pmatrix}\cdot kip$$

Bending plane under full dead and wind load

$$\theta_j := \operatorname{atan}\left(\frac{1.2 \cdot M_{dl_j}}{1.3 \cdot M_{wl_j}}\right) \qquad \theta = \begin{pmatrix} 19.2 \\ 0.0 \end{pmatrix} \cdot deg$$

Calculate the bolt moment arm

$$RC_j := \left(\frac{\frac{b_{conn.plate_j}}{2} - Distance_{bolt.edge_j}}{\cos\left(\theta_j\right)} + \frac{d_{base.arm_j}}{2}\right) \qquad RC = \begin{pmatrix} 22.8 \\ 10 \end{pmatrix} \cdot in$$

$$d_{base} := \begin{pmatrix} Diameter_{temp.arm1} \\ Diameter_{temp.arm2} \end{pmatrix} \qquad d_{base} = \begin{pmatrix} 18.00 \\ 0.00 \end{pmatrix} \cdot in \qquad b_{conn.plate} = \begin{pmatrix} 31.00 \\ 20.00 \end{pmatrix} \cdot in \qquad h_{conn.plate} = 30.00 \cdot in \qquad \theta = \begin{pmatrix} 19.2 \\ 0.0 \end{pmatrix} \cdot deg$$

$$Yieldangle_{test_j} := \operatorname{atan}\left[\frac{\frac{b_{conn.plate_j}}{2} - \frac{d_{base_j}}{2} + \frac{d_{base_j}}{2} \cdot \left(1 - \cos\left(\theta_j\right)\right)}{\frac{h_{conn.plate}}{2} + \frac{d_{base_j}}{2} \cdot \sin\left(\theta_j\right)}\right] \qquad Yieldangle_{test} = \begin{pmatrix} 21.29 \\ 33.69 \end{pmatrix} \cdot de$$

$$Yieldline_j := \frac{\frac{b_{conn.plate_j}}{2} - \frac{d_{base_j}}{2} + \frac{d_{base_j}}{2} \cdot \left(1 - \cos\left(\theta_j\right)\right) + \tan\left(\theta_j\right) \cdot \left(\frac{h_{conn.plate}}{2} - \frac{d_{base_j}}{2} \cdot \sin\left(\theta_j\right)\right)}{\mathrm{if}\left[\left(\sin\left(\theta_j\right) = 0\right), 1, \sin\left(\theta_j\right)\right]} \qquad Yieldline = \begin{pmatrix} 33.99 \\ 10.00 \end{pmatrix} \cdot in$$

$$Yieldline_j := \mathrm{if}\left[\left(Yieldangle_{test_j} \le \theta_j\right), Yieldline_j, \frac{h_{conn.plate}}{\cos\left(\theta_j\right)}\right] \qquad Yieldline = \begin{pmatrix} 31.78 \\ 30.00 \end{pmatrix} \cdot in$$

$$M_{p.plate_j} := Yieldline_j \cdot F_{y.baseplate} \cdot \frac{\left(t_{baseplate.arm_j}\right)^2}{4} \qquad M_{p.plate} = \begin{pmatrix} 148.9 \\ 0 \end{pmatrix} \cdot kip \cdot ft$$

See Reference file for variable definitions

$$CompForceOffset_j := \mathrm{if}\left(0.5 \cdot \frac{b_{conn.plate_j}}{\cos\left(\theta_j\right)} - 0.5 \cdot in < \frac{M_{p.plate_j}}{T_{n.bolts_j}}, 0.5 \cdot \frac{b_{conn.plate_j}}{\cos\left(\theta_j\right)} - 0.5 \cdot in, \frac{M_{p.plate_j}}{T_{n.bolts_j}}\right) \qquad CompForceOffset = \begin{pmatrix} 7.59 \\ 0 \end{pmatrix} \cdot i$$

$$T_{u.conn_j} := \frac{M_{u.conn_j}}{RC_j + CompForceOffset_j + t_{arm_j}} \qquad T_{u.conn} = \begin{pmatrix} 148.3 \\ 0.0 \end{pmatrix} \cdot kip$$

$$DistA_j := \frac{b_{conn.plate_j}}{2} - Distance_{bolt.edge_j} \qquad DistA = \begin{pmatrix} 13.00 \\ 10.00 \end{pmatrix} \cdot in$$

$$T_{u.bolt.max_j} := \frac{T_{u.conn_j}}{0.5\cdot\#ConnBolts_j} + \frac{DistA_j\cdot\tan\left(\theta_j\right)\cdot T_{u.conn_j}\cdot\left(\#ConnBolts_j\cdot 0.25 - 0.5\right)\cdot Spacing_{bolts.conn_j}}{\displaystyle\sum_{n=0}^{floor\left(0.25\cdot\#ConnBolts_j\right)}\left[\frac{\left[\left(\#ConnBolts_j\cdot 0.5\right) - 1\right] - 2\cdot n}{2}\cdot Spacing_{bolts.conn_j}\right]^2\cdot 2}$$

$$T_{u.bolt.max} = \begin{pmatrix} 76.3 \\ 0.0 \end{pmatrix}\cdot kip$$

$$V_{u.bolt_j} := \frac{V_{u.conn_j}}{\#ConnBolts_j}$$

Shear per Bolt

$$V_{u.bolt} = \begin{pmatrix} 1.59 \\ 0.00 \end{pmatrix}\cdot kip$$

$$A_{gross.bolt_j} := \left[\pi\cdot\left(\frac{d_{bolt.conn_j}}{2}\right)^2\right]$$

Gross Bolt Area used for shear

$$A_{gross.bolt} = \begin{pmatrix} 1.227 \\ 0 \end{pmatrix}\cdot in^2$$

$$f_{v_j} := \frac{V_{u.bolt_j}}{A_{gross.bolt_j}}$$

Bolt Shear Stress

$$f_v = \begin{pmatrix} 1.30 \\ 0.00 \end{pmatrix}\cdot ksi$$

$$f_{t_j} := \frac{T_{u.bolt.max_j}}{A_{gross.bolt_j}}$$

Bolt Tensile Stress

$$f_t = \begin{pmatrix} 62.2 \\ 0.0 \end{pmatrix}\cdot ksi$$

$$F_{t_j} := \min\left(\begin{pmatrix} 117\cdot ksi - 1.9\cdot f_{v_j} \\ 90\cdot ksi \end{pmatrix}\right)$$

Tension Stress Limit (A325 bolts)

AISC Table J3.5

$$F_t = \begin{pmatrix} 90.00 \\ 90.00 \end{pmatrix}\cdot ksi$$

$$\phi_t := 0.75$$

$$\phi_t\cdot F_t = \begin{pmatrix} 67.50 \\ 67.50 \end{pmatrix}\cdot ksi$$

$$PR_{bolt_j} := \frac{f_{t_j}}{\phi_t\cdot F_{t_j}}$$

Bolt Capacity Ratio

$$PR_{bolt} = \begin{pmatrix} 0.92 \\ 0 \end{pmatrix}$$

(if PR<= 1, then ok)

Check Arm Base Plate Thickness

See Reference file for formula derivations $\phi := 0.90$

$$t_{baseplate.arm.reqd_j} := if\left[\left(V_{u.conn_j} = 0\right), 0\cdot in, \sqrt{\frac{4\cdot T_{n.bolts_j}\cdot\left(DistA_j - \frac{d_{base.arm_j}}{2}\right)}{\left(\phi\cdot F_{y.baseplate}\right)\cdot h_{conn.plate}}}\right]$$

$$t_{baseplate.arm.reqd} = \begin{pmatrix} 1.97 \\ 0.00 \end{pmatrix}\cdot in$$

$$t_{baseplate.arm} = \begin{pmatrix} 2.500 \\ 0.000 \end{pmatrix}\cdot in$$

$$PR_{t.baseplate.arm_j} := \frac{t_{baseplate.arm.reqd_j}}{t_{baseplate.arm_j}}$$

$$PR_{t.baseplate.arm} = \begin{pmatrix} 0.79 \\ 0 \end{pmatrix}$$

(if PR <= 1.0   ok)

Upright Connection Plate Thickness

See Reference file for formula derivations

$$t_{conn.plate.reqd_j} := \sqrt{\frac{4\cdot T_{n.bolts_j}\cdot\left(\frac{b_{conn.plate_j} - Diameter_{conn.pole} - 2\cdot t_{vertical.plate_j} - 2\cdot Distance_{bolt.edge_j}}{2}\right)}{\left(\phi\cdot F_{y.baseplate}\right)\cdot h_{conn.plate}}}$$

Round up to next quarter inch dimension.

$$t_{conn.plate.reqd} = \begin{pmatrix} 1.61 \\ 0.00 \end{pmatrix}\cdot in$$

$$t_{conn.plate_j} := Ceil\left(t_{conn.plate.reqd_j}, \frac{1}{8}\cdot in\right)$$

$$t_{conn.plate} = \begin{pmatrix} 1.625 \\ 0.000 \end{pmatrix}\cdot in$$

(FR)

(SR)

$$PR_{t.connplate.arm_j} := \frac{t_{conn.plate.reqd_j}}{t_{conn.plate_j}}$$

$$PR_{t.connplate.arm} = \begin{pmatrix} 0.99 \\ 0 \end{pmatrix}$$

Weld Size of Arm to Plate Connection

(Design welds of the socket joint to carry 100% of the design load using an E70 electrode.).

$$S_{weld_j} := \pi\cdot\left(\frac{d_{base.arm_j}}{2}\right)^2 \qquad L_{weld_j} := \pi\cdot d_{base.arm_j}$$

Weld Properties

$$f_{weld_j} := \sqrt{\left(\frac{M_{u.conn_j}}{S_{weld_j}}\right)^2 + \left(\frac{V_{u.conn_j}}{L_{weld_j}}\right)^2}$$

Total Stress on Weld

$$f_{weld} = \begin{pmatrix} 17.91 \\ 0.00 \end{pmatrix}\cdot\frac{kip}{in}$$

Max. Bottom Weld Size

$$w_{bot.arm_j} := if\left[\left(t_{arm_j} = 0\cdot in\right), 0\cdot in, t_{arm_j} - \left(\frac{1}{16}\cdot in\right)\right] \qquad w_{bot.arm_j} := Ceil\left(w_{bot.arm_j}, \frac{1}{16}\cdot in\right)$$

$$w_{bot.arm} = \begin{pmatrix} 0.3125 \\ 0 \end{pmatrix}\cdot in$$

(FM)

(SM)

$$f_{bot.weld_j} := w_{bot.arm_j}\cdot\left[(0.75)\cdot(0.6)\cdot(70\cdot ksi)\cdot\left(\frac{1}{\sqrt{2}}\right)\right]$$

Bottom Weld Stress

AISC Table J2.5

$$f_{bot.weld} = \begin{pmatrix} 6.96 \\ 0.00 \end{pmatrix}\cdot\frac{kip}{in}$$

$$f_{top.weld_j} := f_{weld_j} - f_{bot.weld_j}$$

Top Weld Stress

$$f_{top.weld} = \begin{pmatrix} 10.95 \\ 0.00 \end{pmatrix}\cdot\frac{kip}{in}$$

$$w_{top.arm_j} := \frac{f_{top.weld_j}}{(0.75)\cdot(0.6)\cdot(70\cdot ksi)\cdot\left(\frac{1}{\sqrt{2}}\right)}$$

Top Weld Size

$$w_{top.arm_j} := Ceil\left(w_{top.arm_j}, \frac{1}{16}\cdot in\right)$$

$$w_{top.arm} = \begin{pmatrix} 0.5000 \\ 0.0000 \end{pmatrix}\cdot in$$

$$w_{top.arm_j} := \text{if}\left[\left(w_{top.arm_j} > t_{arm_j}\right), w_{top.arm_j}, \text{Ceil}\left(t_{arm_j}, \frac{1}{16}\cdot \text{in}\right)\right]$$

Round up to next 1/16 inch

$$w_{top.arm} = \begin{pmatrix} 0.5000 \\ 0.0000 \end{pmatrix}\cdot \text{in} \quad \begin{matrix} \textit{(FQ)} \\ \textit{(SQ)} \end{matrix}$$

Size of Vertical Welds to Upright

(Design welds to resist dead load moment , wind load moment, and dead load shear using an E70 electrode)

$$S_{dl.mom} := \frac{h_{conn.plate}^{\;2}}{3}$$

Weld Properties

$$S_{wl.mom} := \text{Diameter}_{conn.pole}\cdot h_{conn.plate}$$

$$A_{dl.shr} := 2\cdot h_{conn.plate} \qquad r_{upright} := \frac{\text{Diameter}_{conn.pole}}{2}$$

$$f_{weld_j} := \sqrt{\left[\frac{1.2\cdot\left[M_{dl_j} + V_{dl.arm_j}\cdot\left[\left(r_{upright}\right) + \text{Gap}_j\right]\right]}{S_{dl.mom}}\right]^2 + \left[\frac{1.3\cdot\left[M_{wl_j} + V_{wl.arm_j}\cdot\left[\left(r_{upright}\right) + \text{Gap}_j\right]\right]}{S_{wl.mom}}\right]^2 + \left(\frac{1.2\cdot V_{dl.arm_j}}{A_{dl.shr}}\right)^2}$$

$$f_{weld} = \begin{pmatrix} 9.3 \\ 0.0 \end{pmatrix}\cdot\frac{\text{kip}}{\text{in}}$$

Plate/Upright Weld size

AISC Table J2.5

$$w_{vert.plate_j} := \frac{f_{weld_j}}{0.75\cdot(0.6\cdot 70\cdot\text{ksi})\cdot\left(\frac{1}{\sqrt{2}}\right)}$$

$$w_{vert.plate_j} := \text{Ceil}\left(w_{vert.plate_j}, \frac{1}{16}\cdot\text{in}\right) \qquad w_{vert.plate} = \begin{pmatrix} 0.4375 \\ 0.0000 \end{pmatrix}\cdot\text{in}$$

$$w_{p.min_j} := \text{if}\left[\left(t_{vertical.plate_j} > \frac{1}{2}\cdot\text{in}\right), \frac{1}{4}\cdot\text{in}, \frac{3}{16}\cdot\text{in}\right]$$

min weld size

AISC Table J2.4

$$w_{p.min_j} := \text{if}\left[\left(t_{vertical.plate_j} = 0\cdot\text{in}\right), 0\cdot\text{in}, w_{p.min_j}\right] \qquad w_{p.min} = \begin{pmatrix} 0.25 \\ 0.1875 \end{pmatrix}\cdot\text{in}$$

$$w_{vertical.plate_j} := \text{if}\left[\left(w_{vert.plate_j} > w_{p.min_j}\right), w_{vert.plate_j}, w_{p.min_j}\right] \qquad w_{vertical.plate} = \begin{pmatrix} 0.4375 \\ 0.1875 \end{pmatrix}\cdot\text{in} \quad \begin{matrix} \textit{(FN)} \\ \textit{(SN)} \end{matrix}$$

Size of Vertical Welds to Connection Plate

$$w_{conn.plate_j} := w_{vert.plate_j} \qquad w_{conn.plate} = \begin{pmatrix} 0.4375 \\ 0.0000 \end{pmatrix}\cdot\text{in}$$

$$w_{c.min_j} := \text{if}\left[\left(t_{conn.plate_j} > \frac{3}{4}\cdot\text{in}\right), \frac{5}{16}\cdot\text{in}, \frac{1}{4}\cdot\text{in}\right]$$

min weld size

AISC Table J2.4

$$w_{c.min} = \begin{pmatrix} 0.3125 \\ 0.2500 \end{pmatrix}\cdot\text{in}$$

$$w_{c.min_j} := \text{if}\left[\left(w_{c.min_j} > t_{vertical.plate_j}\right), t_{vertical.plate_j}, w_{c.min_j}\right]$$

min weld size

AISC p. 8-119

$$w_{c.min} = \begin{pmatrix} 0.3125 \\ 0.1000 \end{pmatrix}\cdot\text{in}$$

$$w_{conn.plate_j} := \text{if}\left[\left(w_{conn.plate_j} > w_{c.min_j}\right), w_{conn.plate_j}, w_{c.min_j}\right] \qquad w_{conn.plate} = \begin{pmatrix} 0.4375 \\ 0.1 \end{pmatrix}\cdot\text{in} \quad \begin{matrix} \textit{(FT)} \\ \textit{(ST)} \end{matrix}$$

Check Thickness of Vertical Plates

$$t_{vertical.plate} = \begin{pmatrix} 0.750 \\ 0.100 \end{pmatrix} \cdot in$$

Trial Plate Thickness

$$h_{vertical.plate} := h_{conn.plate} \qquad A_{vertical.plate_j} := t_{vertical.plate_j} \cdot h_{vertical.plate}$$

$$A_{vertical.plate} = \begin{pmatrix} 22.5 \\ 3 \end{pmatrix} \cdot in^2$$

$$L_{b_j} := \frac{Diameter_{conn.pole}}{2} + Gap_j - t_{conn.plate_j}$$

$$L_b = \begin{pmatrix} 13.4 \\ 9.6 \end{pmatrix} \cdot in$$

$$r_{y_j} := \frac{t_{vertical.plate_j}}{\sqrt{12}}$$

$$r_y = \begin{pmatrix} 0.2 \\ 0.0 \end{pmatrix} \cdot in$$

$$\lambda_j := \text{if}\left[\left(t_{vertical.plate_j} = 0 \cdot in\right), 0, \frac{L_{b_j}}{r_{y_j}}\right]$$

Controlling Slenderness Parameter

$$\lambda = \begin{pmatrix} 62.1 \\ 331.3 \end{pmatrix}$$

$$M_{p_j} := \frac{h_{vertical.plate}^{2} \cdot t_{vertical.plate_j}}{4} \cdot F_{y.baseplate}$$

Plastic Moment

$$M_p = \begin{pmatrix} 506.2 \\ 67.5 \end{pmatrix} \cdot kip \cdot ft$$

$$M_{r_j} := \frac{h_{vertical.plate}^{2} \cdot t_{vertical.plate_j}}{6} \cdot F_{y.baseplate}$$

Limiting Buckling Moment

$$M_r = \begin{pmatrix} 337.5 \\ 45.0 \end{pmatrix} \cdot kip \cdot ft$$

$$J_j := 0.3 \cdot \left(t_{vertical.plate_j}\right)^3 \cdot h_{vertical.plate} \qquad A_j := A_{vertical.plate_j} \qquad E := 29000 \cdot ksi$$

$$\lambda_{p_j} := \frac{(3750 \cdot ksi) \cdot \sqrt{J_j \cdot A_j}}{M_{p_j}}$$

Flexural Slenderness Parameters

$$\lambda_p = \begin{pmatrix} 5.7 \\ 0.8 \end{pmatrix}$$

$$\lambda_{r_j} := \frac{(57000 \cdot ksi) \cdot \sqrt{J_j \cdot A_j}}{M_{r_j}}$$

AISC Table A-F1.1

$$\lambda_r = \begin{pmatrix} 130.1 \\ 17.3 \end{pmatrix}$$

$$M_{n_j} := \left[M_{p_j} - \left(M_{p_j} - M_{r_j}\right) \cdot \left(\frac{\lambda_j - \lambda_{p_j}}{\lambda_{r_j} - \lambda_{p_j}}\right)\right]$$

For $l_p < l <= l_r$
Nominal Flex. Strength
AISC Eqn A-F1-3

$$M_n = \begin{pmatrix} 430 \\ -381 \end{pmatrix} \cdot kip \cdot ft$$

$$M_{cr_j} := \frac{(57000 \cdot ksi) \cdot \sqrt{J_j \cdot A_j}}{\lambda_j}$$

For $l_r < l$
Nominal Flex. Strength
AISC Eqn F1-14

$$M_{cr} = \begin{pmatrix} 707 \\ 2 \end{pmatrix} \cdot kip \cdot ft$$

$$\phi M_{n_j} := \text{if}\left[\left(\lambda_{p_j} < \lambda_j\right), 0.9 \cdot M_{n_j}, 0.9 \cdot M_{p_j}\right]$$

$$\phi M_n = \begin{pmatrix} 386.8 \\ -342.9 \end{pmatrix} \cdot kip \cdot ft$$

$\phi M_{n_j} := \text{if}\left[\left(\lambda_{r_j} < \lambda_j\right), 0.9\cdot M_{cr_j}, \phi M_{n_j}\right]$ $\phi M_n = \begin{pmatrix}386.8\\2.1\end{pmatrix}\cdot\text{kip}\cdot\text{ft}$

$M_{u_j} := \dfrac{1.2\cdot\left[M_{dl_j} + V_{dl.arm_j}\cdot\left(r_{upright} + Gap_j\right)\right]}{2}$ *Required Flexural Strength* $M_u = \begin{pmatrix}65.2\\0.0\end{pmatrix}\cdot\text{kip}\cdot\text{ft}$

$\lambda_{c_j} := \text{if}\left[\left(t_{vertical.plate_j} \neq 0\cdot\text{in}\right), \dfrac{L_{b_j}}{r_{y_j}\cdot\pi}\cdot\sqrt{\dfrac{F_{y.baseplate}}{E}}, ,0\right]$ *Column Slenderness Parameter* ***AISC Eqn E2-4*** $\lambda_c = \begin{pmatrix}0.696\\3.716\end{pmatrix}$

$F_{cr_j} := \text{if}\left[\left(\lambda_{c_j} \le 1.5\right), \left[0.658^{\left(\lambda_{c_j}\right)^2}\right]\cdot F_{y.baseplate}, \left[\dfrac{0.877}{\left(\lambda_{c_j}\right)^2}\right]\cdot F_{y.baseplate}\right]$ *Nominal Critical Stress* ***AISC Eqns E2-2 & E2-3*** $F_{cr} = \begin{pmatrix}29.4\\2.3\end{pmatrix}\cdot\text{ksi}$

$\phi P_{n_j} := 0.85\cdot A_j\cdot F_{cr_j}$ *Nominal Compressive Strength* ***AISC Eqn E2-1*** $\phi P_n = \begin{pmatrix}562.1\\5.8\end{pmatrix}\cdot\text{kip}$

$P_{u_j} := \dfrac{1.3\cdot\left[M_{wl_j} + V_{wl.arm_j}\cdot\left[\left(r_{upright}\right) + Gap_j\right]\right]}{Diameter_{conn.pole}}$ *Required Compressive Strength* $P_u = \begin{pmatrix}231.6\\0\end{pmatrix}\cdot\text{kip}$

$CSR_{t.vert.plate_j} := \text{if}\left[\left(\dfrac{P_{u_j}}{\phi P_{n_j}} \ge 0.2\right), \left(\dfrac{P_{u_j}}{\phi P_{n_j}} + \dfrac{8}{9}\cdot\dfrac{M_{u_j}}{\phi M_{n_j}}\right), \left(\dfrac{P_{u_j}}{2\cdot\phi P_{n_j}} + \dfrac{M_{u_j}}{\phi M_{n_j}}\right)\right]$ *Combined Stress Ratio Flexure and Tension memb* ***AISC Eqns H1-1a & H1-1b*** $CSR_{t.vert.plate} = \begin{pmatrix}0.562\\0.000\end{pmatrix}$

(if CSR<1, then ok)

$PR_0 := \max\left(\begin{pmatrix}PR_{bolt_0}\\PR_{t.baseplate.arm_0}\\PR_{t.connplate.arm_0}\\CSR_{t.vert.plate_0}\end{pmatrix}\right)$ $PR_1 := \text{if}\left[\left(M_{dl_1} = 0\cdot\text{kip}\cdot\text{ft}\right), 0, \max\left(\begin{pmatrix}PR_{bolt_1}\\PR_{t.baseplate.arm_1}\\PR_{t.connplate.arm_1}\\CSR_{t.vert.plate_1}\end{pmatrix}\right)\right]$ $PR = \begin{pmatrix}0.993\\0.000\end{pmatrix}$

(if PR<1, then ok)

$j := 0..1$ $vert_{plt.width_j} := r_{upright} + Gap_j - t_{conn.plate_j}$ $vert_{plt.width_1} := \text{if}\left[\left(M_{dl_1} = 0\cdot\text{kip}\cdot\text{ft}\right), 0\cdot\text{in}, vert_{plt.width_1}\right]$

set variables equal to zero if there is no second arm

$b_{conn.plate_1} := \text{fSetZero}\left(b_{conn.plate_1}, \text{in}\right)$ $t_{vertical.plate_1} := \text{fSetZero}\left(t_{vertical.plate_1}, \text{in}\right)$

$Gap_1 := \text{fSetZero}\left(Gap_1, \text{in}\right)$ $d_{bolt.conn_1} := \text{fSetZero}\left(d_{bolt.conn_1}, \text{in}\right)$

$t_{conn.plate_1} := \text{fSetZero}\left(t_{conn.plate_1}, \text{in}\right)$ $\#ConnBolts_1 := \text{fSetZero}\left(\#ConnBolts_1, 1\right)$

$t_{baseplate.arm_1} := \text{fSetZero}\left(t_{baseplate.arm_1}, \text{in}\right)$ $w_{bot.arm_1} := \text{fSetZero}\left(w_{bot.arm_1}, \text{in}\right)$

$w_{conn.plate_1} := \text{fSetZero}\left(w_{conn.plate_1}, \text{in}\right)$ $Spacing_{bolts.conn_1} := \text{fSetZero}\left(Spacing_{bolts.conn_1}, \text{in}\right)$

$w_{top.arm_1} := fSetZero\left(w_{top.arm_1}, in\right)$ $w_{vertical.plate_1} := fSetZero\left(w_{vertical.plate_1}, in\right)$

$Offset_{conn_1} := fSetZero\left(Offset_{conn_1}, in\right)$

$PR_{bolt_1} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right) + \left(newL_{total.arm2} = "x"\right) + \left(newL_{total.arm2} = "X"\right), 0, PR_{bolt_1}\right]$

$PR_{t.baseplate.arm_1} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right) + \left(newL_{total.arm2} = "x"\right) + \left(newL_{total.arm2} = "X"\right), 0, PR_{t.baseplate.arm_1}\right]$

$CSR_{t.vert.plate_1} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right) + \left(newI_{total.arm2} = "x"\right) + \left(newI_{total.arm2} = "X"\right), 0, CSR_{t.vert.plate_1}\right]$

$PR_{t.connplate.arm_1} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right) + \left(newL_{total.arm2} = "x"\right) + \left(newL_{total.arm2} = "X"\right), 0, PR_{t.connplate.arm_1}\right]$

Analyze Connection

Summary - Connection Geometry

$h_{conn.plate} = 30 \cdot in$ $Gap = \begin{pmatrix} 5.5 \\ 0 \end{pmatrix} \cdot in$ $Offset_{conn} = \begin{pmatrix} 15.065 \\ 0 \end{pmatrix} \cdot in$

$d_{bolt.conn} = \begin{pmatrix} 1.25 \\ 0 \end{pmatrix} \cdot in$ $\#ConnBolts = \begin{pmatrix} 6 \\ 0 \end{pmatrix}$ $Spacing_{bolts.conn} = \begin{pmatrix} 12.5 \\ 0 \end{pmatrix} \cdot in$

$t_{conn.plate} = \begin{pmatrix} 1.625 \\ 0 \end{pmatrix} \cdot in$ $b_{conn.plate} = \begin{pmatrix} 31 \\ 0 \end{pmatrix} \cdot in$ $t_{vertical.plate} = \begin{pmatrix} 0.75 \\ 0 \end{pmatrix} \cdot in$ $t_{baseplate.arm} = \begin{pmatrix} 2.5 \\ 0 \end{pmatrix} \cdot in$

$w_{conn.plate} = \begin{pmatrix} 0.4375 \\ 0 \end{pmatrix} \cdot in$ $w_{vertical.plate} = \begin{pmatrix} 0.4375 \\ 0 \end{pmatrix} \cdot in$

Connection Ratios

$PR_{bolt} = \begin{pmatrix} 0.922 \\ 0 \end{pmatrix}$ $CSR_{t.vert.plate} = \begin{pmatrix} 0.562 \\ 0 \end{pmatrix}$ $PR_{t.baseplate.arm} = \begin{pmatrix} 0.788 \\ 0 \end{pmatrix}$ $PR_{t.connplate.arm} = \begin{pmatrix} 0.993 \\ 0 \end{pmatrix}$

Base Plate Analysis

DataFile = "E7T6.dat" $WindSpeed = 130 \cdot mph$

Base Plate Properties

Current Values

New Values

$\#AnchorRods = 6$ *use 6 bolts minimum*

$d_{bolt.pole} = 2 \cdot in$ *inches (BC)*

Base Plate Properties

Analyze Base Plate & Anchors

Switch values, set values for DataOut

$out := out + 1 \quad out = 33.00$

$\#AnchorRods := fSwitchData(\#AnchorRods, new\#AnchorRods, 1)$ $data_{out} := \#AnchorRods \qquad data_{out} = 6.00$

$out := out + 1 \quad out = 34.00$

$d_{bolt.pole} := fSwitchData\left(d_{bolt.pole}, newd_{bolt.pole}, in\right)$ $data_{out} := \dfrac{d_{bolt.pole}}{in} \qquad data_{out} = 2.00$

Applied Loads (from Upright Design)

$$M_{x.polebase} = \begin{pmatrix} 0.0 \\ 148.5 \\ 148.5 \end{pmatrix} \cdot kip \cdot ft \qquad M_{y.polebase} = \begin{pmatrix} 284.0 \\ 0.0 \\ 284.0 \end{pmatrix} \cdot kip \cdot ft \qquad M_{z.polebase} = \begin{pmatrix} 0.0 \\ 111.5 \\ 111.5 \end{pmatrix} \cdot kip \cdot ft$$

maximum torsion (Mx & Mz not used)
maximum overturning (My not used)
maximum CSR

$$V_{x.polebase} = \begin{pmatrix} 0.0 \\ 0.3 \\ 0.3 \end{pmatrix} \cdot kip \qquad AxialForce_{polebase} = \begin{pmatrix} 5.3 \\ 5.3 \\ 5.3 \end{pmatrix} \cdot kip \qquad V_{z.polebase} = \begin{pmatrix} 0.0 \\ 7.9 \\ 7.9 \end{pmatrix} \cdot kip$$

$Diameter_{base.pole} = 22.00 \cdot in$

$t_{pole} = 0.3750 \cdot in$

$C_{a.pole} = 1.00$

load cases for maximum torsion (T), overturning (OT), and Combined Stress Ratio (CSR)

$LoadCaseT := 0 \qquad LoadCaseOT := 1 \qquad LoadCaseCSR := 2$

$M_{x.polebase_{LoadCaseT}} = 0.0 \cdot kip \cdot ft$ $M_{y.polebase_{LoadCaseT}} = 284.0 \cdot kip \cdot ft$ $M_{z.polebase_{LoadCaseT}} = 0.0 \cdot kip \cdot ft$

$M_{x.polebase_{LoadCaseOT}} = 148.5 \cdot kip \cdot f$ $M_{y.polebase_{LoadCaseOT}} = 0.0 \cdot kip \cdot ft$ $M_{z.polebase_{LoadCaseOT}} = 111.5 \cdot kip \cdot ft$

$M_{x.polebase_{LoadCaseCSR}} = 148.5 \cdot kip \cdot$ $M_{y.polebase_{LoadCaseCSR}} = 284.0 \cdot kip \cdot ft$ $M_{z.polebase_{LoadCaseCSR}} = 111.5 \cdot kip \cdot ft$

Base Plate Size

$Diameter_{baseplate.pole} := Diameter_{base.pole} + 8 \cdot d_{bolt.pole}$ $Diameter_{baseplate.pole} = 38 \cdot in$

$Diameter_{boltcircle.pole} := Diameter_{base.pole} + 2 \cdot (2 \cdot d_{bolt.pole})$ $Diameter_{boltcircle.pole} = 30 \cdot in$

$$I_{rod.group} := \frac{\#AnchorRods}{8} \cdot Diameter_{boltcircle.pole}^{2}$$ $I_{rod.group} = 675 \cdot in^{2}$

$$S_{rod.group} := \frac{I_{rod.group}}{\dfrac{Diameter_{boltcircle.pole}}{2}}$$ $S_{rod.group} = 45 \cdot in$

Bolt Load

AASHTO anchor bolt CSR calcs not used, for future use

$$M_{csr.pole} := \frac{\sqrt{\left(M_{x.polebase_{LoadCaseCSR}}\right)^{2} + \left(M_{z.polebase_{LoadCaseCSR}}\right)^{2}}}{C_{a.pole}}$$ **LTS 5.17**

$M_{csr.pole} = 186.2 \cdot kip \cdot ft$

$$T_{u.rod} := \frac{M_{csr.pole}}{S_{rod.group}}$$ $T_{u.rod} = 49.7 \cdot kip$

$$V_{csr.pole} := \sqrt{\left(V_{x.polebase_{LoadCaseCSR}}\right)^{2} + \left(V_{z.polebase_{LoadCaseCSR}}\right)^{2}}$$ $V_{csr.pole} = 7.9 \cdot kip$

$$V_{u.rod} := \frac{V_{csr.pole}}{\#AnchorRods} + \frac{M_{y.polebase_{LoadCaseCSR}}}{\left(\dfrac{Diameter_{boltcircle.pole}}{2}\right) \cdot \#AnchorRods}$$ $V_{u.rod} = 39.2 \cdot kip$

$$A_{net.rod} := \frac{\pi}{4} \cdot \left(d_{bolt.pole} - \frac{0.9743}{\dfrac{4}{in}}\right)^{2}$$ $A_{net.rod} = 2.42 \cdot in^{2}$ **LTS Eqn 5-23**

$$f_{t.rod} := \frac{T_{u.rod}}{A_{net.rod}}$$ $f_{t.rod} = 20.49 \cdot ksi$

$$f_{v.rod} := \frac{V_{u.rod}}{A_{net.rod}}$$ $f_{v.rod} = 16.17 \cdot ksi$

$F_{y.rod} := 55 \cdot ksi$

$F_{t.rod} := 0.5 \cdot F_{y.rod}$ $F_{t.rod} = 27.50 \cdot ksi$ ***LTS Eqn 5-21***

$F_{v.rod} := 0.3 \cdot F_{y.rod}$ $F_{v.rod} = 16.50 \cdot ksi$ ***LTS Eqn 5-22***

$$CSR_{rod} := \left(\frac{f_{t.rod}}{1.33 \cdot F_{t.rod}}\right)^2 + \left(\frac{f_{v.rod}}{1.33 \cdot F_{v.rod}}\right)^2$$

$CSR_{rod} = 0.857$ ***LTS Eqn 5-24***

Use the AISC LRFD Code, 2nd Edition, for Design of Elements Where Possible

(Design of bolts based on Design Guide for Steel to Concrete Connections by Cook, Doerr & Klingner)
(Research Report 1126-4F by the Bureau of Engineering Research at the Univ. of Texas at Austin)

$T_{u.rod.old} := 1.3 \cdot T_{u.rod}$ *(use a 1.3 load factor since loads are a mix of wind load and dead load)* $T_{u.rod.old} = 64.5 \cdot kip$

$V_{u.rod.old} := 1.3 \cdot V_{u.rod}$ $V_{u.rod.old} = 50.9 \cdot kip$

$$A_{net.rod.old} := 0.75 \cdot \pi \cdot \left(\frac{d_{bolt.pole}}{2}\right)^2$$

$A_{net.rod.old} = 2.36 \cdot in^2$

$F_{u.rod} := 75 \cdot ksi$

$T_{s.rod} := A_{net.rod.old} \cdot F_{u.rod}$ $T_{s.rod} = 176.7 \cdot kip$

$\gamma := 0.5$ *(property of embedded rods)* $T_{n.rod} := \sqrt{T_{s.rod}^{\ 2} - \left(\frac{V_{u.rod}}{\gamma}\right)^2}$ $0.75 \cdot T_{n.rod} = 118.8 \cdot kip$ *(if greater than actual rod tension, bolts are OK)*

$$PR_{rod} := \frac{T_{u.rod.old}}{0.75 \cdot T_{n.rod}}$$

$PR_{rod} = 0.543$

Base Plate Thickness

Design plate thickness based on yield line theory $\phi := 0.90$

$$t_{baseplate.pole.reqd} := \left[(1.3) \cdot \frac{M_{csr.pole}}{\phi} \cdot \frac{\frac{Diameter_{boltcircle.pole}}{2} - \frac{Diameter_{base.pole}}{2}}{F_{y.baseplate} \cdot \frac{Diameter_{boltcircle.pole}}{2} \cdot \frac{Diameter_{base.pole}}{2}}\right]^{\frac{1}{2}}$$

$t_{baseplate.pole.reqd} = 1.47 \cdot in$

minimum base plate thickness

$t_{baseplate.pole.reqd} := if\left(t_{baseplate.pole.reqd} < d_{bolt.pole}, d_{bolt.pole}, t_{baseplate.pole.reqd}\right)$ ***LTS C5.14.2***

$t_{baseplate.pole.reqd} := if\left(t_{baseplate.pole.reqd} < 2.5 \cdot in, 2.5 \cdot in, t_{baseplate.pole.reqd}\right)$

$t_{baseplate.pole} := Ceil\left(t_{baseplate.pole.reqd}, \frac{1}{8} \cdot in\right)$ *Round up to next 1/8 inch dim.* $t_{baseplate.pole} = 2.500 \cdot in$

$PR_{plate.pole} := \frac{t_{baseplate.pole.reqd}}{t_{baseplate.pole}}$ $PR_{plate.pole} = 1.00$

Weld Sizes of Upright to Base Plate Connection

(Design welds of the socket joint to carry 100% of the design load using an E70 electrode.).

$S_{weld.pole} := \pi \cdot \left(\frac{Diameter_{base.pole}}{2}\right)^2$ $L_{weld.pole} := \pi \cdot Diameter_{base.pole}$

AISC LRFD, Vol 1, 6-A4 Specs, 2nd Ed.

$$f_{weld.pole} := \sqrt{\left(\frac{1.3 \cdot M_{csr.pole}}{S_{weld.pole}}\right)^2 + \left(\frac{1.3 \cdot V_{csr.pole}}{L_{weld.pole}} + \frac{1.3 \cdot M_{y.polebase_{LoadCaseCSR}}}{0.5 \cdot Diameter_{base.pole}^{\ 2} \cdot \pi}\right)^2}$$ $f_{weld.pole} = 9.7 \cdot \frac{kip}{in}$

$w_{bot.pole} := t_{pole} - \left(\frac{1}{16} \cdot in\right)$ $w_{bot.pole} := Ceil\left(w_{bot.pole}, \frac{1}{16} \cdot in\right)$ $w_{bot.pole} = 0.3125 \cdot in$

$f_{bot.weld.pole} := w_{bot.pole} \cdot \left[(0.75) \cdot 0.6 \cdot (70 \cdot ksi) \cdot \left(\frac{1}{\sqrt{2}}\right)\right]$ ***AISC Table J2.5*** $f_{bot.weld.pole} = 7 \cdot \frac{kip}{in}$

$f_{top.weld.pole} := f_{weld.pole} - f_{bot.weld.pole}$ $f_{top.weld.pole} = 2.7 \cdot \frac{kip}{in}$

$w_{top.pole} := \frac{f_{top.weld.pole}}{(0.75) \cdot (0.6) \cdot 70 \cdot ksi \cdot \left(\frac{1}{\sqrt{2}}\right)}$ $w_{top.pole} := Ceil\left(w_{top.pole}, \frac{1}{16} \cdot in\right)$ $w_{top.pole} = 0.1250 \cdot in$

$w_{top.pole} := if\left[\left(w_{top.pole} > t_{wall.pole}\right), w_{top.pole}, Ceil\left(t_{wall.pole}, \frac{1}{16} \cdot in\right)\right]$ $w_{top.pole} = 0.3750 \cdot in$

⊞ Analyze Base Plate & Anchors

Summary - Upright Base Plate Geometry

#AnchorRods = 6 $d_{bolt.pole} = 2 \cdot in$ $t_{baseplate.pole} = 2.5 \cdot in$ $Diameter_{baseplate.pole} = 38 \cdot in$

Upright Base Plate Performance Ratios

$PR_{rod} = 0.543$ $PR_{plate.pole} = 1$

Foundation Analysis Cohesionless or Cohesive Soil

DataFile = "E7T6.dat"

Soil Properties

Current Values   New Values

○ Clay

SoilType = 1   ● Sand   *0 - clay 1 - sand*

$\phi_{soil} = 28 \cdot deg$ 28   *degrees, soil friction angle (sand)*

$c_{soil} = 2000 \cdot psf$ ☐   *psf, soil shear strength (clay)*

$\gamma_{soil.dry} = 100 \cdot pcf$ 100   *pcf, dry soil weight*

$\gamma_{water} = 62.4 \cdot pcf$ ☐   *pcf, water weight (zero if no water)*

$\gamma_{soil} := \gamma_{soil.dry} - \gamma_{water}$ $\gamma_{soil} = 37.60 \cdot pcf$

Soil Properties

▼ Analyze Foundation

Switch values, set values for DataOut, and Write Out Data to DataFile and Temp.dat

$out := out + 1 \quad out = 35.00$

$SoilType := if(newSoilType = 0, 0, 1)$ $data_{out} := SoilType$ $data_{out} = 1.00$

$out := out + 1 \quad out = 36.00$

$\phi_{soil} := fSwitchData(\phi_{soil}, new\phi_{soil}, deg)$ $data_{out} := \dfrac{\phi_{soil}}{deg}$ $data_{out} = 28$

$out := out + 1 \quad out = 37.00$

$c_{soil} := fSwitchData(c_{soil}, newc_{soil}, psf)$ $data_{out} := \dfrac{c_{soil}}{psf}$ $data_{out} = 2000$

$out := out + 1 \quad out = 38.00$

$\gamma_{soil.dry} := fSwitchData(\gamma_{soil.dry}, new\gamma_{soil.dry}, pcf)$ $data_{out} := \dfrac{\gamma_{soil.dry}}{pcf}$ $data_{out} = 100.00$

$out := out + 1 \quad out = 39.00$

$\gamma_{water} := fSwitchData(\gamma_{water}, new\gamma_{water}, pcf)$ $data_{out} := \dfrac{\gamma_{water}}{pcf}$ $data_{out} = 62.40$

$out := out + 1 \quad out = 40.00$

Subject := if(**newSubject** = 0, **Subject**, **newSubject**) $data_{out}$:= **Subject**

$data_{out}$ = "E7-T6 Mast Arm"

$out := out + 1 \quad out = 41.00$

ProjectNo := if(**newProjectNumber** = 0, **ProjectNo**, **newProjectNumber**) $data_{out}$:= **ProjectNo**

$data_{out}$ = "00193008015"

out := out + 1   out = 42.00

PoleLocation := if(**newPoleLocation** = 0 , **PoleLocation** , **newPoleLocation**)

$data_{out}$:= **PoleLocation**

$data_{out}$ = "ID No.2"

out := out + 1   out = 43.00

Date := if(**newDate** = 0 , **Date** , **newDate**)

$data_{out}$:= **Date**

$data_{out}$ = "12/5/2012"

out := out + 1   out = 44.00

DesignedBy := if(**newDesignedBy** = 0 , **DesignedBy** , **newDesignedBy**)

$data_{out}$:= **DesignedBy**

$data_{out}$ = "MAV"

out := out + 1   out = 45.00

CheckedBy := if(**newCheckedBy** = 0 , **CheckedBy** , **newCheckedBy**)

$data_{out}$:= **CheckedBy**

$data_{out}$ = "FDOT"

WRITEPRN(DataFile) := data   WRITEPRN("temp.dat") := data

Foundation Design References

LRFD = AASHTO LRFD Bridge Design Specifications

SM V9 = FDOT Structures Manual Volume 9

SDG = FDOT Structures Design Guidelines

Spec = FDOT Standard Specifications

ACI = ACI 318 Structural Concrete Building Code

UF Report = FDOT/University of Florida Report BD545 RPWO #54

Applied Loads

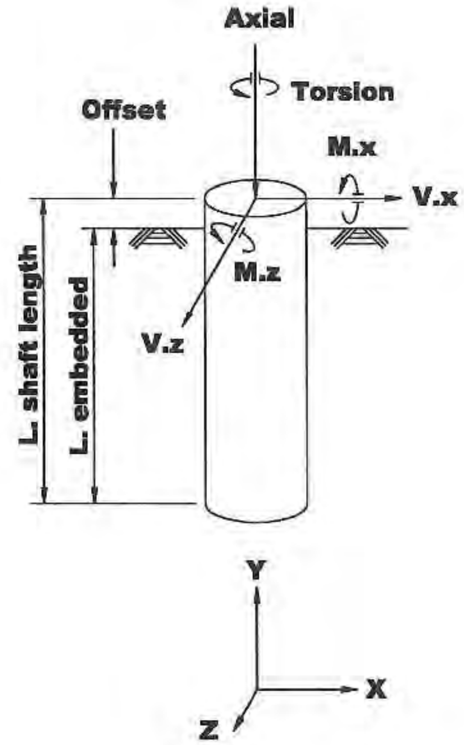
(From Arm1 Design)

WindSpeed = 130.00·mph

(from Base Plate Design)

#AnchorRods = 6.00 $d_{bolt.pole}$ = 2.00·in $Diameter_{boltcircle.pole}$ = 30·in $T_{u.rod}$ = 49.7·kip

(from Upright Design)



$$M_{x.polebase} = \begin{pmatrix} 0 \\ 148.5 \\ 148.5 \end{pmatrix} \cdot kip \cdot ft \quad M_{y.polebase} = \begin{pmatrix} 284 \\ 0 \\ 284 \end{pmatrix} \cdot kip \cdot ft \quad M_{z.polebase} = \begin{pmatrix} 0 \\ 111.5 \\ 111.5 \end{pmatrix} \cdot kip \cdot ft$$

LoadCaseT = 0.00

LoadCaseOT = 1.00

LoadCaseCSR = 2.00

$$V_{x.polebase} = \begin{pmatrix} 0 \\ 0.3 \\ 0.3 \end{pmatrix} \cdot kip \quad AxialForce_{polebase} = \begin{pmatrix} 5.3 \\ 5.3 \\ 5.3 \end{pmatrix} \cdot kip \quad V_{z.polebase} = \begin{pmatrix} 0 \\ 7.9 \\ 7.9 \end{pmatrix} \cdot kip$$

Foundation Diameter

$Diameter_{shaft} := Diameter_{boltcircle.pole} + 12 \cdot in + 12 \cdot in$ $\qquad$ $Diameter_{shaft} = 4.5 \cdot ft$

round shaft diameter up to the nearest half foot dimension to accommodate available coring equipment

$\text{Diameter}_{\text{shaft}} := \text{Ceil}\left(\text{Diameter}_{\text{shaft}}, \frac{1}{2}\cdot \text{ft}\right)$ $\text{Diameter}_{\text{shaft}} = 4.50\,\text{ft}$

$b := \text{Diameter}_{\text{shaft}}$

Shaft Depth Required to Resist Overturning

$SF_{ot} := 2$ *Safety Factor against Overturning* *SM V9 13.6*

$\text{Offset} := 1.0\cdot \text{ft}$ *vertical distance between top of foundation and groundline*

$$M_{total} := SF_{ot}\cdot \frac{\sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2}}{C_{a.pole}} \qquad M_{total} = 372.4\cdot \text{kip}\cdot \text{ft}$$

$$P_{total} := SF_{ot}\cdot \sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2} \qquad P_{total} = 15.7\cdot \text{kip}$$

short free-head pile in cohesionless soil using Broms method

$$K_p := \tan\left(45\cdot \text{deg} + \frac{\phi_{soil}}{2}\right)^2 \qquad e_{sand} := \text{Offset}$$

Guess value $L_{otSand} := 8\cdot \text{ft}$

Given $$\frac{\gamma_{soil}\cdot b\cdot L_{otSand}{}^3\cdot K_p}{2} - P_{total}\cdot\left(e_{sand} + L_{otSand}\right) - M_{total} = 0\cdot \text{kip}\cdot \text{ft}$$

$\text{Temp} := \text{Find}\left(L_{otSand}\right)$ $L_{otSand} := \text{Temp}$ $L_{otSand} = 13.71\cdot \text{ft}$

(round up to next foot) $L_{otSand} := \text{ceil}\left(\frac{L_{otSand}}{\text{ft}}\right)\cdot \text{ft}$ $L_{otSand} = 14.00\,\text{ft}$

$$PR_{otSand} := \frac{M_{total} + P_{total}\cdot\left(e_{sand} + L_{otSand}\right)}{\frac{\gamma_{soil}\cdot b\cdot L_{otSand}{}^3\cdot K_p}{2}} \qquad PR_{otSand} = 0.95$$

short free-head pile in cohesive soil using Modified Broms method for L < 3b (see reference file for derivation)

$$c_{soil} := \text{if}\left(c_{soil} = 0\cdot \text{ksf}, 0.1\cdot \text{ksf}, c_{soil}\right) \qquad \text{Slope} := 8\cdot \frac{c_{soil}}{3\cdot b} \qquad e_{clay} := \frac{M_{total}}{P_{total}} + \text{Offset}$$

$$\text{nforce}(M,N) := \left[\text{Slope}\cdot(2\cdot M + N) + 2\cdot c_{soil}\right]\cdot N\cdot \frac{b}{2} \qquad \text{mforce}(M) := \left(2\cdot c_{soil} + M\cdot \text{Slope}\right)\cdot M\cdot \frac{b}{2}$$

$$\text{m\_arm}(M) := e_{clay} + \frac{M}{3}\cdot\frac{2\cdot(M\cdot Slope + c_{soil}) + c_{soil}}{M\cdot Slope + 2\cdot c_{soil}}$$

$$\text{n\_arm}(M,N) := e_{clay} + M + \frac{N}{3}\cdot\frac{2\cdot(N\cdot Slope + M\cdot Slope + c_{soil}) + (M\cdot Slope + c_{soil})}{Slope\cdot(2\cdot M + N) + 2\cdot c_{soil}}$$

Guess value $M := 4.0\cdot ft$ $N := 4.0\cdot ft$

Given $P_{total} + nforce(M,N) = mforce(M)$ $mforce(M)\cdot \text{m\_arm}(M) = nforce(M,N)\cdot \text{n\_arm}(M,N)$

$\begin{pmatrix} M \\ N \end{pmatrix} := Find(M,N)$ $L_{ot1Clay.temp} := M + N$ $L_{ot1Clay.temp} = 8.32\cdot ft$

(round up to next foot) $L_{ot1Clay} := ceil\left(\frac{L_{ot1Clay.temp}}{ft}\right)\cdot ft$ $L_{ot1Clay} = 9.00\cdot ft$

short free-head pile in ***<u>cohesive soil</u>*** *using Regular Broms method for L > 3b*

$f_{clay} := \frac{P_{total}}{9\cdot c_{soil}\cdot b}$ $M_{maxtemp} := P_{total}\cdot(e_{clay} + 1.5\cdot b + 0.5\cdot f_{clay})$ $g := \sqrt{\frac{M_{maxtemp}}{2.25\cdot c_{soil}\cdot b}}$

$L_{ot2Clay} := (1.5\cdot b + f_{clay} + g)$ $L_{ot2Clay} = 11.89\,ft$

(round up to next foot) $L_{ot2Clay} := ceil\left(\frac{L_{ot2Clay}}{ft}\right)\cdot ft$ $L_{ot2Clay} = 12.00\cdot ft$

$L_{otClay} := if(L_{ot1Clay} < 3\cdot b, L_{ot1Clay}, L_{ot2Clay})$ $L_{otClay} = 9.00\cdot ft$

(If L_{ot} < 3b, use Modified Broms method)

$$PR_{otClay} := if\left(L_{otClay} < 3\cdot b, \frac{L_{ot1Clay.temp}}{L_{ot1Clay}}, \frac{\sqrt{\frac{M_{maxtemp}}{2.25\cdot c_{soil}\cdot b}} + \frac{P_{total}}{9\cdot c_{soil}\cdot b}}{L_{ot2Clay} - 1.5\cdot b}\right) \qquad PR_{otClay} = 0.92$$

$L_{reqdOT} := if(SoilType = 1, L_{otSand}, L_{otClay})$ $L_{reqdOT} = 14.00\,ft$

$PR_{ot} := if(SoilType = 1, PR_{otSand}, PR_{otClay})$ $PR_{ot} = 0.95$

Shaft Depth Required to Resist Torsion

$SF_{tor} := \mathbf{1.0}$ *Safety Factor against Torsion*
1.0 for Mast Arm signal structures
SM V9 13.6

NOTE: ω_{fdot} and μ are based upon CONCRETE and soil interaction. ***This torsion methodology is not to be used with permanent casing.***

$N_{blows} := 15$ *Number of blows per foot. If N< 5, contact the district geotech Engineer*

$$\omega_{fdot} := \text{if}\left(N_{blows} < 5, 0, \text{if}\left(N_{blows} \geq 15, 1.5, 1.5 \cdot \frac{N_{blows}}{15}\right)\right) = 1.50$$ *load transfer ratio*

$\mu := \tan(\phi_{soil}) = 0.53$ *coefficient of friction between concrete shaft and soil*

$\gamma_{concrete} := 150 \cdot pcf$ $\gamma_{concrete} := \gamma_{concrete} - \gamma_{water}$ $\gamma_{concrete} = 87.60 \cdot pcf$

$CohesionFactor := 0.55$ $f_{se} := CohesionFactor \cdot c_{soil}$

$Torsion := SF_{tor} \cdot M_{y.polebase_{LoadCaseT}}$ $Torsion = 284 \cdot kip \cdot ft$

short free-head pile in cohesionless soil

Guess value $L_{torSand} := L_{reqdOT}$

Given

$$Torsion = \frac{\left[\pi \cdot b \cdot (L_{torSand}) \cdot \gamma_{soil} \cdot \left(\frac{L_{torSand}}{2}\right) \cdot (\omega_{fdot}) \cdot \frac{b}{2} + \pi \cdot \left(\frac{b}{2}\right)^2 \cdot L_{torSand} \cdot (\gamma_{concrete}) \cdot \frac{b}{3} \cdot \mu\right]}{SF_{tor}}$$

$Temp := Find(L_{torSand})$ $L_{torSand} := Temp$ $L_{torSand} = 17.2\,ft$

(round up to next foot) $L_{torSand} := ceil\left(\frac{L_{torSand}}{ft}\right) \cdot ft$ $L_{torSand} = 18.00\,ft$

$$PR_{torSand} := \frac{Torsion \cdot SF_{tor}}{\pi \cdot b \cdot (L_{torSand}) \cdot \gamma_{soil} \cdot \left(\frac{L_{torSand}}{2}\right) \cdot (\omega_{fdot}) \cdot \frac{b}{2} + \pi \cdot \left(\frac{b}{2}\right)^2 \cdot L_{torSand} \cdot (\gamma_{concrete}) \cdot \frac{b}{3} \cdot \mu}$$ $PR_{torSand} = 0.91$

short free-head pile in cohesive soil

Guess value $L_{torClay} := L_{reqdOT}$

Given $$\left[f_{se} \cdot (\pi \cdot b) \cdot (L_{torClay} - 1.5 \cdot ft) \cdot \frac{b}{2}\right] + \left[f_{se} \cdot \pi \cdot \left(\frac{b}{2}\right)^2 \cdot \left(\frac{b}{3}\right)\right] = Torsion \cdot SF_{tor}$$

$Temp := Find(L_{torClay})$ $L_{torClay} := Temp$ $L_{torClay} = 8.87\,ft$

(round up to next foot) $L_{torClay} := \text{ceil}\left(\frac{L_{torClay}}{ft}\right)\cdot ft$ $L_{torClay} = 9.00\ ft$

$$PR_{torClay} := \frac{Torsion\cdot SF_{tor}}{\left[f_{se}\cdot(\pi\cdot b)\cdot(L_{torClay} - 1.5\cdot ft)\cdot\frac{b}{2}\right] + \left[f_{se}\cdot\pi\cdot\left(\frac{b}{2}\right)^2\cdot\left(\frac{b}{3}\right)\right]}$$ $PR_{torClay} = 0.98$

$L_{reqdTor} := \text{if}(SoilType = 1, L_{torSand}, L_{torClay})$ $L_{reqdTor} = 18.00\ ft$

$PR_{tor} := \text{if}(SoilType = 1, PR_{torSand}, PR_{torClay})$ $PR_{tor} = 0.91$

$L_{embedded} := \text{if}(L_{reqdTor} > L_{reqdOT}, L_{reqdTor}, L_{reqdOT})$ $L_{embedded} = 18.00\ ft$

$L_{shaft} := L_{embedded} + Offset$ $L_{shaft} = 19.00\ ft$

$PR_{foundation} := \text{if}(L_{reqdTor} > L_{reqdOT}, PR_{tor}, PR_{ot})$ $PR_{foundation} = 0.91$

Unfactored Maximum Moment in Shaft

short free-head pile in cohesionless soil using Broms method

$$f_{sand} := \sqrt{\frac{2\cdot\frac{P_{total}}{SF_{ot}}}{3\cdot\gamma_{soil}\cdot b\cdot K_p}}$$ $f_{sand} = 3.34\ ft$

$$M_{maxSand} := \frac{P_{total}}{SF_{ot}}\cdot(e_{sand} + f_{sand}) - \frac{\frac{P_{total}}{SF_{ot}}\cdot f_{sand}}{3} + \frac{M_{total}}{SF_{ot}}$$ $M_{maxSand} = 211.6\cdot kip\cdot ft$

short free-head pile in cohesive soil using Modified Broms method for L < 3b (see reference file for derivation)

Guess value $f_{mod} := 4.0\cdot ft$

Given $$\frac{P_{total}}{SF_{ot}} = \frac{f_{mod}\cdot b}{2}\cdot(2\cdot c_{soil} + f_{mod}\cdot Slope)$$

$f_{mod} := \text{Find}(f_{mod})$ $\quad f_{mod} = 0.72\,\text{ft}$

$$M_{modBroms} := \frac{P_{total}}{SF_{ot}} \cdot (e_{clay} + f_{mod}) - \frac{c_{soil} \cdot b \cdot f_{mod}^{\,2}}{2} - \frac{b \cdot f_{mod}^{\,3} \cdot \text{Slope}}{6} \qquad M_{modBroms} = 197 \cdot \text{kip} \cdot \text{ft}$$

short free-head pile in <u>cohesive soil</u> using Regular Broms method for L > 3b

$$M_{Broms} := \frac{P_{total}}{SF_{ot}} \cdot (e_{clay} + 1.5 \cdot b + 0.5 \cdot f_{clay}) \qquad M_{Broms} = 247.8 \cdot \text{kip} \cdot \text{ft}$$

$$M_{maxClay} := \text{if}(L_{ot1Clay} < 3 \cdot b, M_{modBroms}, M_{Broms}) \qquad M_{maxClay} = 197 \cdot \text{kip} \cdot \text{ft}$$

(If L_{ot} < 3b, use Modified Broms method)

$M_{max} := \text{if}(\text{SoilType} = 1, M_{maxSand}, M_{maxClay})$ *(this is a Service moment)* $M_{max} = 211.6 \cdot \text{kip} \cdot \text{ft}$

Minimum Reinforcing and Spacing

$F_{y.rebar} := \mathbf{60} \cdot \text{ksi}$	*reinforcing yield strength*	
$f_c := \mathbf{4.0} \cdot \text{ksi}$	*concrete strength* *<u>Spec 346-3</u>*	
$\text{cover} := \mathbf{6} \cdot \text{in}$	*cover* *<u>SDG Table 1.4.2-1</u>*	
$A_{bar} := \mathbf{1.56} \cdot \text{in}^2$	*longitudinal bar area*	
$d_{bar} := \mathbf{1.41} \cdot \text{in}$	*longitudinal bar diameter*	
$A_{v.bar} := \mathbf{0.31} \cdot \text{in}^2$	*stirrup area*	*<u>SM V9 13.6.2</u>*
$d_{v.bar} := \mathbf{0.625} \cdot \text{in}$	*stirrup diameter*	
$s_{v1} := \mathbf{4} \cdot \text{in}$	*stirrup spacing, depth = 0 ft-2 ft*	*<u>SM V9 13.6.2</u>*
$s_{v2} := 8 \cdot \text{in}$	*stirrup spacing, depth = 2 ft-depth.stir*	
$s_{v3} := 12 \cdot \text{in}$	*stirrup spacing, depth > depth.stir*	
$\text{depth}_{stir} := 15 \cdot \text{ft}$	*stirrup depth, see s.v2 and s.v3 above*	
$b = 4.50\,\text{ft}$	*shaft diameter*	

$\text{BarsProv}_1 := \frac{0.01}{A_{bar}} \cdot \frac{\pi \cdot b^2}{4}$ $\text{BarsProv}_1 = 14.68$ ***LRFD 5.7.4.2***

$\text{BarsProv}_2 := \frac{0.135}{A_{bar} \cdot F_{y.rebar}} \cdot \left(\frac{\pi \cdot b^2}{4} \cdot f_c\right)$ $\text{BarsProv}_2 = 13.21$

$\text{BarsProv} := \text{ceil}(\max(\text{BarsProv}_1, \text{BarsProv}_2))$ $\text{BarsProv} = 15.00$ *number of longitudinal bars*

$\text{NumSpaces}_{v.bar} := \text{round}\left(\frac{\text{depth}_{stir} - 2 \cdot ft}{s_{v2}}\right)$ $\text{NumSpaces}_{v.bar} = 20.00$

$\text{ReinfClearSpacing} := \left[b - 2 \cdot \left(\text{cover} + d_{v.bar} + \frac{d_{bar}}{2}\right)\right] \cdot \frac{\pi}{\text{BarsProv}} - d_{bar}$ $\text{ReinfClearSpacing} = 6.83 \cdot in$

CheckReinfClearSpacing := if(ReinfClearSpacing ≥ 6in, "OK" , "No Good") CheckReinfClearSpacing = "OK"

SDG 3.6.10

Check Shear and Torsion

$LF_{shr} := \mathbf{1.3}$ *Shear Load Factor* *1.3 is a reasonable Load Factor for combined WL + DL on sign and signal structures*

$LF_{tor} := \mathbf{1.3}$ *Torsion Load Factor*

$\phi_{shr} := \mathbf{0.90}$ *Shear Resistance Factor* ***LRFD 5.5.4.2.1***

$\phi_{tor} := \mathbf{0.90}$ *Torsion Resistance Factor* ***LRFD 5.5.4.2.1***

$V_u := LF_{shr} \cdot \sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2}$ $V_u = 10.2 \cdot kip$

$T_u := LF_{tor} \cdot \text{Torsion}$ $T_u = 369.25 \cdot kip \cdot ft$

Area and perimeter of concrete cross-section

$A_{cp} := \pi \cdot \left(\frac{b}{2}\right)^2$ $A_{cp} = 2290.2 \cdot in^2$

$p_{cp} := 2 \cdot \pi \cdot \left(\frac{b}{2}\right)$ $p_{cp} = 169.6 \cdot in$

Diameter, perimeter and area enclosed by the centerline of the outermost closed transverse torsion reinforcement

$d_{oh} := b - 2 \cdot \left(\text{cover} + \frac{d_{v.bar}}{2}\right)$ $d_{oh} = 41.4 \cdot in$

$p_h := \pi \cdot d_{oh}$ $p_h = 130 \cdot in$

$A_{oh} := \pi\left(\frac{d_{oh}}{2}\right)^2$ $A_{oh} = 1344.5 \cdot in^2$

$A_o := 0.85 \cdot A_{oh}$ $A_o = 1142.8 \cdot in^2$ ***LRFD C5.8.2.1***

Effective shear depth

$D_r := b - 2\cdot\left(cover + d_{v.bar} + \frac{d_{bar}}{2}\right)$ $d_e := \frac{b}{2} + \frac{D_r}{\pi} = 3.29\,ft$

LRFD C5.8.2.1

$d_v := \max(0.9 \cdot d_e, 0.72 \cdot b) = 3.24\,ft$

Check Shear Strength

$V_c := 0.0316 \cdot (2.0) \cdot \sqrt{\frac{f'_c}{ksi}} \cdot \left(\frac{d_v}{in}\right) \cdot \left(\frac{b}{in}\right) \cdot kip$ $V_c = 265.4 \cdot kip$

LRFD Eqn 5.8.3.3-3
LRFD 5.8.3.4.1

ACI 11.3.3

$V_s := \frac{A_{v.bar} \cdot F_{y.rebar} \cdot (d_v)}{\max(s_{v1}, s_{v2}, s_{v3})}$ $V_s = 60.3 \cdot kip$ ***LRFD Eqn 5.8.3.3-4***

$\phi_{shr} = 0.90$ $V_u = 10.2 \cdot kip$

$ShearRatio := \frac{V_u - \phi_{shr} \cdot V_c}{\phi_{shr} \cdot V_s}$ $ShearRatio = -4.22$

$ShearRatio := if(ShearRatio \le 0, 0, ShearRatio)$ $ShearRatio = 0.00$

Check Torsion Strength

$T_{n1} := \frac{2 \cdot A_o \cdot A_{v.bar} \cdot F_{y.rebar}}{s_{v1}}$ $T_{n1} = 885.7 \cdot kip \cdot ft$ ***LRFD Eqn 5.8.3.6.2-1***

LRFD 5.8.3.4.1

$T_{n2} := \frac{2 \cdot A_o \cdot A_{v.bar} \cdot F_{y.rebar}}{s_{v2}}$ $T_{n2} = 442.8 \cdot kip \cdot ft$

$T_{n3} := \frac{2 \cdot A_o \cdot A_{v.bar} \cdot F_{y.rebar}}{s_{v3}}$ $T_{n3} = 295.2 \cdot kip \cdot ft$

$\phi_{tor} = 0.90$ $T_u = 369.25 \cdot kip \cdot ft$ $L_{reqdTor} = 18.00\,ft$

$Tor2_{sand} := T_u - \max\left[\left[\pi \cdot b \cdot (2 \cdot ft - Offset) \cdot \gamma_{soil} \cdot \left(\frac{2 \cdot ft - Offset}{2}\right) \cdot (\omega_{fdot}) \cdot \frac{b}{2}\right], 0 \cdot kip \cdot ft\right]$ $Tor2_{sand} = 368.4 \cdot kip \cdot ft$

$Tor3_{sand} := T_u - \max\left[\left[\pi\cdot b\cdot\left(depth_{stir} - Offset\right)\cdot\gamma_{soil}\cdot\left(\frac{depth_{stir} - Offset}{2}\right)\cdot\left(\omega_{fdot}\right)\cdot\frac{b}{2}\right], 0\cdot kip\cdot ft\right]$ $Tor3_{sand} = 193.4\cdot kip\cdot ft$

$Tor2_{clay} := T_u - \max\left[\left[f_{se}\cdot(\pi\cdot b)\cdot(2.0\cdot ft - Offset - 1.5\cdot ft)\cdot\frac{b}{2}\right], 0\cdot kip\cdot ft\right]$ $Tor2_{clay} = 369.25\cdot kip\cdot ft$

$Tor3_{clay} := T_u - \max\left[\left[f_{se}\cdot(\pi\cdot b)\cdot\left(depth_{stir} - Offset - 1.5\cdot ft\right)\cdot\frac{b}{2}\right], 0\cdot kip\cdot ft\right]$ $Tor3_{clay} = -68.12\cdot kip\cdot ft$

$Tor2 := if\left(SoilType = 1, Tor2_{sand}, Tor2_{clay}\right)$ $Tor2 = 368.35\cdot kip\cdot ft$

$Tor3 := if\left(SoilType = 1, Tor3_{sand}, Tor3_{clay}\right)$ $Tor3 = 193.44\cdot kip\cdot ft$

$TorsionRatio_{n1} := \frac{T_u}{\phi_{tor}\cdot T_{n1}}$ $TorsionRatio_{n1} = 0.46$

$TorsionRatio_{n2} := \frac{Tor2}{\phi_{tor}\cdot T_{n2}}$ $TorsionRatio_{n2} = 0.92$

$TorsionRatio_{n3} := \frac{Tor3}{\phi_{tor}\cdot T_{n3}}$ $TorsionRatio_{n3} = 0.73$

$TorsionRatio := \max\left(TorsionRatio_{n1}, TorsionRatio_{n2}, TorsionRatio_{n3}\right)$ $TorsionRatio = 0.92$

$T_{cr} := 0.125\sqrt{\frac{f_c}{ksi}}\cdot\left(\frac{A_{cp}^{\ 2}}{p_{cp}\cdot in^3}\right)\cdot kip\cdot in$ $T_{cr} = 644.1\cdot kip\cdot ft$ ***LRFD Eqn 5.8.2.1-4***

$TorsionRatio := if\left(T_u \le 0.25\cdot\phi_{tor}\cdot T_{cr}, 0, TorsionRatio\right)$ $TorsionRatio = 0.92$ ***LRFD Eqn 5.8.2.1-3***

$ShearRatio = 0.00$

$CheckShearTorsion := if(ShearRatio + TorsionRatio \le 1, \text{"OK"}, \text{"No Good"})$ $CheckShearTorsion = \text{"OK"}$

Check Maximum Spacing Transverse Reinforcement

$vu := \frac{V_u}{\phi_{shr}\cdot b\cdot(0.8\cdot b)}$ $vu = 0.004864\cdot ksi$ ***LRFD Eqn 5.8.2.9-1***

$0.125\cdot f_c = 0.50\cdot ksi$

$s_{max1} := if\left(0.8\cdot d_v < 24\cdot in, 0.8\cdot d_v, 24\cdot in\right)$ $s_{max1} = 24\cdot in$ ***LRFD Eqn 5.8.2.7-1***

$s_{max2} := if\left(0.4\cdot d_v < 12\cdot in, 0.4\cdot d_v, 12\cdot in\right)$ $s_{max2} = 12\cdot in$ ***LRFD Eqn 5.8.2.7-2***

$s_{max} := if\left(vu < 0.125\cdot f_c, s_{max1}, s_{max2}\right)$ $s_{max} = 24\cdot in$

$\max(s_{v1}, s_{v2}, s_{v3}) = 12.00 \cdot in$

$CheckMaxSpacingTransvReinf := if(\max(s_{v1}, s_{v2}, s_{v3}) \le s_{max}, "OK", "No\ Good")$ $CheckMaxSpacingTransvReinf = "OK"$

Check Longitudinal Reinforcement for Combined Shear and Torsion ***LRFD Eqn 5.8.3.6.3-1***

LRFD 5.8.3.4.1

$$M_u := LF_{tor} \cdot \sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2} \quad M_u = 241.4 \cdot kip \cdot ft$$

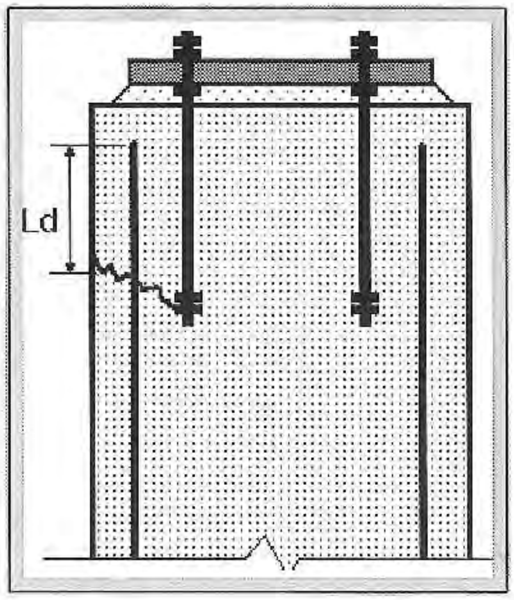
$$V_{temp} := if\left(\frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s > 0 \cdot kip, \frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s, 0 \cdot kip\right) \quad V_{temp} = 0 \cdot kip$$

$$LongReinf_{shr.tor} := \frac{\frac{M_u}{\phi_{tor} \cdot (0.8 \cdot b)} + \sqrt{\left(\frac{V_{temp}}{kip}\right)^2 + \left(\frac{0.45 \cdot p_h \cdot T_u}{2 \cdot A_o \cdot \phi_{tor} \cdot kip}\right)^2} \cdot kip}{F_{y.rebar}} \quad LongReinf_{shr.tor} = 3.34 \cdot in^2$$

$BarsProv \cdot A_{bar} = 23.40 \cdot in^2$

$CheckLongReinf_{shr.tor} := if(BarsProv \cdot A_{bar} \ge LongReinf_{shr.tor}, "OK", "No\ Good")$ $CheckLongReinf_{shr.tor} = "OK"$

Anchor Bolt Embedment



$$Gap_{shaft} := \frac{b - 2 \cdot cover - 2 \cdot d_{v.bar} - Diameter_{boltcircle.pole} - d_{bar}}{2}$$

$Gap_{shaft} = 4.67 \cdot in$

$Diameter_{rebar.circle} := b - 2 \cdot cover - d_{bar} - 2 \cdot d_{v.bar}$

$Diameter_{rebar.circle} = 39.3 \cdot in$

$\#BarsProvided := BarsProv$ $\#BarsProvided = 15.00$

$$\#BarsProvidedPerRod := \min\left(\begin{pmatrix} \frac{\#BarsProvided}{\#AnchorRods} \\ 3 \end{pmatrix}\right)$$

Use a maximum of three rebar per anchor bolt (conservative)

$\#BarsProvidedPerRod = 2.50$

$\phi := 0.9 \qquad \#BarsReqdPerRod := \frac{T_{u.rod}}{A_{bar}\cdot(\phi\cdot F_{y.rebar})}\cdot\frac{Diameter_{boltcircle.pole}}{Diameter_{rebar.circle}}$ $\#BarsReqdPerRod = 0.45$

$AreaRatio := \frac{\#BarsReqdPerRod}{\#BarsProvidedPerRod}$ $AreaRatio = 0.18$

$AreaRatio := if(AreaRatio < 1, AreaRatio, 1)$ $AreaRatio = 0.18$

$$L_{d.bar} := max\left[\begin{bmatrix}\frac{1.25\cdot(A_{bar})\cdot F_{y.rebar}}{\sqrt{f_c\cdot ksi}\cdot in} \\ \frac{0.4\cdot(d_{bar})\cdot F_{y.rebar}}{ksi}\end{bmatrix}\right]$$

development length of bar ***LRFD 5.11.2.1.1***

$L_{d.bar} := if\left(A_{bar} = 2.25\cdot in^2, \frac{2.70\cdot in^2\cdot F_{y.rebar}}{\sqrt{f_c\cdot ksi}\cdot in}, L_{d.bar}\right)$ $L_{d.bar} = 58.5\cdot in$

$SpacingFactor := max\left(\begin{pmatrix}\#BarsProvidedPerRod\cdot 0.5 - 0.5 \\ 0.5\end{pmatrix}\right)$ $SpacingFactor = 0.75$

$L_{embedment.added} := \sqrt{(ReinfClearSpacing\cdot SpacingFactor)^2 + Gap_{shaft}^2}$ $L_{embedment.added} = 6.9\cdot in$

$$L_{embedment.rod} := max\left[\begin{bmatrix}L_{d.bar}\cdot(AreaRatio) + 12\cdot in + L_{embedment.added} \\ 20\cdot d_{bolt.pole}\end{bmatrix}\right]$$

$L_{embedment.rod} := Ceil(L_{embedment.rod}, in)$ $L_{embedment.rod} = 40\cdot in$

$L_{anchor.rod} := Ceil[(L_{embedment.rod} + 8\cdot in), in]$ $L_{anchor.rod} = 48\cdot in$

Anchor Bolt Shear Break-Out Strength

References:
ACI 318-05 Appendix D.
FDOT/University of Florida Report BD545 RPWO #54,
Anchor Embedment Requirements for Signal/Sign Structures, July 2007.

$\#AnchorRods = 6.00$ *number of anchor bolts*

$d_{bolt.pole} = 2.00 \cdot in$ *anchor bolt diameter*

$Diameter_{boltcircle.pole} = 30.00 \cdot in$ *anchor bolt circle diameter*

$L_{embedment.rod} = 40.00 \cdot in$ *anchor bolt embedment*

$b = 54.00 \cdot in$ *shaft diameter*

$r_b := \frac{Diameter_{boltcircle.pole}}{2}$ $r_b = 15.00 \cdot in$

$r := \frac{b}{2}$ $r = 27.00 \cdot in$

$c_{a1} := \frac{\sqrt{r_b^{\,2} + 3.25 \cdot \left(r^2 - r_b^{\,2}\right)} - r_b}{3.25}$ $c_{a1} = 8.67 \cdot in$ *adjusted cover*

UF Report Eqn 3-2

$L_e := \min\left(8 \cdot d_{bolt.pole}, L_{embedment.rod}\right)$ $L_e = 16.00 \cdot in$ *load bearing length of anchor for shear*

ACI D.6.2.2

$V_b := 13 \cdot \left(\frac{L_e}{d_{bolt.pole}}\right)^{0.2} \cdot \sqrt{\frac{d_{bolt.pole}}{in}} \cdot \sqrt{\frac{f_c}{psi}} \left(\frac{c_{a1}}{in}\right)^{1.5} \cdot lbf$ *shear break-out strength (single anchor)*

UF Report Eqn 2-11

$V_b = 45 \cdot kip$

$A := \frac{(360 \cdot deg)}{\#AnchorRods}$ $A = 60 \cdot deg$ ***UF Report Fig 3-7***

$alpha := 2\,asin\left[\frac{\left(1.5 \cdot c_{a1}\right)}{r}\right]$ $alpha = 57.6 \cdot deg$

OverlapTest := if(A ≤ alpha, "Overlap of Failure Cones" , "No Overlap of Failure Cones")

OverlapTest = "No Overlap of Failure Cones"

$chord := 2 \cdot r \cdot \sin\left(\frac{A}{2}\right)$ $chord = 27 \cdot in$ ***UF Report Fig 3-7***

$A_{Vco} := 4.5 \cdot c_{a1}^{\,2}$ $A_{Vco} = 337.9 \cdot in^2$ *projected concrete failure area (single anchor)*

ACI Eqn D-23

$A_{Vc} := chord \cdot 1.5 \cdot c_{a1}$ $A_{Vc} = 350.9 \cdot in^2$ *projected concrete failure area (group)*

ACI D.6.2.1

$A_{Vc} := \text{if}\left(A_{Vc} > A_{Vco}, A_{Vco}, A_{Vc}\right)$ $A_{Vc} = 337.9 \cdot in^2$

$\psi_{ecV} := \mathbf{1.0}$	*eccentric load modifier*	***ACI D.6.2.5***	
$\psi_{edV} := \mathbf{1.0}$	*edge effect modifier*	***ACI D.6.2.6***	
$\psi_{cV} := \mathbf{1.4}$	*cracked section modifier*	***ACI D.6.2.7***	*(stirrup spacing <= 4)*
$\psi_{hV} := \mathbf{1.0}$	*member thickness modifier*	***ACI D.6.2.8***	
$\phi_{breakout} := \mathbf{0.75}$	*strength reduction factor*	***ACI D.4.4.c.i***	*(shear breakout, condition A)*

$V_{cbg} := \#AnchorRods \cdot \left(\frac{A_{Vc}}{A_{Vco}}\right) \cdot \left(\psi_{ecV} \cdot \psi_{edV} \cdot \psi_{cV} \cdot \psi_{hV}\right) \cdot V_b$ $V_{cbg} = 377.6 \cdot kip$ *concrete breakout strength - shear*

ACI Eqn D-22   *Shear force $\perp$ to edge*

$V_{cbg\_parallel} := 2 \cdot V_{cbg}$ $V_{cbg\_parallel} = 755.3 \cdot kip$ ***ACI D.6.2.1.c***   *Shear force || to edge*

$T_{n.breakout} := V_{cbg\_parallel} \cdot r_b$ $T_{n.breakout} = 944.1 \cdot kip \cdot ft$ *concrete breakout strength - torsion*

$\phi_{breakout} \cdot T_{n.breakout} = 708.1 \cdot kip \cdot ft$

$T_u = 369.2 \cdot kip \cdot ft$

$BreakoutTest := \text{if}\left(\phi_{breakout} \cdot T_{n.breakout} \geq T_u, \text{"OK"}, \text{"No Good"}\right)$ BreakoutTest = "OK"

OverlapDesign := if(A ≤ α, "Based on Overlap of Failure Cones" , "Based on No Overlap of Failure Cones")

OverlapDesign = "Based on No Overlap of Failure Cones"

$M_{x.polebase} = \begin{pmatrix} 0.0 \\ 148.5 \\ 148.5 \end{pmatrix} \cdot ki \; M_{y.polebase} = \begin{pmatrix} 284.0 \\ 0.0 \\ 284.0 \end{pmatrix} \cdot kip \cdot \; M_{z.polebase} = \begin{pmatrix} 0.0 \\ 111.5 \\ 111.5 \end{pmatrix} \cdot kip \cdot ft$

maximum torsion (Mx & Mz not used)
maximum overturning (My not used)
maximum CSR

Analyze Foundation

Summary - Soil Properties and Drilled Shaft Geometry

SoilType = 1   *0 - clay*
1 - sand $\phi_{soil} = 28 \cdot deg$ $c_{soil} = 2000 \cdot psf$ $\gamma_{soil} = 37.6 \cdot pcf$

$\text{Diameter}_{shaft} = 4.5\,\text{ft}$ $L_{shaft} = 19\,\text{ft}$ $L_{embedment.rod} = 40 \cdot \text{in}$ $L_{anchor.rod} = 48.00 \cdot \text{in}$

$\#\text{BarsProvided} = 15$ $d_{bar} = 1.41 \cdot \text{in}$

Foundation Performance Ratios

$PR_{foundation} = 0.914$

Fatigue Analysis

DataFile = "E7T6.dat" WindSpeed = 130·mph

Use the member cross section adjacent to the weld toe to compute the nominal stress range. ***LTS 11.9***

FatigueCategory := 2 ***SM V9 11.6***

▶ Analyze Structure for Fatigue

Arm and Pole Welds

$f_{galloping.arm1} = 5.67 \cdot \text{ksi}$ $CAFT_{fullpengroove.weld.arm1} = 7.00 \cdot \text{ksi}$ $\text{Check}_{galloping.arm1} = \text{"OK"}$

$f_{galloping.arm2} = 0.00 \cdot \text{ksi}$ $CAFT_{fullpengroove.weld.arm2} = \text{"NA"} \cdot \text{ksi}$ $\text{Check}_{galloping.arm2} = \text{"NA"}$

$f_{galloping.pole} = 3.75 \cdot \text{ksi}$ $CAFT_{fullpengroove.weld.pole} = 4.50 \cdot \text{ksi}$ $\text{Check}_{galloping.pole} = \text{"OK"}$

$f_{nwg.arm1} = 3.90 \cdot \text{ksi}$ $\text{Check}_{nwg.arm1} = \text{"OK"}$

$f_{nwg.arm2} = 0.00 \cdot \text{ksi}$ $\text{Check}_{nwg.arm2} = \text{"NA"}$

$f_{nwg.pole} = 2.65 \cdot \text{ksi}$ $\text{Check}_{nwg.pole} = \text{"OK"}$

A325 Connection Bolts

$f_{t.g.bolt} = \begin{pmatrix} 7.0 \\ 0.0 \end{pmatrix} \cdot ksi$ $\quad CAFT_{conn.bolt} = 16.00 \cdot ksi$ $\quad Check_{g.conn.bolt} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

$f_{t.nwg.bolt} = \begin{pmatrix} 4.8 \\ 0.0 \end{pmatrix} \cdot ksi$ $\quad Check_{nwg.conn.bolt} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

Anchor Bolts

$f_{t.g.rod} = 4.72 \cdot ksi$ $\quad CAFT_{anchor.rods} = 7.00 \cdot ksi$ $\quad Check_{g.rod} = \text{"OK"}$

$f_{t.nwg.rod} = 2.41 \cdot ksi$ $\quad Check_{nwg.rod} = \text{"OK"}$

▶ Summary

Mast Arm Design and Analysis Summary

DataFile = "E7T6.dat" WindSpeed = 130·mph

Subject = "E7-T6 Mast Arm"

DesignedBy = "MAV"

PoleLocation = "ID No.2"

ProjectNo = "00193008015"

CheckedBy = "FDOT"

Date = "12/5/2012"

1st Mast Arm

$\#Signals_{arm1} = 3$ $\quad \#Panels_{arm1} = 3$

$X_{signal.arm1} = \begin{pmatrix} 40.5 \\ 52.5 \\ 66.5 \end{pmatrix} ft$ $\quad Sections_{signal.arm1} = \begin{pmatrix} 3 \\ 3 \\ 4 \end{pmatrix}$ $\quad Backplate_{signal.arm1} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$

$X_{panel.arm1} = \begin{pmatrix} 32 \\ 71.5 \\ 60.5 \end{pmatrix} ft$ $\quad Area_{panel.arm1} = \begin{pmatrix} 20 \\ 9 \\ 1.56 \end{pmatrix} ft^2$

$L_{total.arm1} = 76 ft$ $\quad L_{splice.provided.arm1} = 24 \cdot in$

'FA'= 'FE'= $L_{arm1} = \begin{pmatrix} 38 \\ 40 \end{pmatrix} \cdot ft$ 'FB'= 'FF'= $Diameter_{tip.arm1} = \begin{pmatrix} 7.7185 \\ 12.4 \end{pmatrix} \cdot in$ 'FC'= 'FG'= $Diameter_{base.arm1} = \begin{pmatrix} 13.0385 \\ 18 \end{pmatrix} \cdot in$

'FD'= 'FH'= $t_{wall.arm1} = \begin{pmatrix} 0.1793 \\ 0.375 \end{pmatrix} \cdot in$ $\max(\Delta_{arm1}) = 15.44 \cdot in$ $\max(CSR_{arm1}) = 0.932$

2nd Mast Arm

$\#Signals_{arm2} = 0$ $\#Panels_{arm2} = 1$

$X_{signal.arm2} = (0)\,ft$ $Sections_{signal.arm2} = (0)$ $Backplate_{signal.arm2} = (0)$

$X_{panel.arm2} = (0.1)\,ft$ $Area_{panel.arm2} = (0.1)\,ft^2$

$L_{total.arm2} = 0\,ft$ $L_{splice.provided.arm2} = 24 \cdot in$ 'UF'= $\alpha = 0 \cdot deg$ **(Angle Between Arms)**

'SA'= 'SE'= $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot ft$ 'SB'= 'SF'= $Diameter_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ 'SC'= 'SG'= $Diameter_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

'SD'= 'SH'= $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $\max(\Delta_{arm2}) = 0 \cdot in$ $\max(CSR_{arm2}) = 0$

Luminaire Arm and Connection

DataFile = "E7T6.dat" WindSpeed = 130·mph

(use MC10x33.6 channel for connection)

'LA'= $Y_{luminaire} = 0\,ft$ 'LB'= $X_{luminaire} = 0\,ft$ 'LC'= $Diameter_{base.lumarm} = 0 \cdot in$

'LD'= $t_{wall.lumarm} = 0 \cdot in$ 'LE'= $Slope_{lumarm} = 0$ 'LF'= $r_{lumarm} = 0\,ft$

'LG'= $d_{bolt.lum} = 0 \cdot in$ 'LH'= $t_{baseplate.lum} = 0 \cdot in$

'LJ'= $w_{base.lum} = 0 \cdot in$ 'LK'= $w_{channel.lum} = 0 \cdot in$

$CSR_{base.lumarm} = 0$ $PR_{bolt.lum} = 0$ $PR_{baseplate.lum} = 0$ $PR_{conn.plate.lum} = 0$

Upright

'UA'= $Y_{pole} = 22 \cdot ft$ 'UB'= $Y_{arm.conn} = 20.5 \cdot ft$ 'UC'= $Diameter_{tip.pole} = 18.92 \cdot in$

'UD'= $Diameter_{base.pole} = 22 \cdot in$ 'UE'= $t_{wall.pole} = 0.375 \cdot in$ 'UF'= $\alpha = 0 \cdot deg$

'UG'= $Y_{lum.conn} = 0\,ft$ $\Delta_{x.dl} = 1.03 \cdot in$ $Slope_x = 0.52 \cdot deg$

$\Delta_{z.dl} = 0 \cdot in$ $\quad$ $Slope_z = 0 \cdot deg$ $\quad$ $C_{a.pole} = 0.997$

$\max(CSR_{pole}) = 0.899$

1st Arm/Upright Connection

$\#ConnBolts_0 = 6$ $\quad$ 'HT'= $h_{conn.plate} = 30 \cdot in$ $\quad$ 'FJ'= $b_{conn.plate_0} = 31.00 \cdot in$

'FK'= $t_{baseplate.arm_0} = 2.5 \cdot in$ $\quad$ 'FL'= $t_{vertical.plate_0} = 0.75 \cdot in$

'FN'= $w_{vertical.plate_0} = 0.4375 \cdot in$ $\quad$ 'FO'= $Offset_{conn_0} = 15.065 \cdot in$

'FP'= $d_{bolt.conn_0} = 1.25 \cdot in$ $\quad$ 'FR'= $t_{conn.plate_0} = 1.625 \cdot in$

'FS'= $Spacing_{bolts.conn_0} = 12.5 \cdot in$ $\quad$ 'FT'= $w_{conn.plate_0} = 0.4375 \cdot in$

$$\begin{pmatrix} PR_{bolt_0} \\ PR_{t.baseplate.arm_0} \\ PR_{t.connplate.arm_0} \\ CSR_{t.vert.plate_0} \end{pmatrix} = \begin{pmatrix} 0.922 \\ 0.788 \\ 0.993 \\ 0.562 \end{pmatrix}$$

2nd Arm/Upright Connection

$\#ConnBolts_1 = 0$ $\quad$ 'HT'= $h_{conn.plate} = 30 \cdot in$ $\quad$ 'SJ'= $b_{conn.plate_1} = 0.00 \cdot in$

'SK'= $t_{baseplate.arm_1} = 0 \cdot in$ $\quad$ 'SL'= $t_{vertical.plate_1} = 0 \cdot in$

'SN'= $w_{vertical.plate_1} = 0 \cdot in$ $\quad$ 'SO'= $Offset_{conn_1} = 0 \cdot in$

'SP'= $d_{bolt.conn_1} = 0 \cdot in$ $\quad$ 'SR'= $t_{conn.plate_1} = 0 \cdot in$

'SS'= $Spacing_{bolts.conn_1} = 0 \cdot in$ $\quad$ 'ST'= $w_{conn.plate_1} = 0 \cdot in$

$$\begin{pmatrix} PR_{bolt_1} \\ PR_{t.baseplate.arm_1} \\ PR_{t.connplate.arm_1} \\ CSR_{t.vert.plate_1} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Pole Baseplate

DataFile = "E7T6.dat" $\quad$ $WindSpeed = 130 \cdot mph$

$\#AnchorRods = 6$ $\quad$ 'BA'= $Diameter_{baseplate.pole} = 38 \cdot in$ $\quad$ 'BB'= $t_{baseplate.pole} = 2.5 \cdot in$

'BC'= $d_{bolt.pole} = 2.00 \cdot in$ $\quad$ 'BF'= $L_{embedment.rod} = 40 \cdot in$

$Diameter_{boltcircle.pole} = 30 \cdot in$

$PR_{rod} = 0.543$

$PR_{plate.pole} = 1$

Foundation

'DA'= $L_{shaft} = 19 \cdot ft$ $\quad$ 'DB'= $Diameter_{shaft} = 4.5 \cdot ft$ $\quad$ $d_{bar} = 1.41 \cdot in$

'RA'= $round\left(\frac{d_{bar}}{0.125in}\right) = 11$ $\quad$ 'RB'= $\#BarsProvided = 15$ $\quad$ $Diameter_{rebar.circle} = 3.2783\ ft$

'RC'= $NumSpaces_{v.bar} = 20$ $\quad$ 'RD'= $s_{v2} = 8 \cdot in$ $\quad$ $PR_{foundation} = 0.914$

▶ WRITEPRN to Line 1-2-3

Mast Arm Tip Deflection

Compare Mast Arm deflection of each arm to a proposed camber

$Camber_{arm1} := 2 \cdot deg$ $\qquad$ $Camber_{arm2} := 2 \cdot deg$

$L_{arm1} := \sum L_{arm1} - if\left[\left(L_{arm1_1} = 0 \cdot ft\right), 0 \cdot ft, 2 \cdot ft\right]$ $\qquad$ $L_{arm2} := \sum L_{arm2} - if\left[\left(L_{arm2_1} = 0 \cdot ft\right), 0 \cdot ft, 2 \cdot ft\right]$

$Deflection_{arm1} := Slope_x \cdot L_{arm1} + max\left(\Delta_{arm1}\right)$ $\qquad$ $Deflection_{arm1} = 23.65 \cdot in$

$CamberArm1_{upward} := sin\left(Camber_{arm1}\right) \cdot L_{arm1}$ $\qquad$ $CamberArm1_{upward} = 31.83 \cdot in$

$Deflection_{arm2} := \left[Slope_z \cdot L_{arm2} \cdot (sin(\alpha))\right] + Slope_x \cdot L_{arm2} \cdot cos(\alpha) + max\left(\Delta_{arm2}\right)$ $\qquad$ $Deflection_{arm2} = 0 \cdot in$

$CamberArm2_{upward} := sin\left(Camber_{arm2}\right) \cdot L_{arm2}$ $\qquad$ $CamberArm2_{upward} = 0 \cdot in$

Check Clearance Between Connection Plates *(for Two Arm Structures only)*

$\alpha = 0.00 \cdot deg$ $\qquad$ $\alpha := if[(\alpha > 180 \cdot deg), (360 \cdot deg - \alpha), \alpha]$

$Offset_{conn_0} = 15.06 \cdot in$ $\qquad$ $b_{conn.plate_0} = 31.00 \cdot in$ $\qquad$ $h_{conn.plate} = 30.00 \cdot in$ $\qquad$ $\alpha = 0.00 \cdot deg$

$Offset_{conn_1} = 0.00 \cdot in$ $\qquad$ $b_{conn.plate_1} = 0.00 \cdot in$

$$x_1 := Offset_{conn_0} - t_{conn.plate_0} - h_{conn.plate} \cdot \frac{sin\left(Camber_{arm1}\right)}{2} \qquad y_1 := \frac{b_{conn.plate_0}}{2} \qquad x_1 = 12.92 \cdot in \quad y_1 = 15.5 \cdot in$$

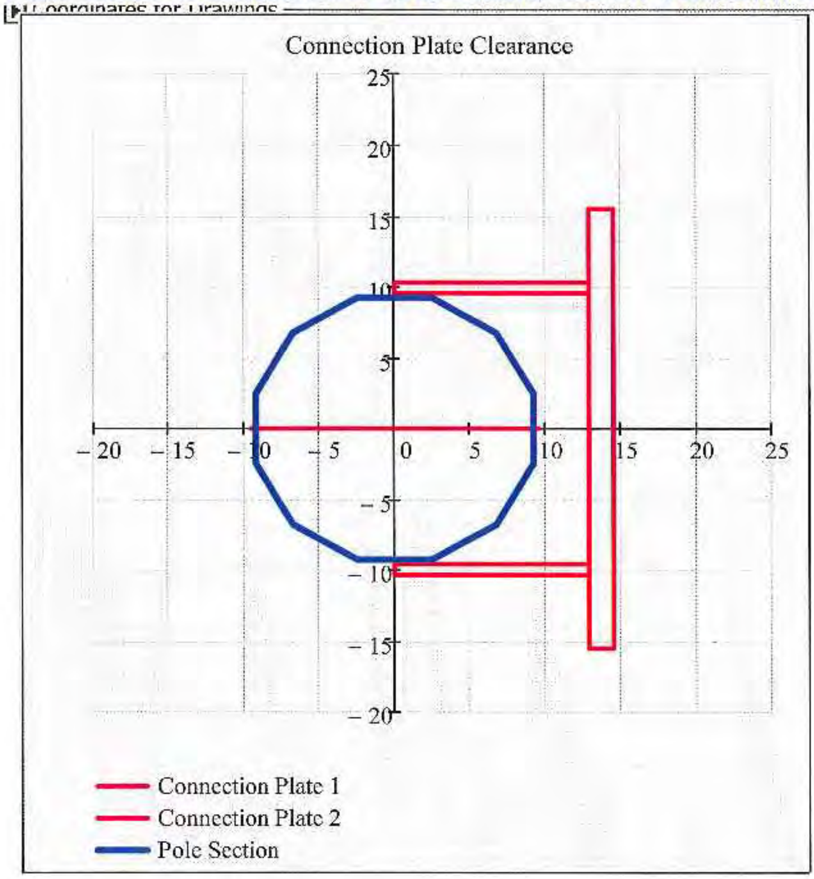
$$x_2 := \left(Offset_{conn_1} - t_{conn.plate_1} - h_{conn.plate} \cdot \frac{sin\left(Camber_{arm2}\right)}{2}\right) \cdot cos(\alpha) + \frac{b_{conn.plate_1}}{2} \cdot sin(\alpha)$$

$$y_2 := \left(Offset_{conn_1} - t_{conn.plate_1} - h_{conn.plate} \cdot \frac{sin\left(Camber_{arm2}\right)}{2}\right) \cdot sin(\alpha) - \frac{b_{conn.plate_1}}{2} \cdot cos(\alpha) \qquad x_2 = -0.52 \cdot in \; y_2 = 0 \cdot in$$

$$Clearance := \sqrt{\left(x_1 - x_2\right)^2 + \left(y_1 - y_2\right)^2} \qquad Clearance := if\left[\left(y_2 \le y_1\right), if\left[\left(x_1 > x_2\right), Clearance, 0 \cdot in\right], Clearance\right] \quad Clearance = 20.52 \cdot in$$

(if Clearance equals 0, then Connection Plates intersect and redesign is required.

Plan View - Connection Plate Clearance for Two Arm Connections



$\text{Clearance} = 20.52\cdot\text{in}$

$\text{Diameter}_{\text{conn.pole}} = 19.13\cdot\text{in}$

$t_{\text{conn.plate}_0} = 1.625\cdot\text{in}$

$b_{\text{conn.plate}_0} = 31\cdot\text{in}$

$t_{\text{vertical.plate}_0} = 0.75\cdot\text{in}$

$\text{Offset}_{\text{conn}_0} = 15.065\cdot\text{in}$

$\text{Gap}_0 = 5.5\cdot\text{in}$

$t_{\text{conn.plate}_1} = 0\cdot\text{in}$

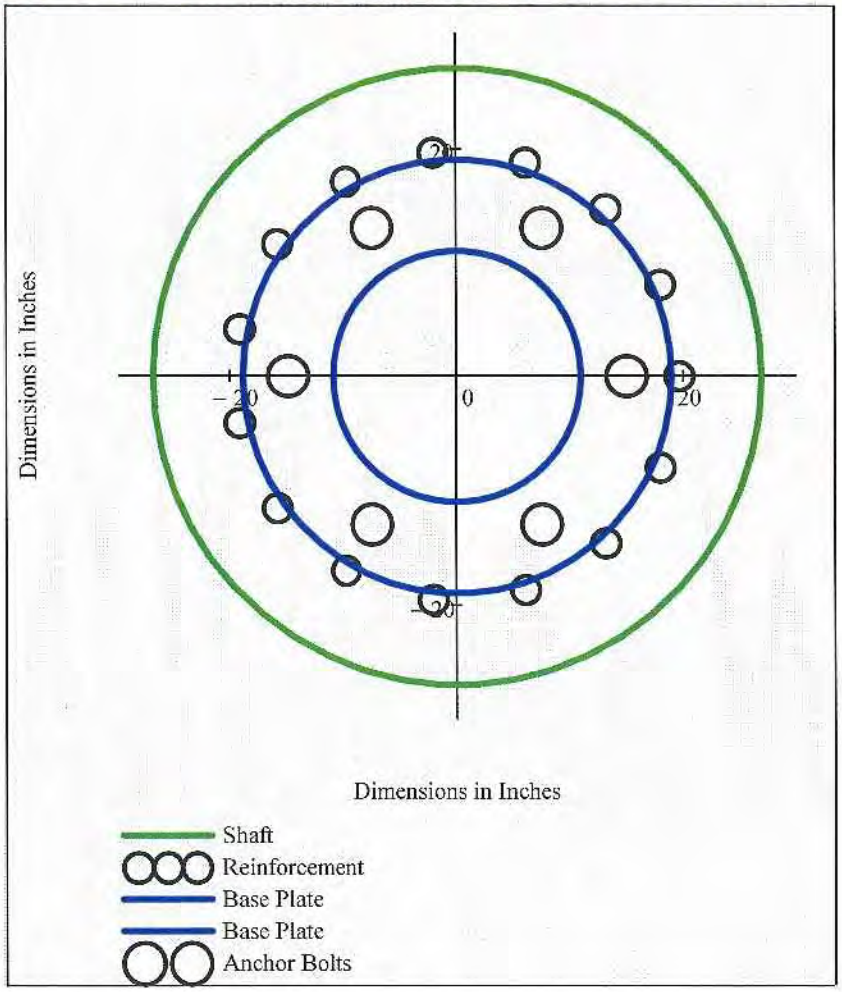
$b_{\text{conn.plate}_1} = 0\cdot\text{in}$

$t_{\text{vertical.plate}_1} = 0\cdot\text{in}$

$\text{Offset}_{\text{conn}_1} = 0\cdot\text{in}$

$\text{Gap}_1 = 0\cdot\text{in}$

Plan View - Drilled Shaft, Base Plate, Anchor Bolts, & Reinforcing Steel



$\text{Diameter}_{\text{base.pole}} = 22 \cdot \text{in}$

$\text{Diameter}_{\text{baseplate.pole}} = 38 \cdot \text{in}$

$\text{Diameter}_{\text{shaft}} = 54 \cdot \text{in}$

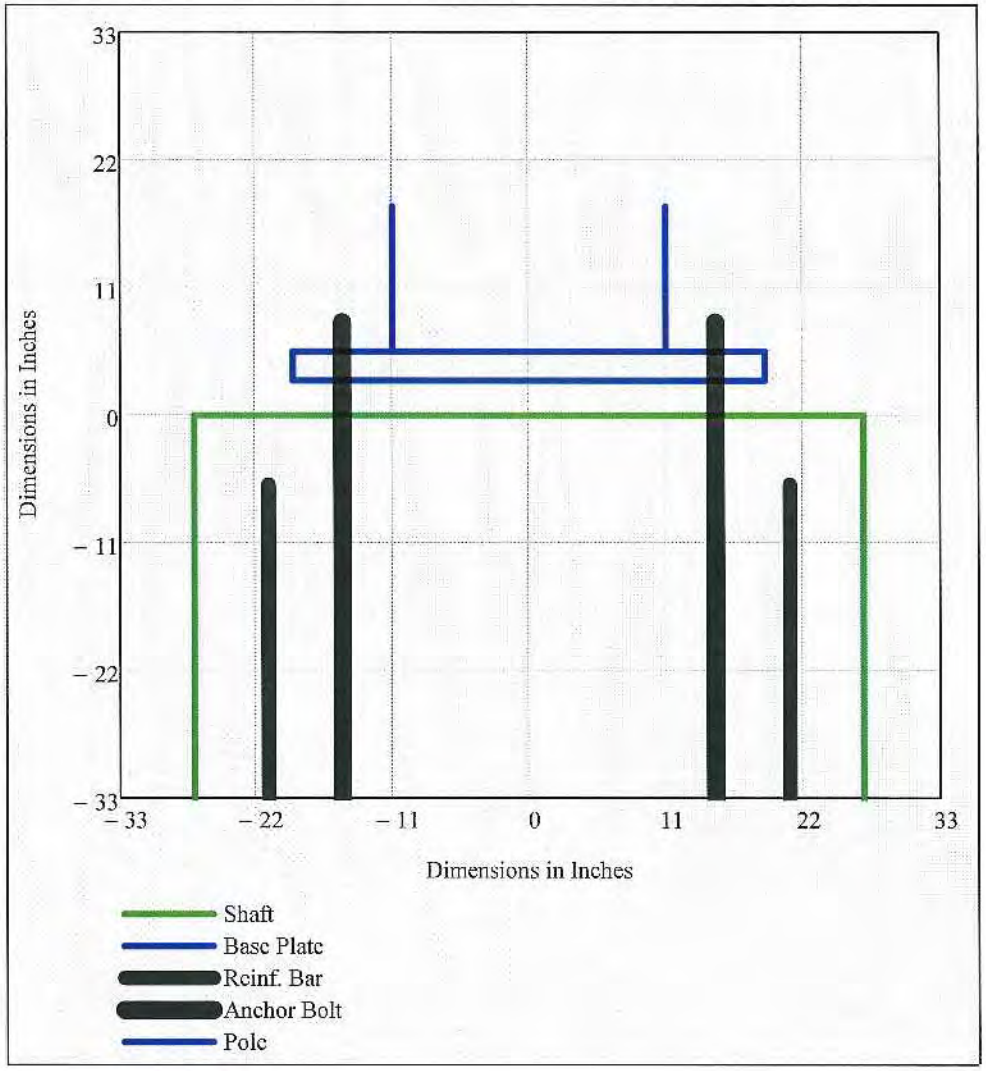
$\text{Diameter}_{\text{boltcircle.pole}} = 30 \cdot \text{in}$

$\text{Diameter}_{\text{rebar.circle}} = 39.34 \cdot \text{in}$

#AnchorRods = 6

#BarsProvided = 15

Elevation View - Drilled Shaft, Base Plate, Anchor Bolts, & Reinforcing Steel



$\text{Diameter}_{\text{base.pole}} = 22.00 \cdot \text{in}$

$\text{Diameter}_{\text{baseplate.pole}} = 38.00 \cdot \text{in}$

$t_{\text{baseplate.pole}} = 2.50 \cdot \text{in}$

$\text{Diameter}_{\text{shaft}} = 4.50 \cdot \text{ft}$

$\text{Diameter}_{\text{boltcircle.pole}} = 30.00 \cdot \text{in}$

$\text{Diameter}_{\text{rebar.circle}} = 39.3 \cdot \text{in}$

ID No. 3: E1-T1

Cortez & 86th St.

Pole ID. No 3

Revision 01/22/13

No Change.

NO CHANGE. CORNER & 86th ST. POLE ID No 3 RSU 01/22/13 MAV

FDOT Mast Arm Analysis Program

Custom File Name (optional) ☐

The new custom file will be a copy of the last file called from the program. A ".dat" extension will be added to the file name.

Add file to file list Refresh File List

Select Data File (required)

- E1T1
- E1T21
- E3E1T2
- E3T2
- E3T22
- E4E4T3
- E5E2T3

All data files are in the same directory as the MastArm.xmcd file.

Path = "J:\00193\00193008.15\DOC\Calcs\ID_N0_3_MastarmV5.02\"

DataFile = "E1T1.dat"

Reference *Changes*

This program works in conjunction with Mastarm Design Standards 17743 and 17745.

References:
AASHTO Standard Specifications for Signs, Luminaires and Traffic Signals, 5th Edition (LTS).
FDOT Structures Manual Vol. 9 (SM V9).

For more information see Reference.xmcd and Changes.xmcd.

▶ Read In Data

General Information DataFile = "E1T1.dat"

Current Values	New Values
Subject = "E1-T1 Mast Arm"	
ProjectNo = "'00193008015"	'00193008015
PoleLocation = "ID No.3"	ID No.3
Date = "01/22/2013"	01/22/2013
DesignedBy = "MAV"	MAV
CheckedBy = "FDOT"	

Use Control+F9 to recalculate the worksheet, once to write out data, twice to read in data

Wind Speed DataFile = "E1T1.dat"

Current Value	New Value		
WindSpeed = 130·mph		*mph*	**SM V9 3.8.2**

Arm 1 Analysis

DataFile = "E1T1.dat" WindSpeed = 130·mph

Arm 1 Loads

$$SignalData_{arm1} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 10.5 & 3 & \text{"yes"} \\ 2 & 18.5 & 3 & \text{"yes"} \\ 3 & 26.5 & 4 & \text{"yes"} \\ 4 & 0 & 0 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values *"yes"or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	10.5	3	"yes"
2	18.5	3	"yes"
3	26.5	4	"yes"
4	0	0	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$SignData_{arm1} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 4.5 & 20 \\ 2 & 31 & 9 \\ 3 & 22 & 1.56 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	4.5	20
2	31	9
3	22	1.56
4	0	0
5	0	0

use X to zero out data
use 0 to keep current values

Arm 1 Loads

Arm 1 Properties

Current Values

New Values

$L_{total.arm1} = 36\,ft$ — *feet, 40 ft. max. for 1 piece arms*

$Diameter_{base.arm1} = 11 \cdot in$ — *inches, measured flat to flat (FG)*

$Dist_{splice.from.base.arm1} = 0\,ft$ — *feet, splice distance, for 2 piece arms, length of piece closest to pole, use X to zero out (FE)*

set $Dist_{splice.from.base.arm1} = 0\,ft$ *for NO SPLICE*

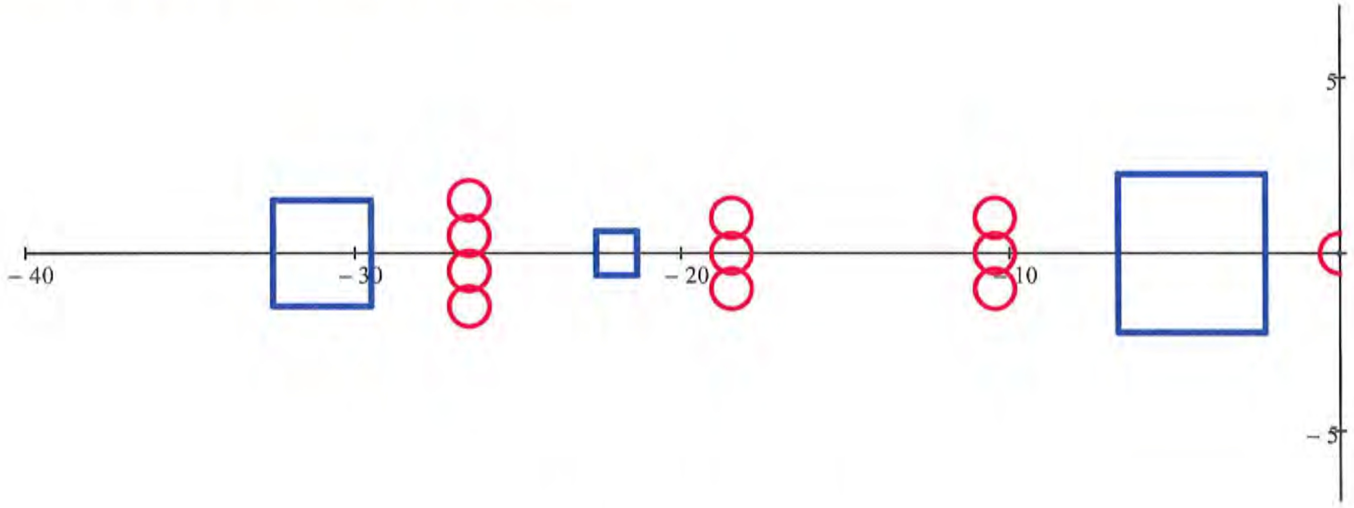
$t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0 \end{pmatrix} \cdot in$ — *inches, this value is used for one piece arms (FD)*

inches, for 2 piece arms, wall thickness of piece closest to the pole, use X to zero out (FH)

Arm 1 Properties

Analyze Arm 1

Summary - Arm 1 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130 \cdot mph$ $L_{total.arm1} = 36.00\,ft$

$Diameter_{tip.arm1} = \begin{pmatrix} 5.96 \\ 0 \end{pmatrix} \cdot in$ $Diameter_{base.arm1} = \begin{pmatrix} 11.00 \\ 0.00 \end{pmatrix} \cdot in$ $L_{arm1} = \begin{pmatrix} 36.00 \\ 0.00 \end{pmatrix} ft$ $t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0 \end{pmatrix} \cdot in$

$X_{signal.arm1_{i1}} =$ (ft)	$Sections_{signal.arm1_{i1}} =$	$X_{panel.arm1_{j1}} =$ (ft)	$Area_{panel.arm1_{j1}} =$ (ft^2)
10.5	3	4.5	20
18.5	3	31	9
26.5	4	22	1.56

Arm 1 Combined Stress Ratio and Deflection

$\max(CSR_{arm1}) = 0.958$ $\max(\Delta_{arm1}) = 3.595 \cdot in$ $2 \cdot deg \cdot \sum (L_{arm1} - L_{splice.provided}) = 13.4 \cdot in$

Arm 2 Analysis

DataFile = "E1T1.dat" WindSpeed = 130·mph

Arm 2 Loads

$$\text{SignalData}_{\text{arm2}} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 0 & 0 & \text{"yes"} \\ 2 & 0 & 0 & \text{"yes"} \\ 3 & 0 & 0 & \text{"yes"} \\ 4 & 0 & 0 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values *"yes"or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	0	0	"yes"
2	0	0	"yes"
3	0	0	"yes"
4	0	0	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$\text{SignData}_{\text{arm2}} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 0 & 0 \\ 2 & 0 & 0 \\ 3 & 0 & 0 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0

use X to zero out
use 0 to keep current values

Arm 2 Loads

Arm 2 Properties

Current Values

New Values

$L_{total.arm2} = 0\,ft$ ☐ *feet, 40 ft. max. for 1 piece arms, use X to zero out* *set* $L_{total.arm2} = 0ft$ *for NO ARM2*

$Diameter_{base.arm2} = 0 \cdot in$ ☐ *inches, measured flat to flat, use X to zero out (SG)*

$Dist_{splice.from.base.arm2} = 0 \cdot ft$ ☐ *feet, splice distance, for 2 piece arms, length of piece closest to pole, use X to zero out (SE)*

set $Dist_{splice.from.base.arm2} = 0ft$ *for NO SPLICE*

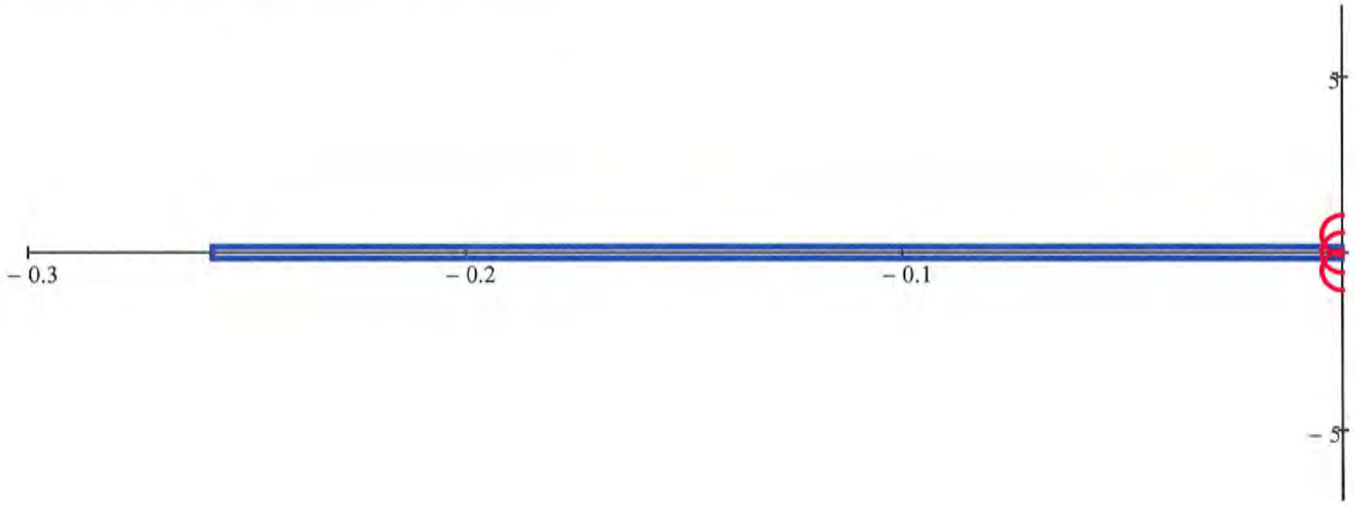
$t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

☐ *inches, use X to zero out (SD)*

☐ *inches, for 2 piece arms, wall thickness of piece closest to the pole, use X to zero out (SH)*

Arm 2 Properties

Summary - Arm 2 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130 \cdot mph$ $L_{total.arm2} = 0.00\,ft$

$Diameter_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $Diameter_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} ft$ $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

$X_{signal.arm2_{i2}} =$	$Sections_{signal.arm2_{i2}} =$	$X_{panel.arm2_{j2}} =$	$Area_{panel.arm2_{j2}} =$
0 ft	0	0.1 ft	0.1 ft^2
0	0		

Arm 2 Combined Stress Ratio and Deflection

$max(CSR_{arm2}) = 0$ $max(\Delta_{arm2}) = 0 \cdot in$ $2 \cdot deg \cdot \sum (L_{arm2} - L_{splice.provided}) = -1.68 \cdot in$

Luminaire Arm Analysis

DataFile = "E1T1.dat" WindSpeed = $130 \cdot mph$

Luminaire Properties

See Design Standards 17743 and 17745 for input values.

Current Values

New Values

set $Y_{luminaire} = 0ft$ *for NO LUMINAIRE*

Current Values	New Values	
$Y_{luminaire} = 0\ ft$	☐	*feet, use X to zero out (Standard LA = 40 feet)*
$X_{luminaire} = 10 \cdot ft$	☐	*feet, use X to zero out (Standard LB = 10 feet)*
$Diameter_{base.lumarm} = 3 \cdot in$	☐	*inches, use X to zero out (Standard LC = 3 inches)*
$t_{wall.lumarm} = 0.125 \cdot in$	☐	*inches, use X to zero out (Standard LD = 0.125 inches)*
$Slope_{lumarm} = 0.5$	☐	*rise/run, use X to zero out (Standard LE = 0.5)*
$r_{lumarm} = 8 \cdot ft$	☐	*feet, use X to zero out (Standard LF = 8 feet)*
$d_{bolt.lum} = 0.5 \cdot in$	☐	*inches, use X to zero out (Standard LG = 0.5 inches)*
$t_{baseplate.lum} = 0.75 \cdot in$	☐	*inches, use X to zero out (Standard LH = 0.75 inches)*

Luminaire Properties

▶ Analyze Luminaire

Summary - Luminaire Arm Geometry

$Y_{luminaire} = 0\ ft$ $X_{luminaire} = 0 \cdot ft$ $Diameter_{base.lumarm} = 0 \cdot in$ $t_{wall.lumarm} = 0 \cdot in$

$Slope_{lumarm} = 0$ $r_{lumarm} = 0 \cdot ft$ $d_{bolt.lum} = 0 \cdot in$ $t_{baseplate.lum} = 0 \cdot in$

$w_{base.lum} = 0 \cdot in$ $w_{channel.lum} = 0 \cdot in$

Luminaire Arm Ratios

$CSR_{base.lumarm} = 0$ $PR_{bolt.lum} = 0$ $PR_{baseplate.lum} = 0$ $PR_{conn.plate.lum} = 0$

Upright Analysis

DataFile = "E1T1.dat" WindSpeed = $130\cdot mph$

Pole Properties

Current Values	New Values	
$Y_{pole} = 22\,ft$	22	*feet (UA)*
$Y_{arm.conn} = 20.5\,ft$	20.5	*feet (UB)*
$Diameter_{base.pole} = 14\cdot in$		*inches, measured flat to flat (UD)*
$t_{wall.pole} = 0.375\cdot in$		*inches (UE)*
$Gap = \begin{pmatrix} 8.5 \\ 0 \end{pmatrix}\cdot in$		*inches, clear distance between connection plate and upright*
		inches, use X to zero out

Common wall thicknesses:
0.1793 in.
0.2391 in.
0.25 in.
0.313 in.
0.375 in.
0.5 in.

Pole Properties

Summary - Upright Geometry

$Y_{pole} = 22\,ft$ $Y_{arm.conn} = 20.5\,ft$ $\alpha = 0\cdot deg$ $Gap = \begin{pmatrix} 8.5 \\ 0 \end{pmatrix}\cdot in$

$Diameter_{tip.pole} = 10.92\cdot in$ $Diameter_{base.pole} = 14\cdot in$ $t_{wall.pole} = 0.375\cdot in$

Upright Combined Stress Ratio and Deflections

$\max(CSR_{pole}) = 0.725$ $\max(\Delta_{x.dl}) = 0.79\cdot in$ $\max(\Delta_{z.dl}) = 0\cdot in$

Mast Arm Connection(s) Analysis

DataFile = "E1T1.dat" WindSpeed = $130\cdot mph$

Connection Properties

Current Values

$h_{conn.plate} = 22\cdot in$

$t_{vertical.plate} = \begin{pmatrix}0.5\\0\end{pmatrix}\cdot in$

$d_{bolt.conn} = \begin{pmatrix}1\\0\end{pmatrix}\cdot in$

$t_{baseplate.arm} = \begin{pmatrix}2\\0\end{pmatrix}\cdot in$

Connection Properties

New Values

inches, for two arm Mast Arms both connection plate heights must be equal (HT)

inches (FL)

inches, use X to zero out (SL)

inches (FP)

inches, use X to zero out (SP)

inches (FK)

inches, use X to zero out (SK)

Summary - Connection Geometry

$h_{conn.plate} = 22\cdot in$

$Gap = \begin{pmatrix}8.5\\0\end{pmatrix}\cdot in$

$Offset_{conn} = \begin{pmatrix}14.065\\0\end{pmatrix}\cdot in$

$d_{bolt.conn} = \begin{pmatrix}1\\0\end{pmatrix}\cdot in$

$\#ConnBolts = \begin{pmatrix}6\\0\end{pmatrix}$

$Spacing_{bolts.conn} = \begin{pmatrix}9\\0\end{pmatrix}\cdot in$

$t_{conn.plate} = \begin{pmatrix}1.625\\0\end{pmatrix}\cdot in$

$b_{conn.plate} = \begin{pmatrix}21\\0\end{pmatrix}\cdot in$

$t_{vertical.plate} = \begin{pmatrix}0.5\\0\end{pmatrix}\cdot in$

$t_{baseplate.arm} = \begin{pmatrix}2\\0\end{pmatrix}\cdot in$

$w_{conn.plate} = \begin{pmatrix}0.3125\\0\end{pmatrix}\cdot in$

$w_{vertical.plate} = \begin{pmatrix}0.25\\0\end{pmatrix}\cdot in$

Connection Ratios

$PR_{bolt} = \begin{pmatrix}0.498\\0\end{pmatrix}$

$CSR_{t.vert.plate} = \begin{pmatrix}0.56\\0\end{pmatrix}$

$PR_{t.baseplate.arm} = \begin{pmatrix}0.839\\0\end{pmatrix}$

$PR_{t.connplate.arm} = \begin{pmatrix}0.93\\0\end{pmatrix}$

Base Plate Analysis

DataFile = "E1T1.dat" WindSpeed = $130 \cdot mph$

Base Plate Properties

Current Values

New Values

$\#AnchorRods = 6$ ☐ *use 6 bolts minimum*

$d_{bolt.pole} = 1.5 \cdot in$ ☐ *inches (BC)*

Base Plate Properties

▸ Summary - Upright Base Plate Geometry

$\#AnchorRods = 6$ $d_{bolt.pole} = 1.5 \cdot in$ $t_{baseplate.pole} = 2.5 \cdot in$ $Diameter_{baseplate.pole} = 26 \cdot in$

Upright Base Plate Performance Ratios

$PR_{rod} = 0.754$ $PR_{plate.pole} = 1$

Foundation Analysis Cohesionless or Cohesive Soil

DataFile = "E1T1.dat"

Soil Properties

Current Values

New Values

○ Clay

$SoilType = 1$ ● Sand *0 - clay 1 - sand*

$\phi_{soil} = 28 \cdot deg$ 28 *degrees, soil friction angle (sand)*

$c_{soil} = 2000 \cdot psf$ ☐ *psf, soil shear strength (clay)*

$\gamma_{soil.dry} = 100 \cdot pcf$ 100 *pcf, dry soil weight*

$\gamma_{water} = 62.4 \cdot pcf$ ☐ *pcf, water weight (zero if no water)*

$\gamma_{soil} := \gamma_{soil.dry} - \gamma_{water}$ $\gamma_{soil} = 37.60 \cdot pcf$

Soil Properties

▾ Analyze Foundation

Switch values, set values for DataOut, and Write Out Data to DataFile and Temp.dat

$out := out + 1 \quad out = 35.00$

$SoilType := if(newSoilType = 0, 0, 1)$ $data_{out} := SoilType$ $data_{out} = 1.00$

$out := out + 1 \quad out = 36.00$

$\phi_{soil} := fSwitchData(\phi_{soil}, new\phi_{soil}, deg)$ $data_{out} := \dfrac{\phi_{soil}}{deg}$ $data_{out} = 28$

$\text{out} := \text{out} + 1 \quad \text{out} = 37.00$

$c_{soil} := \text{fSwitchData}\left(c_{soil}, \text{newc}_{soil}, \text{psf}\right)$ $\quad \text{data}_{\text{out}} := \dfrac{c_{soil}}{\text{psf}} \quad \text{data}_{\text{out}} = 2000$

$\text{out} := \text{out} + 1 \quad \text{out} = 38.00$

$\gamma_{soil.dry} := \text{fSwitchData}\left(\gamma_{soil.dry}, \text{new}\gamma_{soil.dry}, \text{pcf}\right)$ $\quad \text{data}_{\text{out}} := \dfrac{\gamma_{soil.dry}}{\text{pcf}} \quad \text{data}_{\text{out}} = 100.00$

$\text{out} := \text{out} + 1 \quad \text{out} = 39.00$

$\gamma_{water} := \text{fSwitchData}\left(\gamma_{water}, \text{new}\gamma_{water}, \text{pcf}\right)$ $\quad \text{data}_{\text{out}} := \dfrac{\gamma_{water}}{\text{pcf}} \quad \text{data}_{\text{out}} = 62.40$

$\text{out} := \text{out} + 1 \quad \text{out} = 40.00$

Subject := if(**newSubject** = 0, **Subject**, **newSubject**)

data_{out} := **Subject**

data_{out} = "E1-T1 Mast Arm"

$\text{out} := \text{out} + 1 \quad \text{out} = 41.00$

ProjectNo := if(**newProjectNumber** = 0, **ProjectNo**, **newProjectNumber**)

data_{out} := **ProjectNo**

data_{out} = "'00193008015"

$\text{out} := \text{out} + 1 \quad \text{out} = 42.00$

PoleLocation := if(**newPoleLocation** = 0, **PoleLocation**, **newPoleLocation**)

data_{out} := **PoleLocation**

data_{out} = "ID No.3"

$\text{out} := \text{out} + 1 \quad \text{out} = 43.00$

Date := if(**newDate** = 0, **Date**, **newDate**)

data_{out} := **Date**

data_{out} = "01/22/2013"

$\text{out} := \text{out} + 1 \quad \text{out} = 44.00$

DesignedBy := if(**newDesignedBy** = 0, **DesignedBy**, **newDesignedBy**)

data_{out} := **DesignedBy**

data_{out} = "MAV"

$\text{out} := \text{out} + 1 \quad \text{out} = 45.00$

CheckedBy := if(**newCheckedBy** = 0, **CheckedBy**, **newCheckedBy**)

data_{out} := **CheckedBy**

data_{out} = "FDOT"

WRITEPRN(DataFile) := data WRITEPRN("temp.dat") := data

Foundation Design References

LRFD = AASHTO LRFD Bridge Design Specifications

SM V9 = FDOT Structures Manual Volume 9

SDG = FDOT Structures Design Guidelines

Spec = FDOT Standard Specifications

ACI = ACI 318 Structural Concrete Building Code

UF Report = FDOT/University of Florida Report BD545 RPWO #54

Applied Loads

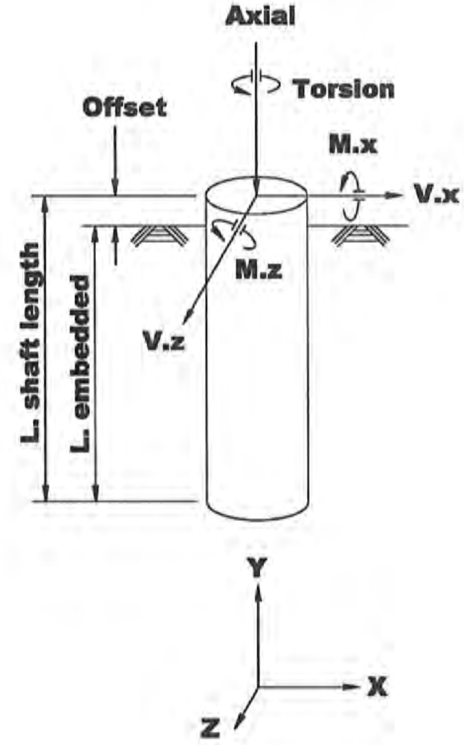
(From Arm1 Design)

WindSpeed = 130.00·mph

(from Base Plate Design)

#AnchorRods = 6.00 $d_{bolt.pole} = 1.50 \cdot in$ $Diameter_{boltcircle.pole} = 20 \cdot in$ $T_{u.rod} = 40.8 \cdot kip$

(from Upright Design)



$$M_{x.polebase} = \begin{pmatrix} 0 \\ 99.5 \\ 99.5 \end{pmatrix} \cdot kip \cdot ft \quad M_{y.polebase} = \begin{pmatrix} 77.7 \\ 0 \\ 77.7 \end{pmatrix} \cdot kip \cdot ft \quad M_{z.polebase} = \begin{pmatrix} 0 \\ 20.8 \\ 20.8 \end{pmatrix} \cdot kip \cdot ft$$

LoadCaseT = 0.00

LoadCaseOT = 1.00

LoadCaseCSR = 2.00

$$V_{x.polebase} = \begin{pmatrix} 0 \\ 0.2 \\ 0.2 \end{pmatrix} \cdot kip \quad AxialForce_{polebase} = \begin{pmatrix} 2.2 \\ 2.2 \\ 2.2 \end{pmatrix} \cdot kip \quad V_{z.polebase} = \begin{pmatrix} 0 \\ 5.2 \\ 5.2 \end{pmatrix} \cdot kip$$

Foundation Diameter

$\text{Diameter}_{\text{shaft}} := \text{Diameter}_{\text{boltcircle.pole}} + 12 \cdot \text{in} + 12 \cdot \text{in}$ $\text{Diameter}_{\text{shaft}} = 3.67 \cdot \text{ft}$

round shaft diameter up to the nearest half foot dimension to accommodate available coring equipment

$\text{Diameter}_{\text{shaft}} := \text{Ceil}\left(\text{Diameter}_{\text{shaft}}, \frac{1}{2} \cdot \text{ft}\right)$ $\text{Diameter}_{\text{shaft}} = 4.00\,\text{ft}$

$b := \text{Diameter}_{\text{shaft}}$

Shaft Depth Required to Resist Overturning

$SF_{ot} := 2$ *Safety Factor against Overturning* *SM V9 13.6*

$\text{Offset} := 1.0 \cdot \text{ft}$ *vertical distance between top of foundation and groundline*

$M_{total} := SF_{ot} \cdot \frac{\sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2}}{C_{a.pole}}$ $M_{total} = 204.1 \cdot \text{kip} \cdot \text{ft}$

$P_{total} := SF_{ot} \cdot \sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2}$ $P_{total} = 10.5 \cdot \text{kip}$

short free-head pile in cohesionless soil using Broms method

$K_p := \tan\left(45 \cdot \text{deg} + \frac{\phi_{soil}}{2}\right)^2$ $e_{sand} := \text{Offset}$

Guess value $L_{otSand} := 8 \cdot \text{ft}$

Given $\frac{\gamma_{soil} \cdot b \cdot L_{otSand}^{3} \cdot K_p}{2} - P_{total} \cdot \left(e_{sand} + L_{otSand}\right) - M_{total} = 0 \cdot \text{kip} \cdot \text{ft}$

$\text{Temp} := \text{Find}\left(L_{otSand}\right)$ $L_{otSand} := \text{Temp}$ $L_{otSand} = 11.74 \cdot \text{ft}$

(round up to next foot) $L_{otSand} := \text{ceil}\left(\frac{L_{otSand}}{\text{ft}}\right) \cdot \text{ft}$ $L_{otSand} = 12.00\,\text{ft}$

$PR_{otSand} := \frac{M_{total} + P_{total} \cdot \left(e_{sand} + L_{otSand}\right)}{\frac{\gamma_{soil} \cdot b \cdot L_{otSand}^{3} \cdot K_p}{2}}$ $PR_{otSand} = 0.94$

short free-head pile in cohesive soil using Modified Broms method for L < 3b (see reference file for derivation)

$c_{soil} := \text{if}\left(c_{soil} = 0\cdot ksf, 0.1\cdot ksf, c_{soil}\right)$ $\text{Slope} := 8\cdot\frac{c_{soil}}{3\cdot b}$ $e_{clay} := \frac{M_{total}}{P_{total}} + \text{Offset}$

$\text{nforce}(M,N) := \left[\text{Slope}\cdot(2\cdot M + N) + 2\cdot c_{soil}\right]\cdot N\cdot\frac{b}{2}$ $\text{mforce}(M) := \left(2\cdot c_{soil} + M\cdot\text{Slope}\right)\cdot M\cdot\frac{b}{2}$

$$\text{m\_arm}(M) := e_{clay} + \frac{M}{3}\cdot\frac{2\cdot\left(M\cdot\text{Slope} + c_{soil}\right) + c_{soil}}{M\cdot\text{Slope} + 2\cdot c_{soil}}$$

$$\text{n\_arm}(M,N) := e_{clay} + M + \frac{N}{3}\cdot\frac{2\cdot\left(N\cdot\text{Slope} + M\cdot\text{Slope} + c_{soil}\right) + \left(M\cdot\text{Slope} + c_{soil}\right)}{\text{Slope}\cdot(2\cdot M + N) + 2\cdot c_{soil}}$$

Guess value $M := 4.0\cdot ft$ $N := 4.0\cdot ft$

Given $P_{total} + \text{nforce}(M,N) = \text{mforce}(M)$ $\text{mforce}(M)\cdot\text{m\_arm}(M) = \text{nforce}(M,N)\cdot\text{n\_arm}(M,N)$

$\begin{pmatrix} M \\ N \end{pmatrix} := \text{Find}(M,N)$ $L_{ot1Clay.temp} := M + N$ $L_{ot1Clay.temp} = 6.74\cdot ft$

(round up to next foot) $L_{ot1Clay} := \text{ceil}\left(\frac{L_{ot1Clay.temp}}{ft}\right)\cdot ft$ $L_{ot1Clay} = 7.00\cdot ft$

short free-head pile in <u>cohesive soil</u> using Regular Broms method for L > 3b

$f_{clay} := \frac{P_{total}}{9\cdot c_{soil}\cdot b}$ $M_{maxtemp} := P_{total}\cdot\left(e_{clay} + 1.5\cdot b + 0.5\cdot f_{clay}\right)$ $g := \sqrt{\frac{M_{maxtemp}}{2.25\cdot c_{soil}\cdot b}}$

$L_{ot2Clay} := \left(1.5\cdot b + f_{clay} + g\right)$ $L_{ot2Clay} = 10.08\,ft$

(round up to next foot) $L_{ot2Clay} := \text{ceil}\left(\frac{L_{ot2Clay}}{ft}\right)\cdot ft$ $L_{ot2Clay} = 11.00\cdot ft$

$L_{otClay} := \text{if}\left(L_{ot1Clay} < 3\cdot b, L_{ot1Clay}, L_{ot2Clay}\right)$ $L_{otClay} = 7.00\cdot ft$

(If $L_{ot} < 3b$, use Modified Broms method)

$$PR_{otClay} := \text{if}\left(L_{otClay} < 3\cdot b, \frac{L_{ot1Clay.temp}}{L_{ot1Clay}}, \frac{\sqrt{\frac{M_{maxtemp}}{2.25\cdot c_{soil}\cdot b}} + \frac{P_{total}}{9\cdot c_{soil}\cdot b}}{L_{ot2Clay} - 1.5\cdot b}\right) \qquad PR_{otClay} = 0.96$$

$L_{reqdOT} := \text{if}\left(\text{SoilType} = 1, L_{otSand}, L_{otClay}\right)$ $L_{reqdOT} = 12.00\,ft$

$PR_{ot} := if(SoilType = 1, PR_{otSand}, PR_{otClay})$ $PR_{ot} = 0.94$

Shaft Depth Required to Resist Torsion

$SF_{tor} := \mathbf{1.0}$ *Safety Factor against Torsion*
1.0 for Mast Arm signal structures
SM V9 13.6

NOTE: ω_{fdot} and μ are based upon CONCRETE and soil interaction. ***This torsion methodology is not to be used with permanent casing.***

$N_{blows} := 15$ *Number of blows per foot. If N< 5, contact the district geotech Engineer*

$$\omega_{fdot} := if\left(N_{blows} < 5, 0, if\left(N_{blows} \ge 15, 1.5, 1.5\cdot\frac{N_{blows}}{15}\right)\right) = 1.50$$ *load transfer ratio*

$\mu := \tan(\phi_{soil}) = 0.53$ *coefficient of friction between concrete shaft and soil*

$\gamma_{concrete} := 150\cdot pcf$ $\gamma_{concrete} := \gamma_{concrete} - \gamma_{water}$ $\gamma_{concrete} = 87.60\cdot pcf$

$CohesionFactor := 0.55$ $f_{se} := CohesionFactor\cdot c_{soil}$

$Torsion := SF_{tor}\cdot M_{y.polebase_{LoadCaseT}}$ $Torsion = 77.7\cdot kip\cdot ft$

short free-head pile in cohesionless soil

Guess value $L_{torSand} := L_{reqdOT}$

Given

$$Torsion = \frac{\left[\pi\cdot b\cdot(L_{torSand})\cdot\gamma_{soil}\cdot\left(\frac{L_{torSand}}{2}\right)\cdot(\omega_{fdot})\cdot\frac{b}{2} + \pi\cdot\left(\frac{b}{2}\right)^2\cdot L_{torSand}\cdot(\gamma_{concrete})\cdot\frac{b}{3}\cdot\mu\right]}{SF_{tor}}$$

$Temp := Find(L_{torSand})$ $L_{torSand} := Temp$ $L_{torSand} = 9.9\,ft$

(round up to next foot) $L_{torSand} := ceil\left(\frac{L_{torSand}}{ft}\right)\cdot ft$ $L_{torSand} = 10.00\,ft$

$$PR_{torSand} := \frac{Torsion\cdot SF_{tor}}{\pi\cdot b\cdot(L_{torSand})\cdot\gamma_{soil}\cdot\left(\frac{L_{torSand}}{2}\right)\cdot(\omega_{fdot})\cdot\frac{b}{2} + \pi\cdot\left(\frac{b}{2}\right)^2\cdot L_{torSand}\cdot(\gamma_{concrete})\cdot\frac{b}{3}\cdot\mu} \qquad PR_{torSand} = 0.99$$

short free-head pile in cohesive soil

Guess value $L_{torClay} := L_{reqdOT}$

Given $$\left[f_{se}\cdot(\pi\cdot b)\cdot(L_{torClay} - 1.5\cdot ft)\cdot\frac{b}{2}\right] + \left[f_{se}\cdot\pi\cdot\left(\frac{b}{2}\right)^2\cdot\left(\frac{b}{3}\right)\right] = Torsion\cdot SF_{tor}$$

$\text{Temp} := \text{Find}(L_{torClay})$ $L_{torClay} := \text{Temp}$ $L_{torClay} = 3.64\,\text{ft}$

(round up to next foot) $L_{torClay} := \text{ceil}\left(\frac{L_{torClay}}{\text{ft}}\right)\cdot\text{ft}$ $L_{torClay} = 4.00\,\text{ft}$

$$PR_{torClay} := \frac{\text{Torsion}\cdot SF_{tor}}{\left[f_{se}\cdot(\pi\cdot b)\cdot(L_{torClay} - 1.5\cdot\text{ft})\cdot\frac{b}{2}\right] + \left[f_{se}\cdot\pi\cdot\left(\frac{b}{2}\right)^2\cdot\left(\frac{b}{3}\right)\right]} \qquad PR_{torClay} = 0.89$$

$L_{reqdTor} := \text{if}(\text{SoilType} = 1, L_{torSand}, L_{torClay})$ $L_{reqdTor} = 10.00\,\text{ft}$

$PR_{tor} := \text{if}(\text{SoilType} = 1, PR_{torSand}, PR_{torClay})$ $PR_{tor} = 0.99$

$L_{embedded} := \text{if}(L_{reqdTor} > L_{reqdOT}, L_{reqdTor}, L_{reqdOT})$ $L_{embedded} = 12.00\,\text{ft}$

$L_{shaft} := L_{embedded} + \text{Offset}$ $L_{shaft} = 13.00\,\text{ft}$

$PR_{foundation} := \text{if}(L_{reqdTor} > L_{reqdOT}, PR_{tor}, PR_{ot})$ $PR_{foundation} = 0.94$

Unfactored Maximum Moment in Shaft

short free-head pile in <u>cohesionless soil</u> using Broms method

$$f_{sand} := \sqrt{\frac{2\cdot\frac{P_{total}}{SF_{ot}}}{3\cdot\gamma_{soil}\cdot b\cdot K_p}} \qquad f_{sand} = 2.89\,\text{ft}$$

$$M_{maxSand} := \frac{P_{total}}{SF_{ot}}\cdot(e_{sand} + f_{sand}) - \frac{\frac{P_{total}}{SF_{ot}}\cdot f_{sand}}{3} + \frac{M_{total}}{SF_{ot}} \qquad M_{maxSand} = 117.4\cdot\text{kip}\cdot\text{ft}$$

short free-head pile in <u>cohesive soil</u> using Modified Broms method for L < 3b (see reference file for derivation)

Guess value $f_{mod} := 4.0\cdot\text{ft}$

Given $\frac{P_{total}}{SF_{ot}} = \frac{f_{mod}\cdot b}{2}\cdot(2\cdot c_{soil} + f_{mod}\cdot\text{Slope})$

$f_{mod} := \text{Find}(f_{mod})$ $f_{mod} = 0.55\,\text{ft}$

$$M_{modBroms} := \frac{P_{total}}{SF_{ot}}\cdot(e_{clay} + f_{mod}) - \frac{c_{soil}\cdot b\cdot f_{mod}^{\,2}}{2} - \frac{b\cdot f_{mod}^{\,3}\cdot\text{Slope}}{6} \qquad M_{modBroms} = 108.8\cdot\text{kip}\cdot\text{ft}$$

short free-head pile in <u>cohesive soil</u> using Regular Broms method for L > 3b

$$M_{Broms} := \frac{P_{total}}{SF_{ot}}\cdot(e_{clay} + 1.5\cdot b + 0.5\cdot f_{clay}) \qquad M_{Broms} = 139\cdot\text{kip}\cdot\text{ft}$$

$M_{maxClay} := \text{if}(L_{ot1Clay} < 3 \cdot b, M_{modBroms}, M_{Broms})$ $M_{maxClay} = 108.8 \cdot \text{kip} \cdot \text{ft}$

(If $L_{ot} < 3b$, use Modified Broms method)

$M_{max} := \text{if}(\text{SoilType} = 1, M_{maxSand}, M_{maxClay})$ *(this is a Service moment)* $M_{max} = 117.4 \cdot \text{kip} \cdot \text{ft}$

Minimum Reinforcing and Spacing

$F_{y.rebar} := 60 \cdot \text{ksi}$ *reinforcing yield strength*

$f_c := 4.0 \cdot \text{ksi}$ *concrete strength* ***Spec 346-3***

$\text{cover} := 6 \cdot \text{in}$ *cover* ***SDG Table 1.4.2-1***

$A_{bar} := 1.56 \cdot \text{in}^2$ *longitudinal bar area*

$d_{bar} := 1.41 \cdot \text{in}$ *longitudinal bar diameter*

$A_{v.bar} := 0.31 \cdot \text{in}^2$ *stirrup area* ***SM V9 13.6.2***

$d_{v.bar} := 0.625 \cdot \text{in}$ *stirrup diameter*

$s_{v1} := 4 \cdot \text{in}$ *stirrup spacing, depth = 0 ft-2 ft* ***SM V9 13.6.2***

$s_{v2} := 12 \cdot \text{in}$ *stirrup spacing, depth = 2 ft-depth.stir*

$s_{v3} := 12 \cdot \text{in}$ *stirrup spacing, depth > depth.stir*

$\text{depth}_{stir} := 9 \cdot \text{ft}$ *stirrup depth, see s.v2 and s.v3 above*

$b = 4.00 \text{ ft}$ *shaft diameter*

$\text{BarsProv}_1 := \frac{0.01}{A_{bar}} \cdot \frac{\pi \cdot b^2}{4}$ $\text{BarsProv}_1 = 11.60$ ***LRFD 5.7.4.2***

$\text{BarsProv}_2 := \frac{0.135}{A_{bar} \cdot F_{y.rebar}} \cdot \left(\frac{\pi \cdot b^2}{4} \cdot f_c\right)$ $\text{BarsProv}_2 = 10.44$

$\text{BarsProv} := \text{ceil}(\max(\text{BarsProv}_1, \text{BarsProv}_2))$ $\text{BarsProv} = 12.00$ *number of longitudinal bars*

$\text{NumSpaces}_{v.bar} := \text{round}\left(\frac{\text{depth}_{stir} - 2 \cdot \text{ft}}{s_{v2}}\right)$ $\text{NumSpaces}_{v.bar} = 7.00$

$\text{ReinfClearSpacing} := \left[b - 2\cdot\left(\text{cover} + d_{v.bar} + \frac{d_{bar}}{2}\right)\right]\cdot\frac{\pi}{\text{BarsProv}} - d_{bar}$ $\text{ReinfClearSpacing} = 7.32\cdot\text{in}$

CheckReinfClearSpacing := if(ReinfClearSpacing ≥ 6in, "OK" , "No Good") CheckReinfClearSpacing = "OK"

SDG 3.6.10

Check Shear and Torsion

$LF_{shr} := \mathbf{1.3}$	*Shear Load Factor*	*1.3 is a reasonable Load Factor for combined WL + DL on sign and signal structures*
$LF_{tor} := \mathbf{1.3}$	*Torsion Load Factor*	
$\phi_{shr} := \mathbf{0.90}$	*Shear Resistance Factor*	*LRFD 5.5.4.2.1*
$\phi_{tor} := \mathbf{0.90}$	*Torsion Resistance Factor*	*LRFD 5.5.4.2.1*

$V_u := LF_{shr}\cdot\sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2}$ $V_u = 6.8\cdot\text{kip}$

$T_u := LF_{tor}\cdot\text{Torsion}$ $T_u = 100.96\cdot\text{kip}\cdot\text{ft}$

Area and perimeter of concrete cross-section

$A_{cp} := \pi\cdot\left(\frac{b}{2}\right)^2$ $A_{cp} = 1809.6\cdot\text{in}^2$

$p_{cp} := 2\cdot\pi\cdot\left(\frac{b}{2}\right)$ $p_{cp} = 150.8\cdot\text{in}$

Diameter, perimeter and area enclosed by the centerline of the outermost closed transverse torsion reinforcement

$d_{oh} := b - 2\cdot\left(\text{cover} + \frac{d_{v.bar}}{2}\right)$ $d_{oh} = 35.4\cdot\text{in}$

$p_h := \pi\cdot d_{oh}$ $p_h = 111.1\cdot\text{in}$

$A_{oh} := \pi\left(\frac{d_{oh}}{2}\right)^2$ $A_{oh} = 982.8\cdot\text{in}^2$

$A_o := 0.85\cdot A_{oh}$ $A_o = 835.4\cdot\text{in}^2$ *LRFD C5.8.2.1*

Effective shear depth

$$D_r := b - 2\cdot\left(\text{cover} + d_{v.bar} + \frac{d_{bar}}{2}\right) \qquad d_e := \frac{b}{2} + \frac{D_r}{\pi} = 2.88\,\text{ft}$$

LRFD C5.8.2.1

$$d_v := \max(0.9\cdot d_e, 0.72\cdot b) = 2.88\,\text{ft}$$

Check Shear Strength

$$V_c := 0.0316\cdot(2.0)\cdot\sqrt{\frac{f'_c}{\text{ksi}}}\cdot\left(\frac{d_v}{\text{in}}\right)\cdot\left(\frac{b}{\text{in}}\right)\cdot\text{kip} \qquad V_c = 209.7\cdot\text{kip}$$

LRFD Eqn 5.8.3.3-3

LRFD 5.8.3.4.1

ACI 11.3.3

$$V_s := \frac{A_{v.bar}\cdot F_{y.rebar}\cdot(d_v)}{\max(s_{v1}, s_{v2}, s_{v3})} \qquad V_s = 53.6\cdot\text{kip}$$

LRFD Eqn 5.8.3.3-4

$$\phi_{shr} = 0.90 \qquad V_u = 6.8\cdot\text{kip}$$

$$\text{ShearRatio} := \frac{V_u - \phi_{shr}\cdot V_c}{\phi_{shr}\cdot V_s} \qquad \text{ShearRatio} = -3.77$$

$$\text{ShearRatio} := \text{if}(\text{ShearRatio} \le 0, 0, \text{ShearRatio}) \; \text{ShearRatio} = 0.00$$

Check Torsion Strength

$$T_{n1} := \frac{2\cdot A_o\cdot A_{v.bar}\cdot F_{y.rebar}}{s_{v1}} \qquad T_{n1} = 647.4\cdot\text{kip}\cdot\text{ft}$$

LRFD Eqn 5.8.3.6.2-1

LRFD 5.8.3.4.1

$$T_{n2} := \frac{2\cdot A_o\cdot A_{v.bar}\cdot F_{y.rebar}}{s_{v2}} \qquad T_{n2} = 215.8\cdot\text{kip}\cdot\text{ft}$$

$$T_{n3} := \frac{2\cdot A_o\cdot A_{v.bar}\cdot F_{y.rebar}}{s_{v3}} \qquad T_{n3} = 215.8\cdot\text{kip}\cdot\text{ft}$$

$$\phi_{tor} = 0.90 \qquad T_u = 100.96\cdot\text{kip}\cdot\text{ft} \qquad L_{reqdTor} = 10.00\,\text{ft}$$

$$\text{Tor2}_{sand} := T_u - \max\left[\left[\pi\cdot b\cdot(2\cdot\text{ft} - \text{Offset})\cdot\gamma_{soil}\cdot\left(\frac{2\cdot\text{ft} - \text{Offset}}{2}\right)\cdot(\omega_{fdot})\cdot\frac{b}{2}\right], 0\cdot\text{kip}\cdot\text{ft}\right] \qquad \text{Tor2}_{sand} = 100.3\cdot\text{kip}\cdot\text{ft}$$

$$\text{Tor3}_{sand} := T_u - \max\left[\left[\pi\cdot b\cdot(\text{depth}_{stir} - \text{Offset})\cdot\gamma_{soil}\cdot\left(\frac{\text{depth}_{stir} - \text{Offset}}{2}\right)\cdot(\omega_{fdot})\cdot\frac{b}{2}\right], 0\cdot\text{kip}\cdot\text{ft}\right] \qquad \text{Tor3}_{sand} = 55.6\cdot\text{kip}\cdot\text{ft}$$

$$\text{Tor2}_{clay} := T_u - \max\left[\left[f_{se}\cdot(\pi\cdot b)\cdot(2.0\cdot\text{ft} - \text{Offset} - 1.5\cdot\text{ft})\cdot\frac{b}{2}\right], 0\cdot\text{kip}\cdot\text{ft}\right] \qquad \text{Tor2}_{clay} = 100.96\cdot\text{kip}\cdot\text{ft}$$

$$\text{Tor3}_{clay} := T_u - \max\left[\left[f_{se}\cdot(\pi\cdot b)\cdot(\text{depth}_{stir} - \text{Offset} - 1.5\cdot\text{ft})\cdot\frac{b}{2}\right], 0\cdot\text{kip}\cdot\text{ft}\right] \qquad \text{Tor3}_{clay} = -78.74\cdot\text{kip}\cdot\text{ft}$$

$$\text{Tor2} := \text{if}(\text{SoilType} = 1, \text{Tor2}_{sand}, \text{Tor2}_{clay}) \qquad \text{Tor2} = 100.25\cdot\text{kip}\cdot\text{ft}$$

$\text{Tor3} := \text{if}(\text{SoilType} = 1, \text{Tor3}_{\text{sand}}, \text{Tor3}_{\text{clay}})$ $\text{Tor3} = 55.60 \cdot \text{kip} \cdot \text{ft}$

$\text{TorsionRatio}_{n1} := \dfrac{T_u}{\phi_{tor} \cdot T_{n1}}$ $\text{TorsionRatio}_{n1} = 0.17$

$\text{TorsionRatio}_{n2} := \dfrac{\text{Tor2}}{\phi_{tor} \cdot T_{n2}}$ $\text{TorsionRatio}_{n2} = 0.52$

$\text{TorsionRatio}_{n3} := \dfrac{\text{Tor3}}{\phi_{tor} \cdot T_{n3}}$ $\text{TorsionRatio}_{n3} = 0.29$

$\text{TorsionRatio} := \max(\text{TorsionRatio}_{n1}, \text{TorsionRatio}_{n2}, \text{TorsionRatio}_{n3})$ $\text{TorsionRatio} = 0.52$

$T_{cr} := 0.125 \sqrt{\dfrac{f_c}{\text{ksi}}} \cdot \left(\dfrac{{A_{cp}}^2}{p_{cp} \cdot \text{in}^3} \right) \cdot \text{kip} \cdot \text{in}$ $T_{cr} = 452.4 \cdot \text{kip} \cdot \text{ft}$ ***LRFD Eqn 5.8.2.1-4***

$\text{TorsionRatio} := \text{if}(T_u \le 0.25 \cdot \phi_{tor} \cdot T_{cr}, 0, \text{TorsionRatio})$ $\text{TorsionRatio} = 0.00$ ***LRFD Eqn 5.8.2.1-3***

$\text{ShearRatio} = 0.00$

$\text{CheckShearTorsion} := \text{if}(\text{ShearRatio} + \text{TorsionRatio} \le 1, \text{"OK"}, \text{"No Good"})$ $\text{CheckShearTorsion} = \text{"OK"}$

Check Maximum Spacing Transverse Reinforcement

$vu := \dfrac{V_u}{\phi_{shr} \cdot b \cdot (0.8 \cdot b)}$ $vu = 0.0041 \cdot \text{ksi}$ ***LRFD Eqn 5.8.2.9-1***

$0.125 \cdot f_c = 0.50 \cdot \text{ksi}$

$s_{max1} := \text{if}(0.8 \cdot d_v < 24 \cdot \text{in}, 0.8 \cdot d_v, 24 \cdot \text{in})$ $s_{max1} = 24 \cdot \text{in}$ ***LRFD Eqn 5.8.2.7-1***

$s_{max2} := \text{if}(0.4 \cdot d_v < 12 \cdot \text{in}, 0.4 \cdot d_v, 12 \cdot \text{in})$ $s_{max2} = 12 \cdot \text{in}$ ***LRFD Eqn 5.8.2.7-2***

$s_{max} := \text{if}(vu < 0.125 \cdot f_c, s_{max1}, s_{max2})$ $s_{max} = 24 \cdot \text{in}$

$\max(s_{v1}, s_{v2}, s_{v3}) = 12.00 \cdot \text{in}$

$\text{CheckMaxSpacingTransvReinf} := \text{if}(\max(s_{v1}, s_{v2}, s_{v3}) \le s_{max}, \text{"OK"}, \text{"No Good"})$ $\text{CheckMaxSpacingTransvReinf} = \text{"OK"}$

Check Longitudinal Reinforcement for Combined Shear and Torsion ***LRFD Eqn 5.8.3.6.3-1***

LRFD 5.8.3.4.1

$M_u := LF_{tor} \cdot \sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2}$ $M_u = 132.1 \cdot \text{kip} \cdot \text{ft}$

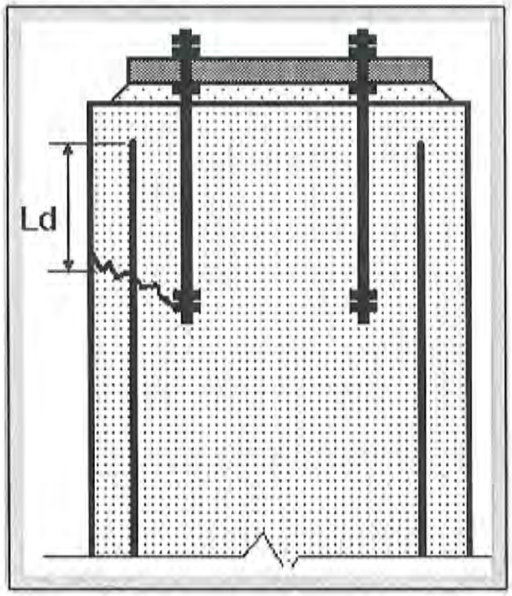
$V_{temp} := \text{if}\left(\frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s > 0 \cdot kip, \frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s, 0 \cdot kip\right)$ $V_{temp} = 0 \cdot kip$

$$LongReinf_{shr.tor} := \frac{\frac{M_u}{\phi_{tor} \cdot (0.8 \cdot b)} + \sqrt{\left(\frac{V_{temp}}{kip}\right)^2 + \left(\frac{0.45 \cdot p_h \cdot T_u}{2 \cdot A_o \cdot \phi_{tor} \cdot kip}\right)^2} \cdot kip}{F_{y.rebar}}$$ $LongReinf_{shr.tor} = 1.44 \cdot in^2$

$BarsProv \cdot A_{bar} = 18.72 \cdot in^2$

$CheckLongReinf_{shr.tor} := \text{if}\left(BarsProv \cdot A_{bar} \geq LongReinf_{shr.tor}, \text{"OK"}, \text{"No Good"}\right)$ $CheckLongReinf_{shr.tor} = \text{"OK"}$

Anchor Bolt Embedment



$$Gap_{shaft} := \frac{b - 2 \cdot cover - 2 \cdot d_{v.bar} - Diameter_{boltcircle.pole} - d_{bar}}{2}$$

$Gap_{shaft} = 6.67 \cdot in$

$Diameter_{rebar.circle} := b - 2 \cdot cover - d_{bar} - 2 \cdot d_{v.bar}$

$Diameter_{rebar.circle} = 33.3 \cdot in$

$\#BarsProvided := BarsProv$ $\#BarsProvided = 12.00$

$$\#BarsProvidedPerRod := \min\left(\begin{pmatrix} \frac{\#BarsProvided}{\#AnchorRods} \\ 3 \end{pmatrix}\right)$$

Use a maximum of three rebar per anchor bolt (conservative)

$\#BarsProvidedPerRod = 2.00$

$\phi := 0.9$ $$\#BarsReqdPerRod := \frac{T_{u.rod}}{A_{bar} \cdot (\phi \cdot F_{y.rebar})} \cdot \frac{Diameter_{boltcircle.pole}}{Diameter_{rebar.circle}}$$ $\#BarsReqdPerRod = 0.29$

$$AreaRatio := \frac{\#BarsReqdPerRod}{\#BarsProvidedPerRod}$$ $AreaRatio = 0.15$

$AreaRatio := \text{if}(AreaRatio < 1, AreaRatio, 1)$ $AreaRatio = 0.15$

$$L_{d.bar} := \max\left[\begin{bmatrix} \dfrac{1.25\cdot(A_{bar})\cdot F_{y.rebar}}{\sqrt{f_c\cdot ksi}\cdot in} \\ \dfrac{0.4\cdot(d_{bar})\cdot F_{y.rebar}}{ksi} \end{bmatrix}\right]$$

development length of bar **_LRFD 5.11.2.1.1_**

$$L_{d.bar} := \mathrm{if}\left(A_{bar} = 2.25\cdot in^2, \frac{2.70\cdot in^2\cdot F_{y.rebar}}{\sqrt{f_c\cdot ksi}\cdot in}, L_{d.bar}\right)$$

$L_{d.bar} = 58.5\cdot in$

$$SpacingFactor := \max\left(\begin{pmatrix} \#BarsProvidedPerRod\cdot 0.5 - 0.5 \\ 0.5 \end{pmatrix}\right)$$

$SpacingFactor = 0.50$

$$L_{embedment.added} := \sqrt{(ReinfClearSpacing\cdot SpacingFactor)^2 + Gap_{shaft}^{\,2}}$$

$L_{embedment.added} = 7.6\cdot in$

$$L_{embedment.rod} := \max\left[\begin{bmatrix} L_{d.bar}\cdot(AreaRatio) + 12\cdot in + L_{embedment.added} \\ 20\cdot d_{bolt.pole} \end{bmatrix}\right]$$

$$L_{embedment.rod} := \mathrm{Ceil}(L_{embedment.rod}, in)$$

$L_{embedment.rod} = 30\cdot in$

$$L_{anchor.rod} := \mathrm{Ceil}[(L_{embedment.rod} + 8\cdot in), in]$$

$L_{anchor.rod} = 38\cdot in$

Anchor Bolt Shear Break-Out Strength

References:
ACI 318-05 Appendix D.
FDOT/University of Florida Report BD545 RPWO #54,
Anchor Embedment Requirements for Signal/Sign Structures, July 2007.

$\#AnchorRods = 6.00$ *number of anchor bolts*

$d_{bolt.pole} = 1.50\cdot in$ *anchor bolt diameter*

$Diameter_{boltcircle.pole} = 20.00\cdot in$ *anchor bolt circle diameter*

$L_{embedment.rod} = 30.00\cdot in$ *anchor bolt embedment*

$b = 48.00\cdot in$ *shaft diameter*

$$r_b := \frac{Diameter_{boltcircle.pole}}{2}$$

$r_b = 10.00\cdot in$

$$r := \frac{b}{2}$$

$r = 24.00\cdot in$

$c_{a1} := \dfrac{\sqrt{r_b^{\,2} + 3.25\cdot\left(r^2 - r_b^{\,2}\right)} - r_b}{3.25}$ $\quad c_{a1} = 9.41\cdot in$ *adjusted cover*

UF Report Eqn 3-2

$L_e := \min\left(8\cdot d_{bolt.pole}, L_{embedment.rod}\right)$ $\quad L_e = 12.00\cdot in$ *load bearing length of anchor for shear*

ACI D.6.2.2

$V_b := 13\cdot\left(\dfrac{L_e}{d_{bolt.pole}}\right)^{0.2}\cdot\sqrt{\dfrac{d_{bolt.pole}}{in}}\cdot\sqrt{\dfrac{f_c}{psi}}\left(\dfrac{c_{a1}}{in}\right)^{1.5}\cdot lbf$ *shear break-out strength (single anchor)*

UF Report Eqn 2-11

$V_b = 44.1\cdot kip$

$A := \dfrac{(360\cdot deg)}{\#AnchorRods}$ $\quad A = 60\cdot deg$ ***UF Report Fig 3-7***

$alpha := 2\ asin\left[\dfrac{\left(1.5\cdot c_{a1}\right)}{r}\right]$ $\quad alpha = 72.1\cdot deg$

OverlapTest := if(A ≤ alpha, "Overlap of Failure Cones" , "No Overlap of Failure Cones")

OverlapTest = "Overlap of Failure Cones"

$chord := 2\cdot r\cdot \sin\left(\dfrac{A}{2}\right)$ $\quad chord = 24\cdot in$ ***UF Report Fig 3-7***

$A_{Vco} := 4.5\cdot c_{a1}^{\;2}$ $\quad A_{Vco} = 398.5\cdot in^2$ *projected concrete failure area (single anchor)*

ACI Eqn D-23

$A_{Vc} := chord\cdot 1.5\cdot c_{a1}$ $\quad A_{Vc} = 338.8\cdot in^2$ *projected concrete failure area (group)*

ACI D.6.2.1

$A_{Vc} := if\left(A_{Vc} > A_{Vco}, A_{Vco}, A_{Vc}\right)$ $\quad A_{Vc} = 338.8\cdot in^2$

$\psi_{ecV} := \mathbf{1.0}$	*eccentric load modifier*	***ACI D.6.2.5***	
$\psi_{edV} := \mathbf{1.0}$	*edge effect modifier*	***ACI D.6.2.6***	
$\psi_{cV} := \mathbf{1.4}$	*cracked section modifier*	***ACI D.6.2.7***	*(stirrup spacing <= 4")*
$\psi_{hV} := \mathbf{1.0}$	*member thickness modifier*	***ACI D.6.2.8***	
$\phi_{breakout} := \mathbf{0.75}$	*strength reduction factor*	***ACI D.4.4.c.i***	*(shear breakout, condition A)*

$V_{cbg} := \#AnchorRods \cdot \left(\frac{A_{Vc}}{A_{Vco}}\right) \cdot \left(\psi_{ecV} \cdot \psi_{edV} \cdot \psi_{cV} \cdot \psi_{hV}\right) \cdot V_b$ $V_{cbg} = 314.6 \cdot kip$ *concrete breakout strength - shear*

ACI Eqn D-22 *Shear force $\perp$ to edge*

$V_{cbg\_parallel} := 2 \cdot V_{cbg}$ $V_{cbg\_parallel} = 629.3 \cdot kip$ ***ACI D.6.2.1.c*** *Shear force || to edge*

$T_{n.breakout} := V_{cbg\_parallel} \cdot r_b$ $T_{n.breakout} = 524.4 \cdot kip \cdot ft$ *concrete breakout strength - torsion*

$\phi_{breakout} \cdot T_{n.breakout} = 393.3 \cdot kip \cdot ft$

$T_u = 101 \cdot kip \cdot ft$

BreakoutTest := $\text{if}\left(\phi_{breakout} \cdot T_{n.breakout} \ge T_u, \text{"OK"}, \text{"No Good"}\right)$ BreakoutTest = "OK"

OverlapDesign := $\text{if}(A \le \alpha$, "Based on Overlap of Failure Cones" , "Based on No Overlap of Failure Cones")

OverlapDesign = "Based on No Overlap of Failure Cones"

$M_{x.polebase} = \begin{pmatrix} 0.0 \\ 99.5 \\ 99.5 \end{pmatrix} \cdot kip \cdot M_{y.polebase} = \begin{pmatrix} 77.7 \\ 0.0 \\ 77.7 \end{pmatrix} \cdot kip \cdot ft \, M_{z.polebase} = \begin{pmatrix} 0.0 \\ 20.8 \\ 20.8 \end{pmatrix} \cdot kip \cdot ft$

maximum torsion (Mx & Mz not used)
maximum overturning (My not used)
maximum CSR

▲ Analyze Foundation

Summary - Soil Properties and Drilled Shaft Geometry

SoilType = 1 *0 - clay* *1 - sand* $\phi_{soil} = 28 \cdot deg$ $c_{soil} = 2000 \cdot psf$ $\gamma_{soil} = 37.6 \cdot pcf$

$Diameter_{shaft} = 4 \, ft$ $L_{shaft} = 13 \, ft$ $L_{embedment.rod} = 30 \cdot in$ $L_{anchor.rod} = 38.00 \cdot in$

#BarsProvided = 12 $d_{bar} = 1.41 \cdot in$

Foundation Performance Ratios

$PR_{foundation} = 0.945$

Fatigue Analysis

DataFile = "E1T1.dat" WindSpeed = $130 \cdot mph$

Use the member cross section adjacent to the weld toe to compute the nominal stress range. **LTS 11.9**

FatigueCategory := 2 **SM V9 11.6**

▼ Analyze Structure for Fatigue

Fatigue Importance Factors

LTS Table 11-1

Galloping: $I_{F.g} := \text{if}(\text{FatigueCategory} = 1, 1.0, \text{if}(\text{FatigueCategory} = 2, 0.65, 0.3)) = 0.65$

Natural Wind Gusts: $I_{F.nw} := \text{if}(\text{FatigueCategory} = 1, 1.0, \text{if}(\text{FatigueCategory} = 2, 0.80, 0.55)) = 0.80$

Vortex Shedding: No check. **LTS Table 11-1**

Truck Gust: No check. **LTS 11.7.4**

Constant Amplitude Fatigue Threshold

LTS Table 11-3

$CAFT_A := 24 \cdot ksi$

$CAFT_B := 16 \cdot ksi$ $CAFT_{B'} := 12 \cdot ksi$

$CAFT_C := 10 \cdot ksi$

$CAFT_D := 7 \cdot ksi$

$CAFT_E := 4.5 \cdot ksi$ $CAFT_{E'} := 2.6 \cdot ksi$

$CAFT_{ET} := 1.2 \cdot ksi$

$CAFT_{K2} := 1.0 \cdot ksi$

Galloping

LTS 11.7.1

Pressure: $Pressure_{galloping} := (21 \cdot psf) \cdot I_{F.g} = 13.65 \cdot psf$

Natural Wind Gust

LTS 11.7.3

$C_{d.nwg.tube} := 1.2$

Pressure: coefficient of drag will be added with each component

$Pressure_{natural.wind.gust} := (5.2 \cdot psf) \cdot I_{F.nw} = 4.16 \cdot psf$

Arm and Pole Welds

*NOTE: *LTS = proposed for 2012*

***LTS 11.9.3.1**

$$^{**}\ b_{conn.plate} = \begin{pmatrix} 21.00 \\ 0.00 \end{pmatrix} \cdot in$$

***NOTE: For Standard Mastarms check Design Standard 17743 for arm plate width FJ.*

$D_{BC.arm1} := b_{conn.plate_0} - 4 \cdot d_{bolt.conn_0} = 17.00 \cdot in$ $D_{OP.arm1} := \max(Diameter_{base.arm1}) - 4 \cdot in = 7.00 \cdot in$

$D_{T.arm1} := \max(Diameter_{base.arm1}) = 11.00 \cdot in$

$D_{BC.arm2} := b_{conn.plate_1} - 4 \cdot d_{bolt.conn_1} = 0.00 \cdot in$ $D_{OP.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 10 \cdot in, \max(Diameter_{base.arm2}) - 4 \cdot in\right] = 10.00 \cdot in$

$D_{T.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 14 \cdot in, \max(Diameter_{base.arm2})\right] = 14.00 \cdot in$

$D_{BC.pole} := Diameter_{boltcircle.pole} = 20.00 \cdot in$ $D_{OP.pole} := Diameter_{base.pole} - 4 \cdot in = 10.00 \cdot in$ $D_{T.pole} := Diameter_{base.pole} = 14.00 \cdot in$

$C_{BC.arm1} := \dfrac{D_{BC.arm1}}{D_{T.arm1}} = 1.55$ $C_{OP.arm1} := \dfrac{D_{OP.arm1}}{D_{T.arm1}} = 0.64$ $t_{T.arm1} := \max(t_{wall.arm1}) = 0.25 \cdot in$

$t_{TP.arm1} := t_{baseplate.arm_0} + t_{conn.plate_0} = 3.625 \cdot in$

$C_{BC.arm2} := \dfrac{D_{BC.arm2}}{D_{T.arm2}} = 0.00$ $C_{OP.arm2} := \dfrac{D_{OP.arm2}}{D_{T.arm2}} = 0.71$ $t_{T.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 0.1 \cdot in, \max(t_{wall.arm2})\right] = 0.1 \cdot in$

$t_{TP.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 0.1 \cdot in, t_{baseplate.arm_1} + t_{conn.plate_1}\right] = 0.1 \cdot in$

$C_{BC.pole} := \dfrac{D_{BC.pole}}{D_{T.pole}} = 1.43$ $C_{OP.pole} := \dfrac{D_{OP.pole}}{D_{T.pole}} = 0.71$ $t_{T.pole} := t_{wall.pole} = 0.375 \cdot in$ $t_{TP.pole} := t_{baseplate.pole} = 2.5 \cdot in$

*LTS Table 11-3, Eqn 11-13

valid for:

$0.179 \cdot in \le t_T \le 0.625 \cdot in$

$8 \cdot in \le D_T \le 50 \cdot in$

$2 \cdot in \le t_{TP} \le 4 \cdot in$

$\le C_{BC} \le 2.5$

$0.3 \le C_{OP} \le 0.9$

$$K_{F.arm1} := 1.35 + 16 \cdot \left(15 \cdot \frac{t_{T.arm1}}{in} + 1\right) \cdot \left(\frac{D_{T.arm1}}{in} - 5\right) \cdot \left(\frac{C_{BC.arm1}{}^{0.02} - 1}{4 \cdot C_{OP.arm1}{}^{-0.7} - 3}\right) \cdot \left(\frac{t_{TP.arm1}}{in}\right)^{-2} = 1.47$$

$$K_{F.arm2} := 1.35 + 16 \cdot \left(15 \cdot \frac{t_{T.arm2}}{in} + 1\right) \cdot \left(\frac{D_{T.arm2}}{in} - 5\right) \cdot \left(\frac{C_{BC.arm2}{}^{0.02} - 1}{4 \cdot C_{OP.arm2}{}^{-0.7} - 3}\right) \cdot \left(\frac{t_{TP.arm2}}{in}\right)^{-2} = -1.75 \times 10^{4}$$

$$K_{F.pole} := 1.35 + 16 \cdot \left(15 \cdot \frac{t_{T.pole}}{in} + 1\right) \cdot \left(\frac{D_{T.pole}}{in} - 5\right) \cdot \left(\frac{C_{BC.pole}{}^{0.02} - 1}{4 \cdot C_{OP.pole}{}^{-0.7} - 3}\right) \cdot \left(\frac{t_{TP.pole}}{in}\right)^{-2} = 1.88$$

$$K_{I.arm1} := \left[\left(1.76 + 1.83 \cdot \frac{t_{T.arm1}}{in}\right) - 4.76 \cdot 0.22^{K_{F.arm1}}\right] \cdot K_{F.arm1} = 2.51$$

$$K_{I.arm2} := if\left[\left(L_{total.arm2} = 0 \cdot ft\right), 100, \left[\left(1.76 + 1.83 \cdot \frac{t_{T.arm2}}{in}\right) - 4.76 \cdot 0.22^{K_{F.arm2}}\right] \cdot K_{F.arm2}\right] = 100.00$$

$$K_{I.pole} := \left[\left(1.76 + 1.83 \cdot \frac{t_{T.pole}}{in}\right) - 4.76 \cdot 0.22^{K_{F.pole}}\right] \cdot K_{F.pole} = 4.08$$

*LTS Table 11-2, Detail 4.5

$$CAFT_{fullpengroove.weld.arm1} := if\left(K_{I.arm1} < 3.0, 10.0\cdot ksi, if\left(K_{I.arm1} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 10.00\cdot ksi$$

$$CAFT_{fullpengroove.weld.arm2} := if\left(K_{I.arm2} < 3.0, 10.0\cdot ksi, if\left(K_{I.arm2} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 4.50\cdot ksi$$

$$CAFT_{fullpengroove.weld.pole} := if\left(K_{I.pole} < 3.0, 10.0\cdot ksi, if\left(K_{I.pole} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 4.50\cdot ksi$$

Galloping Moment: $base1 = 20$ $base2 = 20$ $polebase = 10$

$$M_{galloping.arm1.base} := \left(\frac{M_{wl.signal.arm1_{base1}}}{C_{d.signal}} + \frac{M_{wl.panel.arm1_{base1}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 13.99\cdot kip\cdot ft$$

$$M_{galloping.arm2.base} := \left(\frac{M_{wl.signal.arm2_{base2}}}{C_{d.signal}} + \frac{M_{wl.panel.arm2_{base2}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 0.00\cdot kip\cdot ft$$

$$M_{galloping.pole.base} := max\left(M_{galloping.arm1.base}, M_{galloping.arm2.base}\right) = 13.99\cdot kip\cdot ft$$

Galloping Shear:

$$V_{galloping.arm1.base} := \left(\frac{V_{wl.signal.arm1_{base1}}}{C_{d.signal}} + \frac{V_{wl.panel.arm1_{base1}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 0.86\cdot kip$$

$$V_{galloping.arm2.base} := \left(\frac{V_{wl.signal.arm2_{base2}}}{C_{d.signal}} + \frac{V_{wl.panel.arm2_{base2}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 0\cdot kip$$

Galloping Bending Stress

$$\phi := \frac{180\cdot deg}{Sides} = 15.00\cdot deg$$

$$f_{b.galloping.arm1.base} := \frac{M_{galloping.arm1.base}\cdot\left(\frac{a_{od.arm1_{base1}}}{2\cdot\sin(\phi)}\right)}{I_{arm1_{base1}}} = 7.48\cdot ksi$$

$$f_{b.galloping.arm2.base} := if\left[I_{arm2_{base2}} > 0\cdot in^{4}, \frac{M_{galloping.arm2.base}\cdot\left(\frac{a_{od.arm2_{base2}}}{2\cdot\sin(\phi)}\right)}{I_{arm2_{base2}}}, 0\cdot ksi\right] = 0.00\cdot ksi$$

$$f_{b.galloping.pole.base} := \frac{M_{galloping.pole.base}\cdot\left(\frac{a_{od.pole_{polebase}}}{2\cdot\sin(\phi)}\right)}{I_{pole_{polebase}}} = 3.12\cdot ksi$$

Galloping Shear Stress:

$$f_{v.galloping.arm1.base} := 2.025 \cdot \frac{V_{galloping.arm1.base}}{A_{arm1_{base1}}} = 0.20 \cdot ksi$$

$$f_{v.galloping.arm2.base} := \text{if}\left(A_{arm2_{base2}} > 0 \cdot in^2, 2.025 \cdot \frac{V_{galloping.arm2.base}}{A_{arm2_{base2}}}, 0 \cdot ksi\right) = 0.00 \cdot ksi$$

Check Galloping Stress:

$$f_{galloping.arm1} := \sqrt{f_{b.galloping.arm1.base}{}^2 + f_{v.galloping.arm1.base}{}^2} = 7.48 \cdot ksi \qquad CAFT_{fullpengroove.weld.arm1} = 10.00 \cdot ksi$$

$$Check_{galloping.arm1} := \text{if}\left(CAFT_{fullpengroove.weld.arm1} \geq f_{galloping.arm1}, \text{"OK"}, \text{"No Good"}\right) \qquad Check_{galloping.arm1} = \text{"OK"}$$

$$f_{galloping.arm2} := \sqrt{f_{b.galloping.arm2.base}{}^2 + f_{v.galloping.arm2.base}{}^2} = 0.00 \cdot ksi \qquad CAFT_{fullpengroove.weld.arm2} = 4.50 \cdot ksi$$

$$f_{galloping.arm2} := \text{if}\left(L_{total.arm2} = 0 \cdot ft, 0 \cdot ksi, f_{galloping.arm2}\right) = 0.00 \cdot ksi$$

$$Check_{galloping.arm2} := \text{if}\left(CAFT_{fullpengroove.weld.arm2} \geq f_{galloping.arm2}, \text{"OK"}, \text{"No Good"}\right)$$

$$Check_{galloping.arm2} := \text{if}\left(L_{total.arm2} = 0 \cdot ft, \text{"NA"}, Check_{galloping.arm2}\right) \qquad Check_{galloping.arm2} = \text{"NA"}$$

$$f_{galloping.pole} := f_{b.galloping.pole.base} = 3.12 \cdot ksi \qquad CAFT_{fullpengroove.weld.pole} = 4.50 \cdot ksi$$

$$Check_{galloping.pole} := \text{if}\left(CAFT_{fullpengroove.weld.pole} \geq f_{galloping.pole}, \text{"OK"}, \text{"No Good"}\right) \qquad Check_{galloping.pole} = \text{"OK"}$$

Natural Wind Gust Moment: $base1 = 20 \qquad base2 = 20 \qquad polebase = 10$

$$M_{nwg.arm1.base} := \left(M_{wl.signal.arm1_{base1}} + M_{wl.panel.arm1_{base1}} + M_{wl.tube.arm1_{base1}} \cdot \frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure \cdot K_{z.arm}} = 7.2 \cdot kip \cdot ft$$

$$M_{nwg.arm2.base} := \left(M_{wl.signal.arm2_{base2}} + M_{wl.panel.arm2_{base2}} + M_{wl.tube.arm2_{base2}} \cdot \frac{C_{d.nwg.tube}}{C_{d.segment.arm2_{base2}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure \cdot K_{z.arm}} = 0 \cdot kip \cdot ft$$

$$M_{nwg.pole.base} := \max(M_x) \cdot \left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right) \cdot \frac{Pressure_{natural.wind.gust}}{Pressure \cdot K_{z.pole_{polebase}}} = 14.65 \cdot kip \cdot ft$$

$$M_{x.connect_{\beta}} := M_{x_{\beta,0}}$$

$$M_{nwg.pole.connect} := \max\left(M_{x.connect}\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}} = 5.01\times10^{-3}\cdot kip\cdot ft$$

$$M_{nwg.pole.torsion} := \max\left(M_{y}\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right)\cdot\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}} = 11.44\cdot kip\cdot ft$$

Natural Wind Gust Shear:

$$V_{nwg.arm1.base} := \left(V_{wl.signal.arm1_{base1}} + V_{wl.panel.arm1_{base1}} + V_{wl.tube.arm1_{base1}}\cdot\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 0.44\cdot kip$$

$$V_{nwg.arm2.base} := \left(V_{wl.signal.arm2_{base2}} + V_{wl.panel.arm2_{base2}} + V_{wl.tube.arm2_{base2}}\cdot\frac{C_{d.nwg.tube}}{C_{d.segment.arm2_{base2}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 4.99\times10$$

$$V_{nwg.pole.base} := \max\left(V_{z}\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}}\right) = 0.77\cdot kip$$

$$V_{x.connect_{\beta}} := V_{x_{\beta,0}}$$

$$V_{nwg.pole.connect} := \max\left(V_{x.connect}\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 1.34\times10^{-3}\cdot kip$$

Natural Wind Gust Bending Stress:

$$f_{b.nwg.arm1.base} := \frac{M_{nwg.arm1.base}\cdot\left(\frac{a_{od.arm1_{base1}}}{2\cdot\sin(\phi)}\right)}{I_{arm1_{base1}}} = 3.86\cdot ksi$$

$$f_{b.nwg.arm2.base} := \mathrm{if}\left[I_{arm2_{base2}} > 0\cdot in^{4}, \frac{M_{nwg.arm2.base}\cdot\left(\frac{a_{od.arm2_{base2}}}{2\cdot\sin(\phi)}\right)}{I_{arm2_{base2}}}, 0\cdot ksi\right] = 0.00\cdot ksi$$

$$f_{b.nwg.pole.base} := \frac{M_{nwg.pole.base}\cdot\left(\frac{a_{od.pole_{polebase}}}{2\cdot\sin(\phi)}\right)}{I_{pole_{polebase}}} = 3.27\cdot ksi$$

$$f_{b.nwg.pole.connect} := \frac{M_{nwg.pole.connect}\cdot\left(\frac{a_{od.pole_{0}}}{2\cdot\sin(\phi)}\right)}{I_{pole_{0}}} = 1.81\times10^{-3}\cdot ksi$$

Natural Wind Gust Shear Stress:

$$f_{v.nwg.arm1.base} := 2.025\cdot\frac{V_{nwg.arm1.base}}{A_{arm1_{base1}}} = 0.10\cdot ksi$$

$$f_{v.nwg.arm2.base} := if\left(A_{arm2_{base2}} > 0\cdot in^2, 2.025\cdot\frac{V_{nwg.arm2.base}}{A_{arm2_{base2}}}, 0\cdot ksi\right) = 0.00\cdot ksi$$

$$f_{v.nwg.pole.base.shear} := 2.025\cdot\frac{V_{nwg.pole.base}}{A_{pole_{polebase}}} = 0.09\cdot ksi$$

$$f_{v.nwg.pole.connect.shear} := 2.025\cdot\frac{V_{nwg.pole.connect}}{A_{pole_0}} = 2.09\times 10^{-4}\cdot ksi$$

$$f_{v.nwg.pole.base.torsion} := \frac{M_{nwg.pole.torsion}\cdot k_{t_{polebase}}}{6.43\cdot\left(R_{b_{polebase}}\right)^2\cdot t_{pole}} = 1.27\cdot ksi$$

$$f_{v.nwg.pole.connect.torsion} := \frac{M_{nwg.pole.torsion}\cdot k_{t_0}}{6.43\cdot\left(R_{b_0}\right)^2\cdot t_{pole}} = 2.01\cdot ksi$$

$$f_{v.nwg.pole.base} := \sqrt{f_{v.nwg.pole.base.shear}^2 + f_{v.nwg.pole.base.torsion}^2} = 1.27\cdot ksi$$

$$f_{v.nwg.pole.connect} := \sqrt{f_{v.nwg.pole.connect.shear}^2 + f_{v.nwg.pole.connect.torsion}^2} = 2.01\cdot ksi$$

Check Natural Wind Gust Stress:

$$f_{nwg.arm1} := \sqrt{f_{b.nwg.arm1.base}^2 + f_{v.nwg.arm1.base}^2} = 3.86\cdot ksi$$

$CAFT_{fullpengroove.weld.arm1} = 10.00\cdot ksi$

$Check_{nwg.arm1} := if\left(CAFT_{fullpengroove.weld.arm1} \geq f_{nwg.arm1}, \text{"OK"}, \text{"No Good"}\right)$

$Check_{nwg.arm1} = \text{"OK"}$

$$f_{nwg.arm2} := \sqrt{f_{b.nwg.arm2.base}^2 + f_{v.nwg.arm2.base}^2} = 0.00\cdot ksi$$

$CAFT_{fullpengroove.weld.arm2} = 4.50\cdot ksi$

$$f_{nwg.arm2} := if\left(L_{total.arm2} = 0\cdot ft, 0\cdot ksi, f_{nwg.arm2}\right) = 0.00\cdot ksi$$

$\mathrm{Check}_{nwg.arm2} := \mathrm{if}(\mathrm{CAFT}_{fullpengroove.weld.arm2} \geq f_{nwg.arm2}, \text{"OK"}, \text{"No Good"})$

$\mathrm{Check}_{nwg.arm2} := \mathrm{if}(L_{total.arm2} = 0\cdot \mathrm{ft}, \text{"NA"}, \mathrm{Check}_{nwg.arm2})$

$\mathrm{Check}_{nwg.arm2} = \text{"NA"}$

$f_{nwg.pole.base} := \sqrt{f_{b.nwg.pole.base}^{2} + f_{v.nwg.pole.base}^{2}} = 3.51\cdot \mathrm{ksi}$

$f_{nwg.pole.connect} := \sqrt{f_{b.nwg.pole.connect}^{2} + f_{v.nwg.pole.connect}^{2}} = 2.01\cdot \mathrm{ksi}$

$f_{nwg.pole} := \mathrm{if}(f_{nwg.pole.connect} > f_{nwg.pole.base}, f_{nwg.pole.connect}, f_{nwg.pole.base}) = 3.51\cdot \mathrm{ksi}$

$\mathrm{CAFT}_{fullpengroove.weld.pole} = 4.50\cdot \mathrm{ksi}$

$\mathrm{Check}_{nwg.pole} := \mathrm{if}(\mathrm{CAFT}_{fullpengroove.weld.pole} \geq f_{nwg.pole}, \text{"OK"}, \text{"No Good"})$

$\mathrm{Check}_{nwg.pole} = \text{"OK"}$

A325 Connection Bolts

$\mathrm{CAFT}_{conn.bolt} := \mathrm{CAFT}_{B} = 16.00\cdot \mathrm{ksi}$ ***LTS Table 11-2, Detail 3***

Galloping

$M_{galloping.arms_0} := M_{galloping.arm1.base}$

$M_{galloping.arms_1} := M_{galloping.arm2.base}$

$$T_{g.conn_j} := \frac{M_{galloping.arms_j}}{RC_j + \mathrm{CompForceOffset}_j + t_{arm_j}}$$

$$T_{g.conn} = \begin{pmatrix} 8.7 \\ 2.7 \times 10^{-4} \end{pmatrix}\cdot \mathrm{kip}$$

$$T_{g.bolt.max_j} := \mathrm{if}\left[\#\mathrm{ConnBolts}_j = 0, 0\cdot \mathrm{ksi}, \frac{T_{g.conn_j}}{0.5\cdot \#\mathrm{ConnBolts}_j} + \frac{\mathrm{DistA}_j\cdot \tan(\theta_j)\cdot T_{g.conn_j}\cdot (\#\mathrm{ConnBolts}_j\cdot 0.25 - 0.5)\cdot \mathrm{Spacing}_{bolts.conn_j}}{\displaystyle\sum_{n=0}^{\mathrm{floor}(0.25\cdot \#\mathrm{ConnBolts}_j)} \left[\left[\frac{\lfloor(\#\mathrm{ConnBolts}_j\cdot 0.5) - 1\rfloor - 2\cdot n}{2}\cdot \mathrm{Spacing}_{bolts.conn_j}\right]^2\right]}\right.$$

$$T_{g.bolt.max} = \begin{pmatrix} 3.8 \\ 0.0 \end{pmatrix}\cdot \mathrm{kip}$$

$$f_{t.g.bolt_j} := \frac{T_{g.bolt.max_j}}{A_{gross.bolt_j}}$$ *Bolt Tensile Stress*

$$f_{t.g.bolt} = \begin{pmatrix} 4.9 \\ 0.0 \end{pmatrix}\cdot \mathrm{ksi}$$

$\text{Check}_{g.conn.bolt_j} := \text{if}\left(\text{CAFT}_{conn.bolt} \geq f_{t.g.bolt_j}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{g.conn.bolt} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

Natural wind gust

$M_{nwg.arms_0} := M_{nwg.arm1.base}$

$M_{nwg.arms_1} := M_{nwg.arm2.base}$

$$T_{nwg.conn_j} := \frac{M_{nwg.arms_j}}{RC_j + \text{CompForceOffset}_j + t_{arm_j}} \qquad T_{nwg.conn} = \begin{pmatrix} 4.5 \\ 10.0 \times 10^{-5} \end{pmatrix} \cdot \text{kip}$$

$$T_{nwg.bolt.max_j} := \text{if}\left[\#\text{ConnBolts}_j = 0, 0 \cdot \text{ksi}, \frac{T_{nwg.conn_j}}{0.5 \cdot \#\text{ConnBolts}_j} + \frac{\text{DistA}_j \cdot \tan(\theta_j) \cdot T_{nwg.conn_j} \cdot (\#\text{ConnBolts}_j \cdot 0.25 - 0.5) \cdot \text{Spacing}_{bolts.co}}{\sum_{n=0}^{\text{floor}(0.25 \cdot \#\text{ConnBolts}_j)} \left[\frac{\left[(\#\text{ConnBolts}_j \cdot 0.5) - 1\right] - 2 \cdot n}{2} \cdot \text{Spacing}_{bolts.co}\right.}\right.$$

$$T_{nwg.bolt.max} = \begin{pmatrix} 2.0 \\ 0.0 \end{pmatrix} \cdot \text{kip}$$

$f_{t.nwg.bolt_j} := \dfrac{T_{nwg.bolt.max_j}}{A_{gross.bolt_j}}$ *Bolt Tensile Stress* $f_{t.nwg.bolt} = \begin{pmatrix} 2.5 \\ 0.0 \end{pmatrix} \cdot \text{ksi}$

$\text{Check}_{nwg.conn.bolt_j} := \text{if}\left(\text{CAFT}_{conn.bolt} \geq f_{t.nwg.bolt_j}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{nwg.conn.bolt} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

Anchor Bolts

$\text{CAFT}_{anchor.rods} := \text{CAFT}_D = 7.00 \cdot \text{ksi}$ ***LTS Table 11-2, Detail 5***

Galloping

$T_{g.rod} := \dfrac{M_{galloping.arm1.base}}{S_{rod.group}}$ $T_{g.rod} = 5.6 \cdot \text{kip}$

$f_{t.g.rod} := \dfrac{T_{g.rod}}{A_{net.rod}}$ $f_{t.g.rod} = 4.51 \cdot \text{ksi}$

$\text{Check}_{g.rod} := \text{if}\left(\text{CAFT}_{anchor.rods} \geq f_{t.g.rod}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{g.rod} = \text{"OK"}$

Natural Wind Gust

$T_{nwg.rod} := \dfrac{M_{nwg.pole.base}}{S_{rod.group}}$ $T_{nwg.rod} = 5.9 \cdot \text{kip}$

$f_{t.nwg.rod} := \dfrac{T_{nwg.rod}}{A_{net.rod}}$ $f_{t.nwg.rod} = 4.73 \cdot \text{ksi}$

$\text{Check}_{\text{nwg.rod}} := \text{if}\left(\text{CAFT}_{\text{anchor.rods}} \ge f_{\text{t.nwg.rod}}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{\text{nwg.rod}} = \text{"OK"}$

Longitudinal Seam Weld on Arm and Upright Tubes

$\text{CAFT}_{\text{seam.weld}} := \text{CAFT}_{\text{B'}} = 12.00 \cdot \text{ksi}$ ***LTS Table 11-2, Detail 8***

$\text{CAFT}_{\text{seam.weld}}$ > galloping or natural wind gust stress. No check.

Arm Telescopic Splice

$\text{CAFT}_{\text{splice}} := \text{CAFT}_{\text{B}} = 16.00 \cdot \text{ksi}$ ***LTS Table 11-2, Detail 2***

$\text{CAFT}_{\text{splice}}$ > galloping or natural wind gust stress. No check.

Reinforced Handhole

$\text{CAFT}_{\text{handhole}} := 7 \cdot \text{ksi}$ ****LTS Table 11-2, Detail 3.2***

$\text{CAFT}_{\text{handhole}}$ > galloping or natural wind gust stress. No check.

$\text{CAFT}_{\text{fullpengroove.weld.arm2}} := \text{if}\left(L_{\text{total.arm2}} = 0 \cdot \text{ft}, \text{"NA"}, \text{CAFT}_{\text{fullpengroove.weld.arm2}}\right)$

Analyze Structure for Fatigue

Arm and Pole Welds

$f_{\text{galloping.arm1}} = 7.48 \cdot \text{ksi}$ $\text{CAFT}_{\text{fullpengroove.weld.arm1}} = 10.00 \cdot \text{ksi}$ $\text{Check}_{\text{galloping.arm1}} = \text{"OK"}$

$f_{\text{galloping.arm2}} = 0.00 \cdot \text{ksi}$ $\text{CAFT}_{\text{fullpengroove.weld.arm2}} = \text{"NA"} \cdot \text{ksi}$ $\text{Check}_{\text{galloping.arm2}} = \text{"NA"}$

$f_{\text{galloping.pole}} = 3.12 \cdot \text{ksi}$ $\text{CAFT}_{\text{fullpengroove.weld.pole}} = 4.50 \cdot \text{ksi}$ $\text{Check}_{\text{galloping.pole}} = \text{"OK"}$

$f_{\text{nwg.arm1}} = 3.86 \cdot \text{ksi}$ $\text{Check}_{\text{nwg.arm1}} = \text{"OK"}$

$f_{\text{nwg.arm2}} = 0.00 \cdot \text{ksi}$ $\text{Check}_{\text{nwg.arm2}} = \text{"NA"}$

$f_{\text{nwg.pole}} = 3.51 \cdot \text{ksi}$ $\text{Check}_{\text{nwg.pole}} = \text{"OK"}$

A325 Connection Bolts

$f_{\text{t.g.bolt}} = \begin{pmatrix} 4.9 \\ 0.0 \end{pmatrix} \cdot \text{ksi}$ $\text{CAFT}_{\text{conn.bolt}} = 16.00 \cdot \text{ksi}$ $\text{Check}_{\text{g.conn.bolt}} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

$f_{\text{t.nwg.bolt}} = \begin{pmatrix} 2.5 \\ 0.0 \end{pmatrix} \cdot \text{ksi}$ $\text{Check}_{\text{nwg.conn.bolt}} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

Anchor Bolts

$f_{\text{t.g.rod}} = 4.51 \cdot \text{ksi}$ $\text{CAFT}_{\text{anchor.rods}} = 7.00 \cdot \text{ksi}$ $\text{Check}_{\text{g.rod}} = \text{"OK"}$

$f_{t.nwg.rod} = 4.73 \cdot ksi$

$Check_{nwg.rod} = "OK"$

▶ Summary

Mast Arm Design and Analysis Summary

$DataFile = "E1T1.dat"$ $WindSpeed = 130 \cdot mph$

Subject = "E1-T1 Mast Arm"

DesignedBy = "MAV"

PoleLocation = "ID No.3"

ProjectNo = "'00193008015"

CheckedBy = "FDOT"

Date = "01/22/2013"

1st Mast Arm

$\#Signals_{arm1} = 3$

$\#Panels_{arm1} = 3$

$$X_{signal.arm1} = \begin{pmatrix} 10.5 \\ 18.5 \\ 26.5 \end{pmatrix} ft \qquad Sections_{signal.arm1} = \begin{pmatrix} 3 \\ 3 \\ 4 \end{pmatrix} \qquad Backplate_{signal.arm1} = \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$$

$$X_{panel.arm1} = \begin{pmatrix} 4.5 \\ 31 \\ 22 \end{pmatrix} ft \qquad Area_{panel.arm1} = \begin{pmatrix} 20 \\ 9 \\ 1.56 \end{pmatrix} ft^2$$

$L_{total.arm1} = 36\,ft$ $L_{splice.provided.arm1} = 24 \cdot in$

$$\begin{matrix} \text{'FA'=} \\ \text{'FE'=} \end{matrix}\ L_{arm1} = \begin{pmatrix} 36 \\ 0 \end{pmatrix} \cdot ft \qquad \begin{matrix} \text{'FB'=} \\ \text{'FF'=} \end{matrix}\ Diameter_{tip.arm1} = \begin{pmatrix} 5.96 \\ 0 \end{pmatrix} \cdot in \qquad \begin{matrix} \text{'FC'=} \\ \text{'FG'=} \end{matrix}\ Diameter_{base.arm1} = \begin{pmatrix} 11 \\ 0 \end{pmatrix} \cdot in$$

$$\begin{matrix} \text{'FD'=} \\ \text{'FH'=} \end{matrix}\ t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0 \end{pmatrix} \cdot in \qquad \max(\Delta_{arm1}) = 3.59 \cdot in \qquad \max(CSR_{arm1}) = 0.958$$

2nd Mast Arm

$\#Signals_{arm2} = 0$

$\#Panels_{arm2} = 1$

$X_{signal.arm2} = (0)\,ft$ $Sections_{signal.arm2} = (0)$ $Backplate_{signal.arm2} = (0)$

$X_{panel.arm2} = (0.1)\,ft$ $Area_{panel.arm2} = (0.1)\,ft^2$

$L_{total.arm2} = 0\,ft$ $L_{splice.provided.arm2} = 24 \cdot in$ 'UF'= $\alpha = 0 \cdot deg$ **(Angle Between Arms)**

'SA'= 'SE'= $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot ft$

'SB'= 'SF'= $Diameter_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

'SC'= 'SG'= $Diameter_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

'SD'= 'SH'= $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

$\max(\Delta_{arm2}) = 0 \cdot in$

$\max(CSR_{arm2}) = 0$

Luminaire Arm and Connection

DataFile = "E1T1.dat" WindSpeed = 130·mph

(use MC10x33.6 channel for connection)

'LA'= $Y_{luminaire} = 0\,ft$

'LB'= $X_{luminaire} = 0\,ft$

'LC'= $Diameter_{base.lumarm} = 0 \cdot in$

'LD'= $t_{wall.lumarm} = 0 \cdot in$

'LE'= $Slope_{lumarm} = 0$

'LF'= $r_{lumarm} = 0\,ft$

'LG'= $d_{bolt.lum} = 0 \cdot in$

'LH'= $t_{baseplate.lum} = 0 \cdot in$

'LJ'= $w_{base.lum} = 0 \cdot in$

'LK'= $w_{channel.lum} = 0 \cdot in$

$CSR_{base.lumarm} = 0$ $PR_{bolt.lum} = 0$ $PR_{baseplate.lum} = 0$ $PR_{conn.plate.lum} = 0$

Upright

'UA'= $Y_{pole} = 22 \cdot ft$

'UB'= $Y_{arm.conn} = 20.5 \cdot ft$

'UC'= $Diameter_{tip.pole} = 10.92 \cdot in$

'UD'= $Diameter_{base.pole} = 14 \cdot in$

'UE'= $t_{wall.pole} = 0.375 \cdot in$

'UF'= $\alpha = 0 \cdot deg$

'UG'= $Y_{lum.conn} = 0\,ft$

$\Delta_{x.dl} = 0.79 \cdot in$

$Slope_x = 0.42 \cdot deg$

$\Delta_{z.dl} = 0 \cdot in$

$Slope_z = 0 \cdot deg$

$C_{a.pole} = 0.996$

$\max(CSR_{pole}) = 0.725$

1st Arm/Upright Connection

$\#ConnBolts_0 = 6$

'HT'= $h_{conn.plate} = 22 \cdot in$

'FJ'= $b_{conn.plate_0} = 21.00 \cdot in$

'FK'= $t_{baseplate.arm_0} = 2 \cdot in$

'FL'= $t_{vertical.plate_0} = 0.5 \cdot in$

'FN'= $w_{vertical.plate_0} = 0.25 \cdot in$

'FO'= $Offset_{conn_0} = 14.065 \cdot in$

'FP'= $d_{bolt.conn_0} = 1 \cdot in$

'FR'= $t_{conn.plate_0} = 1.625 \cdot in$

'FS'= $Spacing_{bolts.conn_0} = 9 \cdot in$

'FT'= $w_{conn.plate_0} = 0.3125 \cdot in$

$$\begin{pmatrix} PR_{bolt_0} \\ PR_{t.baseplate.arm_0} \\ PR_{t.connplate.arm_0} \\ CSR_{t.vert.plate_0} \end{pmatrix} = \begin{pmatrix} 0.498 \\ 0.839 \\ 0.93 \\ 0.56 \end{pmatrix}$$

2nd Arm/Upright Connection

$\#ConnBolts_1 = 0$

'HT'= $h_{conn.plate} = 22 \cdot in$

'SJ'= $b_{conn.plate_1} = 0.00 \cdot in$

'SK'= $t_{baseplate.arm_1} = 0 \cdot in$ 'SL'= $t_{vertical.plate_1} = 0 \cdot in$

'SN'= $w_{vertical.plate_1} = 0 \cdot in$ 'SO'= $Offset_{conn_1} = 0 \cdot in$

'SP'= $d_{bolt.conn_1} = 0 \cdot in$ 'SR'= $t_{conn.plate_1} = 0 \cdot in$

'SS'= $Spacing_{bolts.conn_1} = 0 \cdot in$ 'ST'= $w_{conn.plate_1} = 0 \cdot in$

$$\begin{pmatrix} PR_{bolt_1} \\ PR_{t.baseplate.arm_1} \\ PR_{t.connplate.arm_1} \\ CSR_{t.vert.plate_1} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Pole Baseplate

DataFile = "E1T1.dat" WindSpeed = $130 \cdot mph$

$\#AnchorRods = 6$ 'BA'= $Diameter_{baseplate.pole} = 26 \cdot in$ 'BB'= $t_{baseplate.pole} = 2.5 \cdot in$

'BC'= $d_{bolt.pole} = 1.50 \cdot in$ 'BF'= $L_{embedment.rod} = 30 \cdot in$

$Diameter_{boltcircle.pole} = 20 \cdot in$ $PR_{rod} = 0.754$

$PR_{plate.pole} = 1$

Foundation

'DA'= $L_{shaft} = 13 \cdot ft$ 'DB'= $Diameter_{shaft} = 4 \cdot ft$ $d_{bar} = 1.41 \cdot in$

'RA'= $round\left(\frac{d_{bar}}{0.125in}\right) = 11$ 'RB'= $\#BarsProvided = 12$ $Diameter_{rebar.circle} = 2.7783\, ft$

'RC'= $NumSpaces_{v.bar} = 7$ 'RD'= $s_{v2} = 12 \cdot in$ $PR_{foundation} = 0.945$

▶ WRITEPRN to Line 1-2-3

Mast Arm Tip Deflection

Compare Mast Arm deflection of each arm to a proposed camber

$Camber_{arm1} := \mathbf{2} \cdot deg$ $Camber_{arm2} := \mathbf{2} \cdot deg$

$L_{arm1} := \sum L_{arm1} - if\left[\left(L_{arm1_1} = 0 \cdot ft\right), 0 \cdot ft, 2 \cdot ft\right]$ $L_{arm2} := \sum L_{arm2} - if\left[\left(L_{arm2_1} = 0 \cdot ft\right), 0 \cdot ft, 2 \cdot ft\right]$

$Deflection_{arm1} := Slope_x \cdot L_{arm1} + max\left(\Delta_{arm1}\right)$ $Deflection_{arm1} = 6.75 \cdot in$

$CamberArm1_{upward} := sin\left(Camber_{arm1}\right) \cdot L_{arm1}$ $CamberArm1_{upward} = 15.08 \cdot in$

$Deflection_{arm2} := \left[Slope_z \cdot L_{arm2} \cdot (sin(\alpha))\right] + Slope_x \cdot L_{arm2} \cdot cos(\alpha) + max\left(\Delta_{arm2}\right)$ $Deflection_{arm2} = 0 \cdot in$

$CamberArm2_{upward} := sin\left(Camber_{arm2}\right) \cdot L_{arm2}$ $CamberArm2_{upward} = 0 \cdot in$

Check Clearance Between Connection Plates *(for Two Arm Structures only)*

$\alpha = 0.00\cdot \mathrm{deg}$ $\qquad \alpha := \mathrm{if}[(\alpha > 180\cdot \mathrm{deg}),(360\cdot \mathrm{deg} - \alpha),\alpha]$

$\mathrm{Offset}_{\mathrm{conn}_0} = 14.06\cdot \mathrm{in}$ $\qquad b_{\mathrm{conn.plate}_0} = 21.00\cdot \mathrm{in}$ $\qquad h_{\mathrm{conn.plate}} = 22.00\cdot \mathrm{in}$ $\qquad \alpha = 0.00\cdot \mathrm{deg}$

$\mathrm{Offset}_{\mathrm{conn}_1} = 0.00\cdot \mathrm{in}$ $\qquad b_{\mathrm{conn.plate}_1} = 0.00\cdot \mathrm{in}$

$$x_1 := \mathrm{Offset}_{\mathrm{conn}_0} - t_{\mathrm{conn.plate}_0} - h_{\mathrm{conn.plate}}\cdot\frac{\sin\left(\mathrm{Camber}_{\mathrm{arm1}}\right)}{2} \qquad y_1 := \frac{b_{\mathrm{conn.plate}_0}}{2} \qquad x_1 = 12.06\cdot \mathrm{in} \quad y_1 = 10.5\cdot \mathrm{in}$$

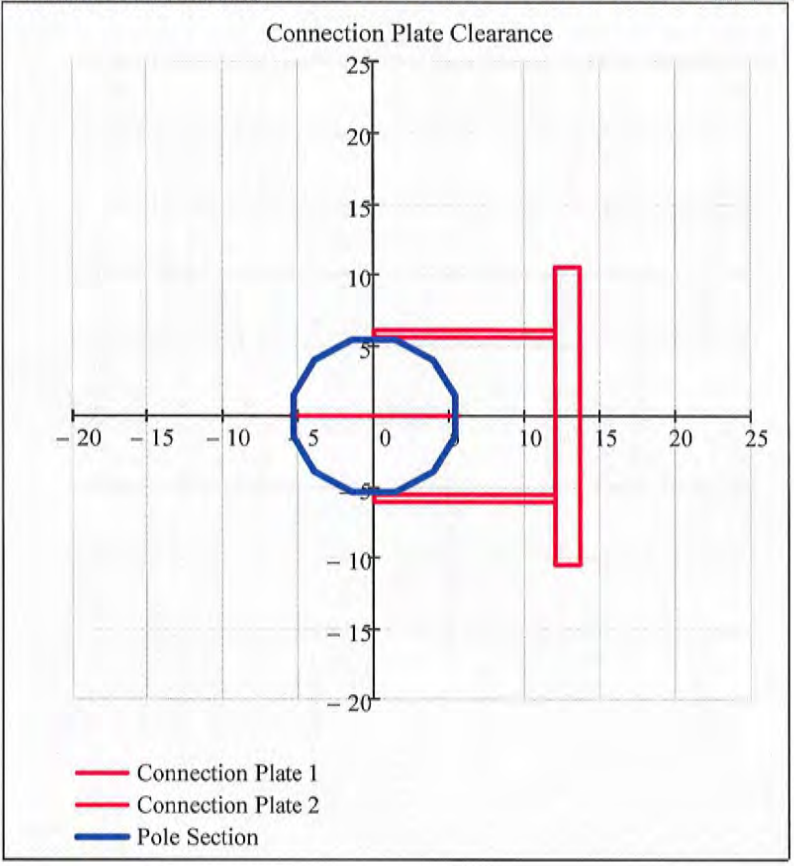
$$x_2 := \left(\mathrm{Offset}_{\mathrm{conn}_1} - t_{\mathrm{conn.plate}_1} - h_{\mathrm{conn.plate}}\cdot\frac{\sin\left(\mathrm{Camber}_{\mathrm{arm2}}\right)}{2}\right)\cdot\cos(\alpha) + \frac{b_{\mathrm{conn.plate}_1}}{2}\cdot\sin(\alpha)$$

$$y_2 := \left(\mathrm{Offset}_{\mathrm{conn}_1} - t_{\mathrm{conn.plate}_1} - h_{\mathrm{conn.plate}}\cdot\frac{\sin\left(\mathrm{Camber}_{\mathrm{arm2}}\right)}{2}\right)\cdot\sin(\alpha) - \frac{b_{\mathrm{conn.plate}_1}}{2}\cdot\cos(\alpha) \qquad x_2 = -0.38\cdot \mathrm{in}\, y_2 = 0\cdot \mathrm{in}$$

$$\mathrm{Clearance} := \sqrt{\left(x_1 - x_2\right)^2 + \left(y_1 - y_2\right)^2} \qquad \mathrm{Clearance} := \mathrm{if}\left[\left(y_2 \le y_1\right),\mathrm{if}\left[\left(x_1 > x_2\right),\mathrm{Clearance},0\cdot \mathrm{in}\right],\mathrm{Clearance}\right] \quad \mathrm{Clearance} = 16.28\cdot \mathrm{in}$$

(if Clearance equals 0, then Connection Plates intersect and redesign is required.

Plan View - Connection Plate Clearance for Two Arm Connections



$\text{Clearance} = 16.28 \cdot \text{in}$

$\text{Diameter}_{\text{conn.pole}} = 11.13 \cdot \text{in}$

$t_{\text{conn.plate}_0} = 1.625 \cdot \text{in}$

$b_{\text{conn.plate}_0} = 21 \cdot \text{in}$

$t_{\text{vertical.plate}_0} = 0.5 \cdot \text{in}$

$\text{Offset}_{\text{conn}_0} = 14.065 \cdot \text{in}$

$\text{Gap}_0 = 8.5 \cdot \text{in}$

$t_{\text{conn.plate}_1} = 0 \cdot \text{in}$

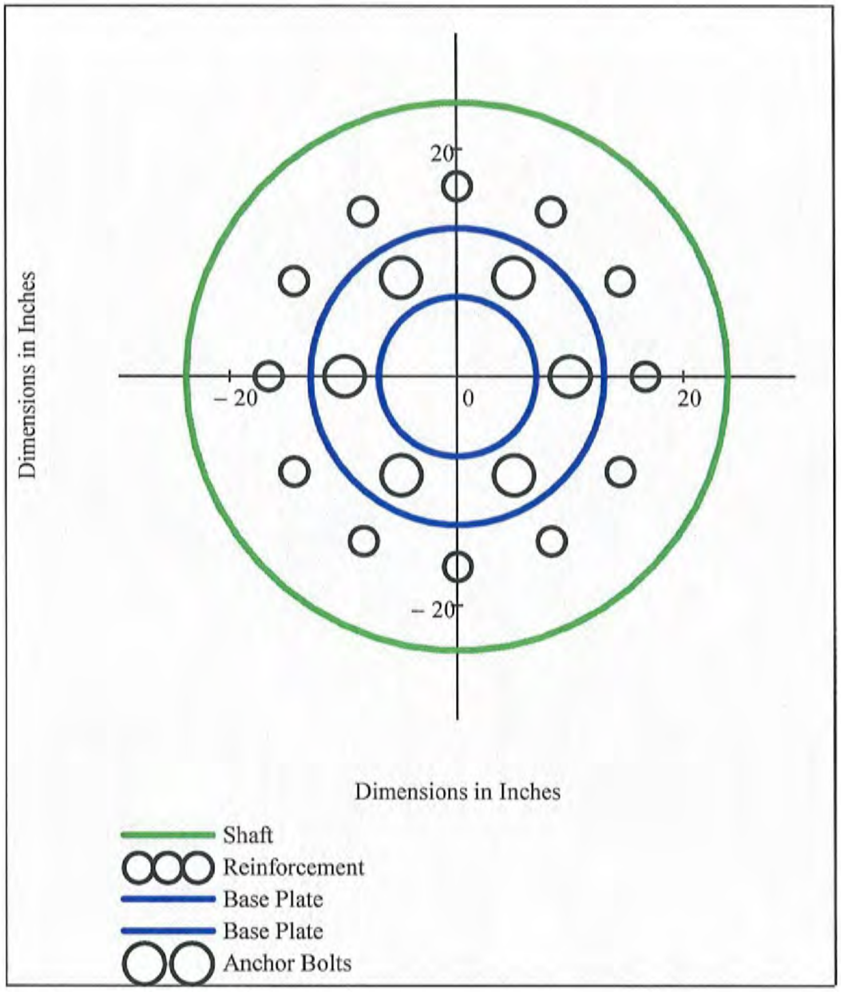
$b_{\text{conn.plate}_1} = 0 \cdot \text{in}$

$t_{\text{vertical.plate}_1} = 0 \cdot \text{in}$

$\text{Offset}_{\text{conn}_1} = 0 \cdot \text{in}$

$\text{Gap}_1 = 0 \cdot \text{in}$

Plan View - Drilled Shaft, Base Plate, Anchor Bolts, & Reinforcing Steel



$\text{Diameter}_{\text{base.pole}} = 14\cdot\text{in}$

$\text{Diameter}_{\text{baseplate.pole}} = 26\cdot\text{in}$

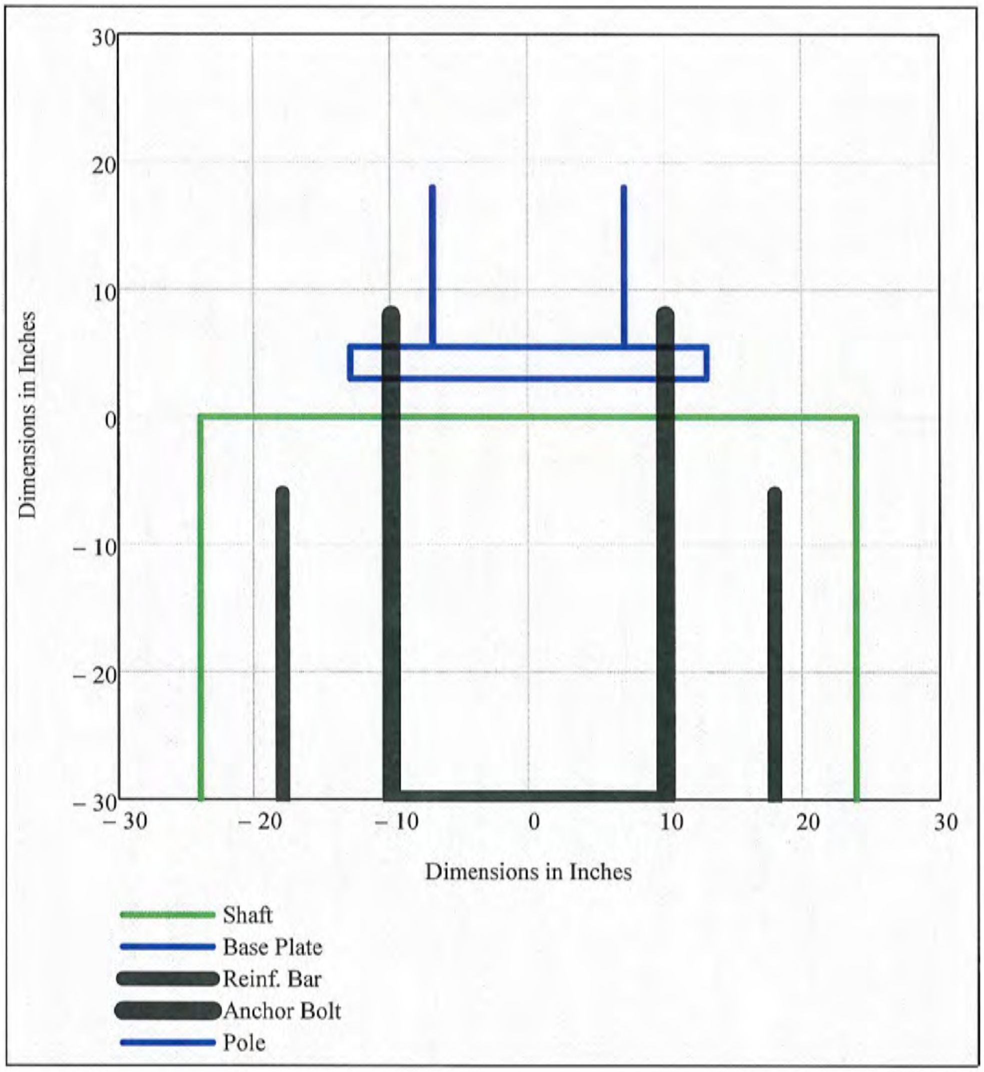
$\text{Diameter}_{\text{shaft}} = 48\cdot\text{in}$

$\text{Diameter}_{\text{boltcircle.pole}} = 20\cdot\text{in}$

$\text{Diameter}_{\text{rebar.circle}} = 33.34\cdot\text{in}$

#AnchorRods = 6

#BarsProvided = 12



$\text{Diameter}_{\text{base.pole}} = 14.00 \cdot \text{in}$

$\text{Diameter}_{\text{baseplate.pole}} = 26.00 \cdot \text{in}$

$t_{\text{baseplate.pole}} = 2.50 \cdot \text{in}$

$\text{Diameter}_{\text{shaft}} = 4.00 \cdot \text{ft}$

$\text{Diameter}_{\text{boltcircle.pole}} = 20.00 \cdot \text{in}$

$\text{Diameter}_{\text{rebar.circle}} = 33.3 \cdot \text{in}$

ID № 4: ES-T3

ID. No 4 : E5-T3

FDOT Mast Arm Analysis Program

Custom File Name (optional) [ ]

The new custom file will be a copy of the last file called from the program. A ".dat" extension will be added to the file name.

Add file to file list [Refresh File List]

Select Data File (required)

E5E2T3
E5E4T4
E5E5T4
E5T23
E5T3
E6E2T4
E6E4T4

All data files are in the same directory as the MastArm.xmcd file.

Path = "J:\00193\00193008.15\DOC\Calcs\ID_N0_4_MastarmV5.02\"

DataFile = "E5T3.dat"

Reference *Changes*

This program works in conjunction with Mastarm Design Standards 17743 and 17745.

References:
AASHTO Standard Specifications for Signs, Luminaires and Traffic Signals, 5th Edition (LTS).
FDOT Structures Manual Vol. 9 (SM V9).

For more information see Reference.xmcd and Changes.xmcd.

▶ Read In Data

General Information DataFile = "E5T3.dat"

Current Values	New Values
Subject = "E5-T3 Mast Arm"	
ProjectNo = "00193008015"	"00193008015"
PoleLocation = "ID No.4"	ID No.4
Date = "12/5/2012"	12/5/2012
DesignedBy = "MAV"	MAV
CheckedBy = "FDOT"	

Use Control+F9 to recalculate the worksheet, once to write out data, twice to read in data

Wind Speed DataFile = "E5T3.dat"

Current Value	New Value		
WindSpeed = 130·mph		*mph*	SM V9 3.8.2

Arm 1 Analysis

DataFile = "E5T3.dat" WindSpeed = 130·mph

Arm 1 Loads

$$\text{SignalData}_{\text{arm1}} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 21 & 3 & \text{"yes"} \\ 2 & 29 & 3 & \text{"yes"} \\ 3 & 40 & 3 & \text{"yes"} \\ 4 & 52 & 5 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values *"yes"or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	21	3	"yes"
2	29	3	"yes"
3	40	3	"yes"
4	52	5	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$\text{SignData}_{\text{arm1}} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 35 & 9 \\ 2 & 44 & 5 \\ 3 & 22 & 1.56 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	35	9
2	44	5
3	22	1.56
4	0	0
5	0	0

use X to zero out data
use 0 to keep current values

Arm 1 Loads

Arm 1 Properties

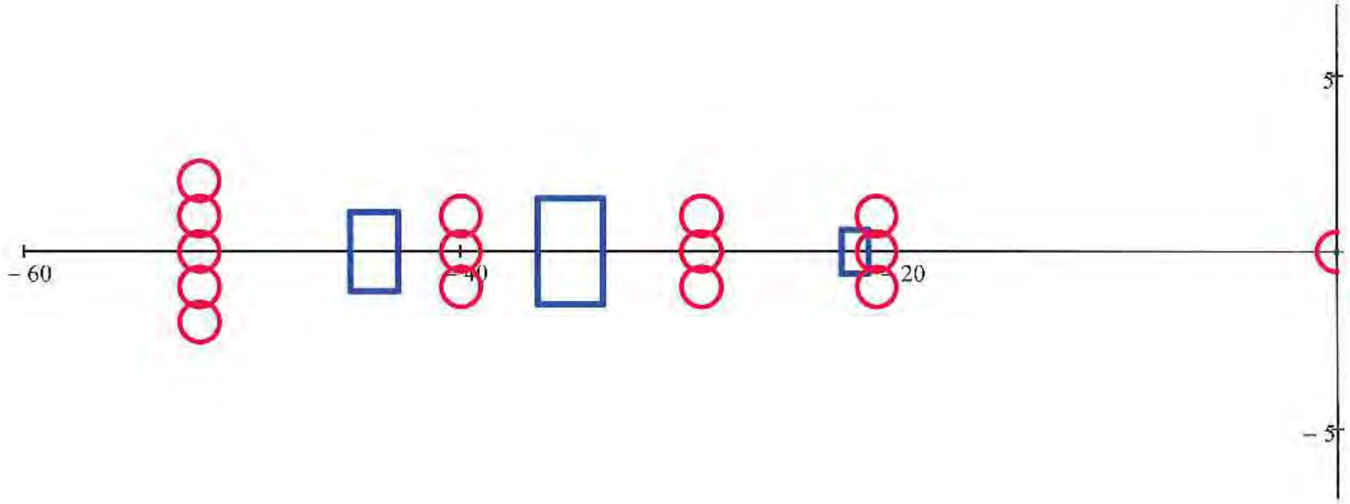
Current Values	New Values	
$L_{total.arm1} = 54\,ft$	54	*feet, 40 ft. max. for 1 piece arms*
$Diameter_{base.arm1} = 14\cdot in$		*inches, measured flat to flat (FG)*
$Dist_{splice.from.base.arm1} = 26\,ft$		*feet, splice distance, for 2 piece arms, length of piece closest to pole, use X to zero out (FE)*
$t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0.375 \end{pmatrix}\cdot in$		*inches, this value is used for one piece arms (FD)*
		inches, for 2 piece arms, wall thickness of piece closest to the pole, use X to zero out (FH)

set $Dist_{splice.from.base.arm1} = 0\,ft$ *for NO SPLICE*

Arm 1 Properties

▶ Analyze Arm 1

Summary - Arm 1 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130\cdot mph$ $L_{total.arm1} = 54.00\,ft$

$Diameter_{tip.arm1} = \begin{pmatrix} 6.94 \\ 10.36 \end{pmatrix}\cdot in$ $Diameter_{base.arm1} = \begin{pmatrix} 11.14 \\ 14.00 \end{pmatrix}\cdot in$ $L_{arm1} = \begin{pmatrix} 30.00 \\ 26.00 \end{pmatrix}ft$ $t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0.375 \end{pmatrix}\cdot in$

$X_{signal.arm1_{i1}} =$ (ft)	$Sections_{signal.arm1_{i1}} =$	$X_{panel.arm1_{j1}} =$ (ft)	$Area_{panel.arm1_{j1}} =$ (ft^2)
21	3	35	9
29	3	44	5
40	3	22	1.56
52	5		

Arm 1 Combined Stress Ratio and Deflection

$max(CSR_{arm1}) = 0.945$ $max(\Delta_{arm1}) = 8.723\cdot in$ $2\cdot deg\cdot\sum(L_{arm1} - L_{splice.provided}) = 21.78\cdot in$

Arm 2 Analysis

DataFile = "E5T3.dat"   WindSpeed = 130·mph

Arm 2 Loads

$$\text{SignalData}_{\text{arm2}} = \begin{pmatrix} \text{"SignalNumber"} & \text{"DistanceToSignal(ft)"} & \text{"NumberOfSignalHeads"} & \text{"BackPlate"} \\ 1 & 0 & 0 & \text{"yes"} \\ 2 & 0 & 0 & \text{"yes"} \\ 3 & 0 & 0 & \text{"yes"} \\ 4 & 0 & 0 & \text{"yes"} \\ 5 & 0 & 0 & \text{"yes"} \\ 6 & 0 & 0 & \text{"yes"} \\ 7 & 0 & 0 & \text{"yes"} \\ 8 & 0 & 0 & \text{"yes"} \\ 9 & 0 & 0 & \text{"yes"} \\ 10 & 0 & 0 & \text{"yes"} \end{pmatrix}$$

use X to zero out data
use 0 to keep current values   *"yes"or "no"*

New Values

"SignalNumber"	"DistToSignal(ft)"	"#SignalHeads"	"BackPlate"
1	0	0	"yes"
2	0	0	"yes"
3	0	0	"yes"
4	0	0	"yes"
5	0	0	"yes"
6	0	0	"yes"
7	0	0	"yes"
8	0	0	"yes"
9	0	0	"yes"
10	0	0	"yes"

$$\text{SignData}_{\text{arm2}} = \begin{pmatrix} \text{"PanelNumber"} & \text{"DistanceToPanelCentroid(ft)"} & \text{"PanelArea(sf)"} \\ 1 & 0 & 0 \\ 2 & 0 & 0 \\ 3 & 0 & 0 \\ 4 & 0 & 0 \\ 5 & 0 & 0 \end{pmatrix}$$

New Values

"Panel#"	"DistToCentroid(ft)"	"PanelArea(sf)"
1	0	0
2	0	0
3	0	0
4	0	0
5	0	0

use X to zero out
use 0 to keep current values

Arm 2 Loads

Arm 2 Properties

Current Values

New Values

$L_{total.arm2} = 0\ ft$

feet, 40 ft. max. for 1 piece arms, use X to zero out *set* $L_{total.arm2} = 0ft$ *for NO ARM2*

$Diameter_{base.arm2} = 0 \cdot in$

inches, measured flat to flat, use X to zero out (SG)

$Dist_{splice.from.base.arm2} = 0 \cdot ft$

feet, splice distance, for 2 piece arms,
length of piece closest to pole,
use X to zero out (SE)

set $Dist_{splice.from.base.arm2} = 0ft$
for NO SPLICE

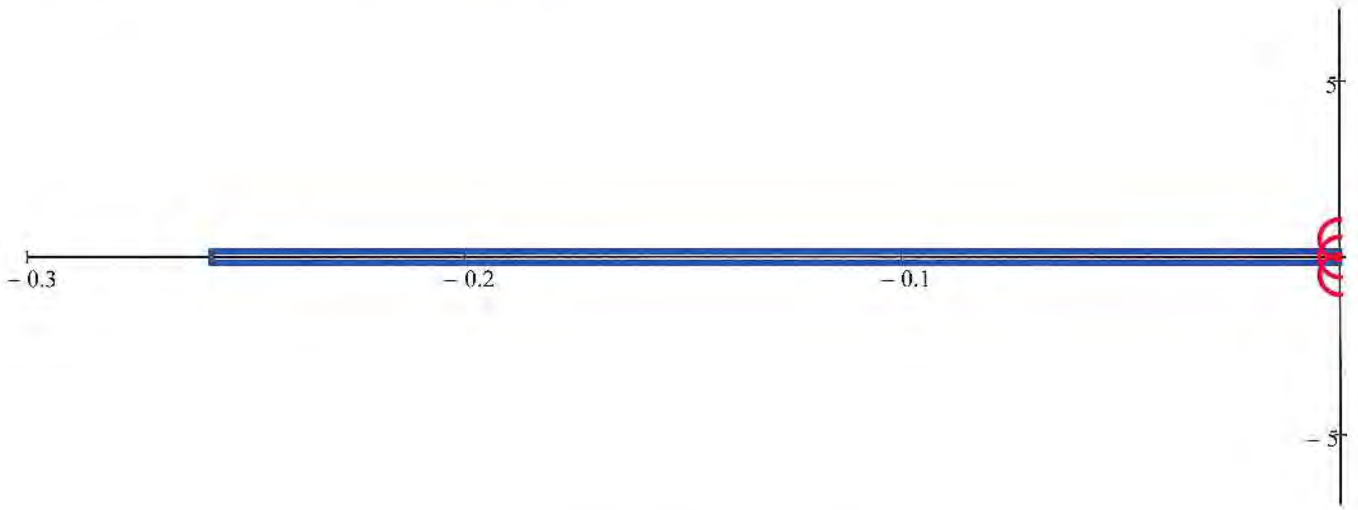
$t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

inches, use X to zero out (SD)

inches, for 2 piece arms, wall thickness of piece closest to the pole,
use X to zero out (SH)

Arm 2 Properties

Summary - Arm 2 Geometry and Loading



Location of Signs and Signals

$WindSpeed = 130 \cdot mph$ $L_{total.arm2} = 0.00\ ft$

$Diameter_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $Diameter_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} ft$ $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

$X_{signal.arm2_{i2}} = \begin{array}{|c|} \hline 0 \\ \hline 0 \\ \hline \end{array}\ ft$ $Sections_{signal.arm2_{i2}} = \begin{array}{|c|} \hline 0 \\ \hline 0 \\ \hline \end{array}$ $X_{panel.arm2_{j2}} = \boxed{0.1}\ ft$ $Area_{panel.arm2_{j2}} = \boxed{0.1}\ ft^2$

Arm 2 Combined Stress Ratio and Deflection

$\max(CSR_{arm2}) = 0$ $\max(\Delta_{arm2}) = 0 \cdot in$ $2 \cdot deg \cdot \sum (L_{arm2} - L_{splice.provided}) = -1.68 \cdot in$

Luminaire Arm Analysis   DataFile = "E5T3.dat"   WindSpeed = 130·mph

Luminaire Properties

See Design Standards 17743 and 17745 for input values.

Current Values	New Values	*set* $Y_{luminaire} = 0ft$ *for NO LUMINAIRE*
$Y_{luminaire} = 0\ ft$	☐	*feet, use X to zero out (Standard LA = 40 feet)*
$X_{luminaire} = 10 \cdot ft$	☐	*feet, use X to zero out (Standard LB = 10 feet)*
$Diameter_{base.lumarm} = 3 \cdot in$	☐	*inches, use X to zero out (Standard LC = 3 inches)*
$t_{wall.lumarm} = 0.125 \cdot in$	☐	*inches, use X to zero out (Standard LD = 0.125 inches)*
$Slope_{lumarm} = 0.5$	☐	*rise/run, use X to zero out (Standard LE = 0.5)*
$r_{lumarm} = 8 \cdot ft$	☐	*feet, use X to zero out (Standard LF = 8 feet)*
$d_{bolt.lum} = 0.5 \cdot in$	☐	*inches, use X to zero out (Standard LG = 0.5 inches)*
$t_{baseplate.lum} = 0.75 \cdot in$	☐	*inches, use X to zero out (Standard LH = 0.75 inches)*

Luminaire Properties

▶ Analyze Luminaire

Summary - Luminaire Arm Geometry

$Y_{luminaire} = 0\ ft$ $X_{luminaire} = 0 \cdot ft$ $Diameter_{base.lumarm} = 0 \cdot in$ $t_{wall.lumarm} = 0 \cdot in$

$Slope_{lumarm} = 0$ $r_{lumarm} = 0 \cdot ft$ $d_{bolt.lum} = 0 \cdot in$ $t_{baseplate.lum} = 0 \cdot in$

$w_{base.lum} = 0 \cdot in$ $w_{channel.lum} = 0 \cdot in$

Luminaire Arm Ratios

$CSR_{base.lumarm} = 0$ $PR_{bolt.lum} = 0$ $PR_{baseplate.lum} = 0$ $PR_{conn.plate.lum} = 0$

Upright Analysis

DataFile = "E5T3.dat" WindSpeed = 130·mph

Pole Properties

Current Values

$Y_{pole} = 22\,ft$

$Y_{arm.conn} = 20.5\,ft$

$Diameter_{base.pole} = 19 \cdot in$

$t_{wall.pole} = 0.375 \cdot in$

$Gap = \begin{pmatrix} 11.5 \\ 0 \end{pmatrix} \cdot in$

New Values

22 *feet (UA)*

20.5 *feet (UB)*

inches, measured flat to flat (UD)

inches (UE)

inches, clear distance between connection plate and upright

inches, use X to zero out

Common wall thicknesses:
0.1793 in.
0.2391 in.
0.25 in.
0.313 in.
0.375 in.
0.5 in.

Pole Properties

Summary - Upright Geometry

$Y_{pole} = 22\,ft$ $Y_{arm.conn} = 20.5\,ft$ $\alpha = 0 \cdot deg$ $Gap = \begin{pmatrix} 11.5 \\ 0 \end{pmatrix} \cdot in$

$Diameter_{tip.pole} = 15.92 \cdot in$ $Diameter_{base.pole} = 19 \cdot in$ $t_{wall.pole} = 0.375 \cdot in$

Upright Combined Stress Ratio and Deflections

$\max(CSR_{pole}) = 0.689$ $\max(\Delta_{x.dl}) = 0.88 \cdot in$ $\max(\Delta_{z.dl}) = 0 \cdot in$

Mast Arm Connection(s) Analysis

DataFile = "E5T3.dat" WindSpeed = $130 \cdot mph$

Connection Properties

Current Values

$h_{conn.plate} = 30 \cdot in$

$t_{vertical.plate} = \begin{pmatrix} 0.75 \\ 0 \end{pmatrix} \cdot in$

$d_{bolt.conn} = \begin{pmatrix} 1.25 \\ 0 \end{pmatrix} \cdot in$

$t_{baseplate.arm} = \begin{pmatrix} 2.75 \\ 0 \end{pmatrix} \cdot in$

Connection Properties

New Values

☐ *inches, for two arm Mast Arms both connection plate heights must be equal (HT)*

☐ *inches (FL)*

☐ *inches, use X to zero out (SL)*

☐ *inches (FP)*

☐ *inches, use X to zero out (SP)*

☐ *inches (FK)*

☐ *inches, use X to zero out (SK)*

Summary - Connection Geometry

$h_{conn.plate} = 30 \cdot in$

$Gap = \begin{pmatrix} 11.5 \\ 0 \end{pmatrix} \cdot in$

$Offset_{conn} = \begin{pmatrix} 19.565 \\ 0 \end{pmatrix} \cdot in$

$d_{bolt.conn} = \begin{pmatrix} 1.25 \\ 0 \end{pmatrix} \cdot in$

$\#ConnBolts = \begin{pmatrix} 6 \\ 0 \end{pmatrix}$

$Spacing_{bolts.conn} = \begin{pmatrix} 12.5 \\ 0 \end{pmatrix} \cdot in$

$t_{conn.plate} = \begin{pmatrix} 1.625 \\ 0 \end{pmatrix} \cdot in$

$b_{conn.plate} = \begin{pmatrix} 28 \\ 0 \end{pmatrix} \cdot in$

$t_{vertical.plate} = \begin{pmatrix} 0.75 \\ 0 \end{pmatrix} \cdot in$

$t_{baseplate.arm} = \begin{pmatrix} 2.75 \\ 0 \end{pmatrix} \cdot in$

$w_{conn.plate} = \begin{pmatrix} 0.3125 \\ 0 \end{pmatrix} \cdot in$

$w_{vertical.plate} = \begin{pmatrix} 0.3125 \\ 0 \end{pmatrix} \cdot in$

Connection Ratios

$PR_{bolt} = \begin{pmatrix} 0.547 \\ 0 \end{pmatrix}$

$CSR_{t.vert.plate} = \begin{pmatrix} 0.442 \\ 0 \end{pmatrix}$

$PR_{t.baseplate.arm} = \begin{pmatrix} 0.759 \\ 0 \end{pmatrix}$

$PR_{t.connplate.arm} = \begin{pmatrix} 0.993 \\ 0 \end{pmatrix}$

Base Plate Analysis

DataFile = "E5T3.dat" WindSpeed = $130 \cdot mph$

Base Plate Properties

Current Values

New Values

#AnchorRods = 6 ☐ *use 6 bolts minimum*

$d_{bolt.pole} = 2 \cdot in$ ☐ *inches (BC)*

Base Plate Properties

Summary - Upright Base Plate Geometry

#AnchorRods = 6 $d_{bolt.pole} = 2 \cdot in$ $t_{baseplate.pole} = 2.5 \cdot in$ $Diameter_{baseplate.pole} = 35 \cdot in$

Upright Base Plate Performance Ratios

$PR_{rod} = 0.405$ $PR_{plate.pole} = 1$

Foundation Analysis Cohesionless or Cohesive Soil

DataFile = "E5T3.dat"

Soil Properties

Current Values

New Values

○ Clay

SoilType = 1 ● Sand *0 - clay 1 - sand*

$\phi_{soil} = 28 \cdot deg$ 28 *degrees, soil friction angle (sand)*

$c_{soil} = 2000 \cdot psf$ ☐ *psf, soil shear strength (clay)*

$\gamma_{soil.dry} = 100 \cdot pcf$ 100 *pcf, dry soil weight*

$\gamma_{water} = 62.4 \cdot pcf$ ☐ *pcf, water weight (zero if no water)*

$\gamma_{soil} := \gamma_{soil.dry} - \gamma_{water}$ $\gamma_{soil} = 37.60 \cdot pcf$

Soil Properties

Analyze Foundation

Switch values, set values for DataOut, and Write Out Data to DataFile and Temp.dat

out := out + 1 out = 35.00

SoilType := if(newSoilType = 0, 0, 1) $data_{out} := SoilType$ $data_{out} = 1.00$

$out := out + 1 \quad out = 36.00$

$\phi_{soil} := fSwitchData(\phi_{soil}, new\phi_{soil}, deg)$ $\quad data_{out} := \frac{\phi_{soil}}{deg} \quad data_{out} = 28$

$out := out + 1 \quad out = 37.00$

$c_{soil} := fSwitchData(c_{soil}, newc_{soil}, psf)$ $\quad data_{out} := \frac{c_{soil}}{psf} \quad data_{out} = 2000$

$out := out + 1 \quad out = 38.00$

$\gamma_{soil.dry} := fSwitchData(\gamma_{soil.dry}, new\gamma_{soil.dry}, pcf)$ $\quad data_{out} := \frac{\gamma_{soil.dry}}{pcf} \quad data_{out} = 100.00$

$out := out + 1 \quad out = 39.00$

$\gamma_{water} := fSwitchData(\gamma_{water}, new\gamma_{water}, pcf)$ $\quad data_{out} := \frac{\gamma_{water}}{pcf} \quad data_{out} = 62.40$

$out := out + 1 \quad out = 40.00$

Subject := if(**newSubject** = 0, **Subject**, **newSubject**) $\quad data_{out} :=$ **Subject**

$data_{out} =$ "E5-T3 Mast Arm"

$out := out + 1 \quad out = 41.00$

ProjectNo := if(**newProjectNumber** = 0, **ProjectNo**, **newProjectNumber**) $\quad data_{out} :=$ **ProjectNo**

$data_{out} =$ "00193008015"

$out := out + 1 \quad out = 42.00$

PoleLocation := if(**newPoleLocation** = 0, **PoleLocation**, **newPoleLocation**) $\quad data_{out} :=$ **PoleLocation**

$data_{out} =$ "ID No.4"

$out := out + 1 \quad out = 43.00$

Date := if(**newDate** = 0, **Date**, **newDate**) $\quad data_{out} :=$ **Date**

$data_{out} =$ "12/5/2012"

$out := out + 1 \quad out = 44.00$

DesignedBy := if(**newDesignedBy** = 0, **DesignedBy**, **newDesignedBy**) $\quad data_{out} :=$ **DesignedBy**

$data_{out} =$ "MAV"

$out := out + 1 \quad out = 45.00$

CheckedBy := if(**newCheckedBy** = 0, **CheckedBy**, **newCheckedBy**) $\quad data_{out} :=$ **CheckedBy**

$data_{out} =$ "FDOT"

WRITEPRN(DataFile) := data   WRITEPRN("temp.dat") := data

Foundation Design References

LRFD = AASHTO LRFD Bridge Design Specifications

SM V9 = FDOT Structures Manual Volume 9

SDG = FDOT Structures Design Guidelines

Spec = FDOT Standard Specifications

ACI = ACI 318 Structural Concrete Building Code

UF Report = FDOT/University of Florida Report BD545 RPWO #54

Applied Loads

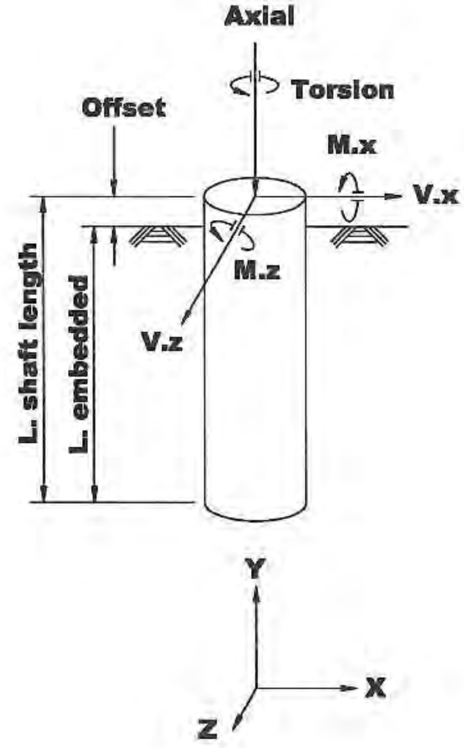
(From Arm1 Design)

$\text{WindSpeed} = 130.00 \cdot \text{mph}$

(from Base Plate Design)

$\#\text{AnchorRods} = 6.00$ $\quad d_{bolt.pole} = 2.00 \cdot \text{in}$ $\quad \text{Diameter}_{boltcircle.pole} = 27 \cdot \text{in}$ $\quad T_{u,rod} = 39.3 \cdot \text{kip}$

(from Upright Design)



$$M_{x.polebase} = \begin{pmatrix} 0 \\ 117.6 \\ 117.6 \end{pmatrix} \cdot \text{kip} \cdot \text{ft} \quad M_{y.polebase} = \begin{pmatrix} 176.9 \\ 0 \\ 176.9 \end{pmatrix} \cdot \text{kip} \cdot \text{ft} \quad M_{z.polebase} = \begin{pmatrix} 0 \\ 60.2 \\ 60.2 \end{pmatrix} \cdot \text{kip} \cdot \text{ft}$$

LoadCaseT = 0.00

LoadCaseOT = 1.00

LoadCaseCSR = 2.00

$$V_{x.polebase} = \begin{pmatrix} 0 \\ 0.2 \\ 0.2 \end{pmatrix} \cdot \text{kip} \quad \text{AxialForce}_{polebase} = \begin{pmatrix} 3.8 \\ 3.8 \\ 3.8 \end{pmatrix} \cdot \text{kip} \quad V_{z.polebase} = \begin{pmatrix} 0 \\ 6.3 \\ 6.3 \end{pmatrix} \cdot \text{kip}$$

Foundation Diameter

$Diameter_{shaft} := Diameter_{boltcircle.pole} + 12\cdot in + 12\cdot in$ $\qquad Diameter_{shaft} = 4.25\cdot ft$

round shaft diameter up to the nearest half foot dimension to accommodate available coring equipment

$Diameter_{shaft} := Ceil\left(Diameter_{shaft}, \frac{1}{2}\cdot ft\right)$ $\qquad Diameter_{shaft} = 4.50\,ft$

$b := Diameter_{shaft}$

Shaft Depth Required to Resist Overturning

$SF_{ot} := 2$ *Safety Factor against Overturning* SM V9 13.6 $\qquad Offset := 1.0\cdot ft$ *vertical distance between top of foundation and groundline*

$$M_{total} := SF_{ot}\cdot\frac{\sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2}}{C_{a.pole}} \qquad M_{total} = 265\cdot kip\cdot ft$$

$$P_{total} := SF_{ot}\cdot\sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2} \qquad P_{total} = 12.5\cdot kip$$

short free-head pile in cohesionless soil using Broms method

$K_p := \tan\left(45\cdot deg + \frac{\phi_{soil}}{2}\right)^2$ $\qquad e_{sand} := Offset$

Guess value $\qquad L_{otSand} := 8\cdot ft$

Given $\qquad \frac{\gamma_{soil}\cdot b\cdot L_{otSand}^{\ 3}\cdot K_p}{2} - P_{total}\cdot\left(e_{sand} + L_{otSand}\right) - M_{total} = 0\cdot kip\cdot ft$

$Temp := Find\left(L_{otSand}\right)$ $\qquad L_{otSand} := Temp$ $\qquad L_{otSand} = 12.25\cdot ft$

(round up to next foot) $\qquad L_{otSand} := ceil\left(\frac{L_{otSand}}{ft}\right)\cdot ft$ $\qquad L_{otSand} = 13.00\,ft$

$$PR_{otSand} := \frac{M_{total} + P_{total}\cdot\left(e_{sand} + L_{otSand}\right)}{\frac{\gamma_{soil}\cdot b\cdot L_{otSand}^{\ 3}\cdot K_p}{2}} \qquad PR_{otSand} = 0.86$$

short free-head pile in <u>cohesive soil</u> using Modified Broms method for L < 3b (see reference file for derivation)

$c_{soil} := \text{if}(c_{soil} = 0 \cdot ksf, 0.1 \cdot ksf, c_{soil})$ $\quad$ $Slope := 8 \cdot \frac{c_{soil}}{3 \cdot b}$ $\quad$ $e_{clay} := \frac{M_{total}}{P_{total}} + Offset$

$nforce(M,N) := \left[Slope \cdot (2 \cdot M + N) + 2 \cdot c_{soil}\right] \cdot N \cdot \frac{b}{2}$ $\quad$ $mforce(M) := \left(2 \cdot c_{soil} + M \cdot Slope\right) \cdot M \cdot \frac{b}{2}$

$$m\_arm(M) := e_{clay} + \frac{M}{3} \cdot \frac{2 \cdot \left(M \cdot Slope + c_{soil}\right) + c_{soil}}{M \cdot Slope + 2 \cdot c_{soil}}$$

$$n\_arm(M,N) := e_{clay} + M + \frac{N}{3} \cdot \frac{2 \cdot \left(N \cdot Slope + M \cdot Slope + c_{soil}\right) + \left(M \cdot Slope + c_{soil}\right)}{Slope \cdot (2 \cdot M + N) + 2 \cdot c_{soil}}$$

Guess value $\quad M := 4.0 \cdot ft \quad N := 4.0 \cdot ft$

Given $\quad P_{total} + nforce(M,N) = mforce(M) \quad mforce(M) \cdot m\_arm(M) = nforce(M,N) \cdot n\_arm(M,N)$

$\begin{pmatrix} M \\ N \end{pmatrix} := Find(M,N)$ $\quad$ $L_{ot1Clay.temp} := M + N$ $\quad$ $L_{ot1Clay.temp} = 7.31 \cdot ft$

(round up to next foot) $\quad L_{ot1Clay} := ceil\left(\frac{L_{ot1Clay.temp}}{ft}\right) \cdot ft \quad L_{ot1Clay} = 8.00 \cdot ft$

short free-head pile in <u>cohesive soil</u> using Regular Broms method for L > 3b

$f_{clay} := \frac{P_{total}}{9 \cdot c_{soil} \cdot b}$ $\quad$ $M_{maxtemp} := P_{total} \cdot \left(e_{clay} + 1.5 \cdot b + 0.5 \cdot f_{clay}\right)$ $\quad$ $g := \sqrt{\frac{M_{maxtemp}}{2.25 \cdot c_{soil} \cdot b}}$

$L_{ot2Clay} := \left(1.5 \cdot b + f_{clay} + g\right)$ $\quad$ $L_{ot2Clay} = 11.14 ft$

(round up to next foot) $\quad L_{ot2Clay} := ceil\left(\frac{L_{ot2Clay}}{ft}\right) \cdot ft \quad L_{ot2Clay} = 12.00 \cdot ft$

$L_{otClay} := \text{if}\left(L_{ot1Clay} < 3 \cdot b, L_{ot1Clay}, L_{ot2Clay}\right)$ $\quad$ $L_{otClay} = 8.00 \cdot ft$

(If L_{ot} < 3b, use Modified Broms method)

$$PR_{otClay} := \mathrm{if}\left(L_{otClay} < 3\cdot b, \frac{L_{ot1Clay.temp}}{L_{ot1Clay}}, \frac{\sqrt{\frac{M_{maxtemp}}{2.25\cdot c_{soil}\cdot b} + \frac{P_{total}}{9\cdot c_{soil}\cdot b}}}{L_{ot2Clay} - 1.5\cdot b}\right) \qquad PR_{otClay} = 0.91$$

$$L_{reqdOT} := \mathrm{if}\left(\mathrm{SoilType} = 1, L_{otSand}, L_{otClay}\right) \qquad L_{reqdOT} = 13.00\,\mathrm{ft}$$

$$PR_{ot} := \mathrm{if}\left(\mathrm{SoilType} = 1, PR_{otSand}, PR_{otClay}\right) \qquad PR_{ot} = 0.86$$

Shaft Depth Required to Resist Torsion

$SF_{tor} := \mathbf{1.0}$ *Safety Factor against Torsion*
1.0 for Mast Arm signal structures
SM V9 13.6

*NOTE: ω_{fdot} and μ are based upon CONCRETE and soil interaction. **This torsion methodology is not to be used with permanent casing.***

$N_{blows} := 15$ *Number of blows per foot. If N< 5, contact the district geotech Engineer*

$$\omega_{fdot} := \mathrm{if}\left(N_{blows} < 5, 0, \mathrm{if}\left(N_{blows} \geq 15, 1.5, 1.5\cdot\frac{N_{blows}}{15}\right)\right) = 1.50$$ *load transfer ratio*

$\mu := \tan(\phi_{soil}) = 0.53$ *coefficient of friction between concrete shaft and soil*

$\gamma_{concrete} := 150\cdot \mathrm{pcf}$ $\quad \gamma_{concrete} := \gamma_{concrete} - \gamma_{water}$ $\quad \gamma_{concrete} = 87.60\cdot \mathrm{pcf}$

$\mathrm{CohesionFactor} := 0.55$ $\quad f_{sc} := \mathrm{CohesionFactor}\cdot c_{soil}$

$\mathrm{Torsion} := SF_{tor}\cdot {M_{y.polebase}}_{LoadCaseT}$ $\quad \mathrm{Torsion} = 176.9\cdot \mathrm{kip}\cdot \mathrm{ft}$

short free-head pile in cohesionless soil

Guess value $\quad L_{torSand} := L_{reqdOT}$

Given

$$\mathrm{Torsion} = \frac{\left[\pi\cdot b\cdot\left(L_{torSand}\right)\cdot\gamma_{soil}\cdot\left(\frac{L_{torSand}}{2}\right)\cdot\left(\omega_{fdot}\right)\cdot\frac{b}{2} + \pi\cdot\left(\frac{b}{2}\right)^2\cdot L_{torSand}\cdot\left(\gamma_{concrete}\right)\cdot\frac{b}{3}\cdot\mu\right]}{SF_{tor}}$$

$\mathrm{Temp} := \mathrm{Find}\left(L_{torSand}\right)$ $\quad L_{torSand} := \mathrm{Temp}$ $\quad L_{torSand} = 13.4\,\mathrm{ft}$

(round up to next foot) $\quad L_{torSand} := \mathrm{ceil}\left(\frac{L_{torSand}}{\mathrm{ft}}\right)\cdot \mathrm{ft}$ $\quad L_{torSand} = 14.00\,\mathrm{ft}$

$$PR_{torSand} := \frac{\mathrm{Torsion}\cdot SF_{tor}}{\pi\cdot b\cdot\left(L_{torSand}\right)\cdot\gamma_{soil}\cdot\left(\frac{L_{torSand}}{2}\right)\cdot\left(\omega_{fdot}\right)\cdot\frac{b}{2} + \pi\cdot\left(\frac{b}{2}\right)^2\cdot L_{torSand}\cdot\left(\gamma_{concrete}\right)\cdot\frac{b}{3}\cdot\mu} \qquad PR_{torSand} = 0.92$$

short free-head pile in <u>cohesive soil</u>

Guess value $L_{torClay} := L_{reqdOT}$

Given $\left[f_{se}\cdot(\pi\cdot b)\cdot\left(L_{torClay} - 1.5\cdot ft\right)\cdot\frac{b}{2}\right] + \left[f_{se}\cdot\pi\cdot\left(\frac{b}{2}\right)^2\cdot\left(\frac{b}{3}\right)\right] = Torsion\cdot SF_{tor}$

$Temp := Find\left(L_{torClay}\right)$ $L_{torClay} := Temp$ $L_{torClay} = 5.81\,ft$

(round up to next foot) $L_{torClay} := ceil\left(\frac{L_{torClay}}{ft}\right)\cdot ft$ $L_{torClay} = 6.00\,ft$

$$PR_{torClay} := \frac{Torsion\cdot SF_{tor}}{\left[f_{se}\cdot(\pi\cdot b)\cdot\left(L_{torClay} - 1.5\cdot ft\right)\cdot\frac{b}{2}\right] + \left[f_{se}\cdot\pi\cdot\left(\frac{b}{2}\right)^2\cdot\left(\frac{b}{3}\right)\right]}$$ $PR_{torClay} = 0.96$

$L_{reqdTor} := if\left(SoilType = 1, L_{torSand}, L_{torClay}\right)$ $L_{reqdTor} = 14.00\,ft$

$PR_{tor} := if\left(SoilType = 1, PR_{torSand}, PR_{torClay}\right)$ $PR_{tor} = 0.92$

$L_{embedded} := if\left(L_{reqdTor} > L_{reqdOT}, L_{reqdTor}, L_{reqdOT}\right)$ $L_{embedded} = 14.00\,ft$

$L_{shaft} := L_{embedded} + Offset$ $L_{shaft} = 15.00\,ft$

$PR_{foundation} := if\left(L_{reqdTor} > L_{reqdOT}, PR_{tor}, PR_{ot}\right)$ $PR_{foundation} = 0.92$

Unfactored Maximum Moment in Shaft

short free-head pile in <u>cohesionless soil</u> using Broms method

$$f_{sand} := \sqrt{\frac{2\cdot\frac{P_{total}}{SF_{ot}}}{3\cdot\gamma_{soil}\cdot b\cdot K_p}}$$ $f_{sand} = 2.98\,ft$

$$M_{maxSand} := \frac{P_{total}}{SF_{ot}}\cdot\left(e_{sand} + f_{sand}\right) - \frac{\frac{P_{total}}{SF_{ot}}\cdot f_{sand}}{3} + \frac{M_{total}}{SF_{ot}}$$ $M_{maxSand} = 151.2\cdot kip\cdot ft$

short free-head pile in <u>cohesive soil</u> using Modified Broms method for L < 3b (see reference file for derivation)

Guess value $f_{mod} := 4.0\cdot ft$

Given $\frac{P_{total}}{SF_{ot}} = \frac{f_{mod}\cdot b}{2}\cdot\left(2\cdot c_{soil} + f_{mod}\cdot Slope\right)$

$f_{mod} := Find\left(f_{mod}\right)$ $f_{mod} = 0.59\,ft$

$M_{modBroms} := \frac{P_{total}}{SF_{ot}} \cdot (e_{clay} + f_{mod}) - \frac{c_{soil} \cdot b \cdot f_{mod}^{2}}{2} - \frac{b \cdot f_{mod}^{3} \cdot Slope}{6}$ $M_{modBroms} = 140.7 \cdot kip \cdot ft$

short free-head pile in <u>cohesive soil</u> using Regular Broms method for L > 3b

$M_{Broms} := \frac{P_{total}}{SF_{ot}} \cdot (e_{clay} + 1.5 \cdot b + 0.5 \cdot f_{clay})$ $M_{Broms} = 181.5 \cdot kip \cdot ft$

$M_{maxClay} := if(L_{ot1Clay} < 3 \cdot b, M_{modBroms}, M_{Broms})$ $M_{maxClay} = 140.7 \cdot kip \cdot ft$

(If $L_{ot} < 3b$, use Modified Broms method)

$M_{max} := if(SoilType = 1, M_{maxSand}, M_{maxClay})$ *(this is a Service moment)* $M_{max} = 151.2 \cdot kip \cdot ft$

Minimum Reinforcing and Spacing

$F_{y.rebar} := 60 \cdot ksi$ *reinforcing yield strength*

$f_c := 4.0 \cdot ksi$ *concrete strength* ***<u>Spec 346-3</u>***

$cover := 6 \cdot in$ *cover* ***<u>SDG Table 1.4.2-1</u>***

$A_{bar} := 1.56 \cdot in^2$ *longitudinal bar area*

$d_{bar} := 1.41 \cdot in$ *longitudinal bar diameter*

$A_{v.bar} := 0.31 \cdot in^2$ *stirrup area* ***<u>SM V9 13.6.2</u>***

$d_{v.bar} := 0.625 \cdot in$ *stirrup diameter*

$s_{v1} := 4 \cdot in$ *stirrup spacing, depth = 0 ft-2 ft* ***<u>SM V9 13.6.2</u>***

$s_{v2} := 9 \cdot in$ *stirrup spacing, depth = 2 ft-depth.stir*

$s_{v3} := 12 \cdot in$ *stirrup spacing, depth > depth.stir*

$depth_{stir} := 11 \cdot ft$ *stirrup depth, see s.v2 and s.v3 above*

$b = 4.50\, ft$ *shaft diameter*

$BarsProv_1 := \frac{0.01}{A_{bar}} \cdot \frac{\pi \cdot b^2}{4}$ $BarsProv_1 = 14.68$ ***<u>LRFD 5.7.4.2</u>***

$\text{BarsProv}_2 := \dfrac{0.135}{A_{bar} \cdot F_{y.rebar}} \cdot \left(\dfrac{\pi \cdot b^2}{4} \cdot f_c \right)$ $\text{BarsProv}_2 = 13.21$

$\text{BarsProv} := \text{ceil}\left(\max\left(\text{BarsProv}_1, \text{BarsProv}_2\right)\right)$ $\text{BarsProv} = 15.00$ *number of longitudinal bars*

$\text{NumSpaces}_{v.bar} := \text{round}\left(\dfrac{\text{depth}_{stir} - 2 \cdot \text{ft}}{s_{v2}} \right)$ $\text{NumSpaces}_{v.bar} = 12.00$

$\text{ReinfClearSpacing} := \left[b - 2 \cdot \left(\text{cover} + d_{v.bar} + \dfrac{d_{bar}}{2} \right) \right] \cdot \dfrac{\pi}{\text{BarsProv}} - d_{bar}$ $\text{ReinfClearSpacing} = 6.83 \cdot \text{in}$

CheckReinfClearSpacing := if(ReinfClearSpacing ≥ 6in, "OK" , "No Good") CheckReinfClearSpacing = "OK"

SDG 3.6.10

Check Shear and Torsion

$LF_{shr} := \mathbf{1.3}$ *Shear Load Factor* *1.3 is a reasonable Load Factor for combined WL + DL on sign and signal structures*

$LF_{tor} := \mathbf{1.3}$ *Torsion Load Factor*

$\phi_{shr} := \mathbf{0.90}$ *Shear Resistance Factor* ***LRFD 5.5.4.2.1***

$\phi_{tor} := \mathbf{0.90}$ *Torsion Resistance Factor* ***LRFD 5.5.4.2.1***

$V_u := LF_{shr} \cdot \sqrt{\left(V_{x.polebase_{LoadCaseOT}}\right)^2 + \left(V_{z.polebase_{LoadCaseOT}}\right)^2}$ $V_u = 8.1 \cdot \text{kip}$

$T_u := LF_{tor} \cdot \text{Torsion}$ $T_u = 229.96 \cdot \text{kip} \cdot \text{ft}$

Area and perimeter of concrete cross-section

$A_{cp} := \pi \cdot \left(\dfrac{b}{2} \right)^2$ $A_{cp} = 2290.2 \cdot \text{in}^2$

$p_{cp} := 2 \cdot \pi \cdot \left(\dfrac{b}{2} \right)$ $p_{cp} = 169.6 \cdot \text{in}$

Diameter, perimeter and area enclosed by the centerline of the outermost closed transverse torsion reinforcement

$d_{oh} := b - 2 \cdot \left(\text{cover} + \dfrac{d_{v.bar}}{2} \right)$ $d_{oh} = 41.4 \cdot \text{in}$

$p_h := \pi \cdot d_{oh}$ $p_h = 130 \cdot \text{in}$

$A_{oh} := \pi \left(\dfrac{d_{oh}}{2} \right)^2$ $A_{oh} = 1344.5 \cdot \text{in}^2$

$A_o := 0.85 \cdot A_{oh}$ $A_o = 1142.8 \cdot \text{in}^2$ ***LRFD C5.8.2.1***

Effective shear depth

$D_r := b - 2\cdot\left(cover + d_{v.bar} + \frac{d_{bar}}{2}\right)$ $\qquad d_e := \frac{b}{2} + \frac{D_r}{\pi} = 3.29\,\text{ft}$

LRFD C5.8.2.1

$d_v := \max\left(0.9\cdot d_e, 0.72\cdot b\right) = 3.24\,\text{ft}$

Check Shear Strength

$V_c := 0.0316\cdot(2.0)\cdot\sqrt{\frac{f_c}{ksi}}\cdot\left(\frac{d_v}{in}\right)\cdot\left(\frac{b}{in}\right)\cdot kip$ $\qquad V_c = 265.4\cdot kip$

LRFD Eqn 5.8.3.3-3

LRFD 5.8.3.4.1

ACI 11.3.3

$V_s := \frac{A_{v.bar}\cdot F_{y.rebar}\cdot\left(d_v\right)}{\max\left(s_{v1}, s_{v2}, s_{v3}\right)}$ $\qquad V_s = 60.3\cdot kip$

LRFD Eqn 5.8.3.3-4

$\phi_{shr} = 0.90$ $\qquad V_u = 8.1\cdot kip$

$ShearRatio := \frac{V_u - \phi_{shr}\cdot V_c}{\phi_{shr}\cdot V_s}$ $\qquad ShearRatio = -4.25$

$ShearRatio := if(ShearRatio \le 0, 0, ShearRatio)$ $\quad ShearRatio = 0.00$

Check Torsion Strength

$T_{n1} := \frac{2\cdot A_o\cdot A_{v.bar}\cdot F_{y.rebar}}{s_{v1}}$ $\qquad T_{n1} = 885.7\cdot kip\cdot ft$

LRFD Eqn 5.8.3.6.2-1

LRFD 5.8.3.4.1

$T_{n2} := \frac{2\cdot A_o\cdot A_{v.bar}\cdot F_{y.rebar}}{s_{v2}}$ $\qquad T_{n2} = 393.6\cdot kip\cdot ft$

$T_{n3} := \frac{2\cdot A_o\cdot A_{v.bar}\cdot F_{y.rebar}}{s_{v3}}$ $\qquad T_{n3} = 295.2\cdot kip\cdot ft$

$\phi_{tor} = 0.90$ $\qquad T_u = 229.96\cdot kip\cdot ft$ $\qquad L_{reqdTor} = 14.00\,\text{ft}$

$Tor2_{sand} := T_u - \max\left[\left[\pi\cdot b\cdot(2\cdot ft - Offset)\cdot\gamma_{soil}\cdot\left(\frac{2\cdot ft - Offset}{2}\right)\cdot\left(\omega_{fdot}\right)\cdot\frac{b}{2}\right], 0\cdot kip\cdot ft\right]$ $\qquad Tor2_{sand} = 229.1\cdot kip\cdot ft$

$Tor3_{sand} := T_u - \max\left[\left[\pi\cdot b\cdot\left(depth_{stir} - Offset\right)\cdot\gamma_{soil}\cdot\left(\frac{depth_{stir} - Offset}{2}\right)\cdot\left(\omega_{fdot}\right)\cdot\frac{b}{2}\right], 0\cdot kip\cdot ft\right]$ $\qquad Tor3_{sand} = 140.3\cdot kip\cdot ft$

$Tor2_{clay} := T_u - \max\left[\left[f_{se}\cdot(\pi\cdot b)\cdot(2.0\cdot ft - Offset - 1.5\cdot ft)\cdot\frac{b}{2}\right], 0\cdot kip\cdot ft\right]$ $\qquad Tor2_{clay} = 229.96\cdot kip\cdot ft$

$Tor3_{clay} := T_u - \max\left[\left[f_{se}\cdot(\pi\cdot b)\cdot\left(depth_{stir} - Offset - 1.5\cdot ft\right)\cdot\frac{b}{2}\right], 0\cdot kip\cdot ft\right]$ $\qquad Tor3_{clay} = -67.45\cdot kip\cdot ft$

$\mathrm{Tor2} := \mathrm{if}\left(\mathrm{SoilType} = 1, \mathrm{Tor2}_{\mathrm{sand}}, \mathrm{Tor2}_{\mathrm{clay}}\right)$ $\mathrm{Tor2} = 229.07 \cdot \mathrm{kip} \cdot \mathrm{ft}$

$\mathrm{Tor3} := \mathrm{if}\left(\mathrm{SoilType} = 1, \mathrm{Tor3}_{\mathrm{sand}}, \mathrm{Tor3}_{\mathrm{clay}}\right)$ $\mathrm{Tor3} = 140.26 \cdot \mathrm{kip} \cdot \mathrm{ft}$

$\mathrm{TorsionRatio}_{n1} := \dfrac{T_u}{\phi_{tor} \cdot T_{n1}}$ $\mathrm{TorsionRatio}_{n1} = 0.29$

$\mathrm{TorsionRatio}_{n2} := \dfrac{\mathrm{Tor2}}{\phi_{tor} \cdot T_{n2}}$ $\mathrm{TorsionRatio}_{n2} = 0.65$

$\mathrm{TorsionRatio}_{n3} := \dfrac{\mathrm{Tor3}}{\phi_{tor} \cdot T_{n3}}$ $\mathrm{TorsionRatio}_{n3} = 0.53$

$\mathrm{TorsionRatio} := \max\left(\mathrm{TorsionRatio}_{n1}, \mathrm{TorsionRatio}_{n2}, \mathrm{TorsionRatio}_{n3}\right)$ $\mathrm{TorsionRatio} = 0.65$

$T_{cr} := 0.125 \sqrt{\dfrac{f_c}{\mathrm{ksi}}} \cdot \left(\dfrac{A_{cp}{}^2}{p_{cp} \cdot \mathrm{in}^3}\right) \cdot \mathrm{kip} \cdot \mathrm{in}$ $T_{cr} = 644.1 \cdot \mathrm{kip} \cdot \mathrm{ft}$ ***LRFD Eqn 5.8.2.1-4***

$\mathrm{TorsionRatio} := \mathrm{if}\left(T_u \le 0.25 \cdot \phi_{tor} \cdot T_{cr}, 0, \mathrm{TorsionRatio}\right)$ $\mathrm{TorsionRatio} = 0.65$ ***LRFD Eqn 5.8.2.1-3***

$\mathrm{ShearRatio} = 0.00$

$\mathrm{CheckShearTorsion} := \mathrm{if}(\mathrm{ShearRatio} + \mathrm{TorsionRatio} \le 1, \text{"OK"}, \text{"No Good"})$ $\mathrm{CheckShearTorsion} = \text{"OK"}$

Check Maximum Spacing Transverse Reinforcement

$vu := \dfrac{V_u}{\phi_{shr} \cdot b \cdot (0.8 \cdot b)}$ $vu = 0.003878 \cdot \mathrm{ksi}$ ***LRFD Eqn 5.8.2.9-1***

$0.125 \cdot f_c = 0.50 \cdot \mathrm{ksi}$

$s_{max1} := \mathrm{if}\left(0.8 \cdot d_v < 24 \cdot \mathrm{in}, 0.8 \cdot d_v, 24 \cdot \mathrm{in}\right)$ $s_{max1} = 24 \cdot \mathrm{in}$ ***LRFD Eqn 5.8.2.7-1***

$s_{max2} := \mathrm{if}\left(0.4 \cdot d_v < 12 \cdot \mathrm{in}, 0.4 \cdot d_v, 12 \cdot \mathrm{in}\right)$ $s_{max2} = 12 \cdot \mathrm{in}$ ***LRFD Eqn 5.8.2.7-2***

$s_{max} := \mathrm{if}\left(vu < 0.125 \cdot f_c, s_{max1}, s_{max2}\right)$ $s_{max} = 24 \cdot \mathrm{in}$

$\max\left(s_{v1}, s_{v2}, s_{v3}\right) = 12.00 \cdot \mathrm{in}$

$\mathrm{CheckMaxSpacingTransvReinf} := \mathrm{if}\left(\max\left(s_{v1}, s_{v2}, s_{v3}\right) \le s_{max}, \text{"OK"}, \text{"No Good"}\right)$ $\mathrm{CheckMaxSpacingTransvReinf} = \text{"OK"}$

Check Longitudinal Reinforcement for Combined Shear and Torsion ***LRFD Eqn 5.8.3.6.3-1***

LRFD 5.8.3.4.1

$M_u := LF_{tor} \cdot \sqrt{\left(M_{x.polebase_{LoadCaseOT}}\right)^2 + \left(M_{z.polebase_{LoadCaseOT}}\right)^2}$ $M_u = 171.8 \cdot \mathrm{kip} \cdot \mathrm{ft}$

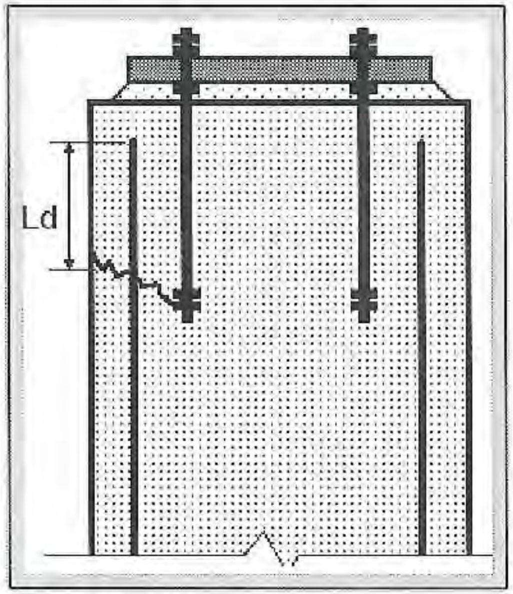
$$V_{temp} := \text{if}\left(\frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s > 0 \cdot kip, \frac{V_u}{\phi_{shr}} - 0.5 \cdot V_s, 0 \cdot kip\right) \quad V_{temp} = 0 \cdot kip$$

$$LongReinf_{shr.tor} := \frac{\dfrac{M_u}{\phi_{tor} \cdot (0.8 \cdot b)} + \sqrt{\left(\dfrac{V_{temp}}{kip}\right)^2 + \left(\dfrac{0.45 \cdot p_h \cdot T_u}{2 \cdot A_o \cdot \phi_{tor} \cdot kip}\right)^2} \cdot kip}{F_{y.rebar}} \qquad LongReinf_{shr.tor} = 2.19 \cdot in^2$$

$BarsProv \cdot A_{bar} = 23.40 \cdot in^2$

$CheckLongReinf_{shr.tor} := \text{if}\left(BarsProv \cdot A_{bar} \geq LongReinf_{shr.tor}, \text{"OK"}, \text{"No Good"}\right)$ $CheckLongReinf_{shr.tor} = \text{"OK"}$

Anchor Bolt Embedment



$$Gap_{shaft} := \frac{b - 2 \cdot cover - 2 \cdot d_{v.bar} - Diameter_{boltcircle.pole} - d_{bar}}{2}$$

$Gap_{shaft} = 6.17 \cdot in$

$Diameter_{rebar.circle} := b - 2 \cdot cover - d_{bar} - 2 \cdot d_{v.bar}$

$Diameter_{rebar.circle} = 39.3 \cdot in$

$\#BarsProvided := BarsProv$ $\#BarsProvided = 15.00$

$$\#BarsProvidedPerRod := \min\left(\begin{pmatrix} \dfrac{\#BarsProvided}{\#AnchorRods} \\ 3 \end{pmatrix}\right)$$

Use a maximum of three rebar per anchor bolt (conservative)

$\#BarsProvidedPerRod = 2.50$

$$\phi := 0.9 \qquad \#BarsReqdPerRod := \frac{T_{u.rod}}{A_{bar} \cdot (\phi \cdot F_{y.rebar})} \cdot \frac{Diameter_{boltcircle.pole}}{Diameter_{rebar.circle}}$$

$\#BarsReqdPerRod = 0.32$

$$AreaRatio := \frac{\#BarsReqdPerRod}{\#BarsProvidedPerRod}$$

$AreaRatio = 0.13$

$AreaRatio := \text{if}(AreaRatio < 1, AreaRatio, 1)$ $AreaRatio = 0.13$

$$L_{d.bar} := \max\left(\begin{bmatrix} \dfrac{1.25\cdot(A_{bar})\cdot F_{y.rebar}}{\sqrt{f_c\cdot ksi}\cdot in} \\ \dfrac{0.4\cdot(d_{bar})\cdot F_{y.rebar}}{ksi} \end{bmatrix}\right)$$

development length of bar ***LRFD 5.11.2.1.1***

$$L_{d.bar} := if\left(A_{bar} = 2.25\cdot in^2, \frac{2.70\cdot in^2\cdot F_{y.rebar}}{\sqrt{f_c\cdot ksi}\cdot in}, L_{d.bar}\right)$$

$L_{d.bar} = 58.5\cdot in$

$$SpacingFactor := \max\left(\begin{pmatrix} \#BarsProvidedPerRod\cdot 0.5 - 0.5 \\ 0.5 \end{pmatrix}\right)$$

$SpacingFactor = 0.75$

$$L_{embedment.added} := \sqrt{(ReinfClearSpacing\cdot SpacingFactor)^2 + Gap_{shaft}^{\;2}}$$

$L_{embedment.added} = 8.0\cdot in$

$$L_{embedment.rod} := \max\left(\begin{bmatrix} L_{d.bar}\cdot(AreaRatio) + 12\cdot in + L_{embedment.added} \\ 20\cdot d_{bolt.pole} \end{bmatrix}\right)$$

$$L_{embedment.rod} := Ceil(L_{embedment.rod}, in)$$

$L_{embedment.rod} = 40\cdot in$

$$L_{anchor.rod} := Ceil[(L_{embedment.rod} + 8\cdot in), in]$$

$L_{anchor.rod} = 48\cdot in$

Anchor Bolt Shear Break-Out Strength

References:
ACI 318-05 Appendix D.
FDOT/University of Florida Report BD545 RPWO #54,
Anchor Embedment Requirements for Signal/Sign Structures, July 2007.

$\#AnchorRods = 6.00$ *number of anchor bolts*

$d_{bolt.pole} = 2.00\cdot in$ *anchor bolt diameter*

$Diameter_{boltcircle.pole} = 27.00\cdot in$ *anchor bolt circle diameter*

$L_{embedment.rod} = 40.00\cdot in$ *anchor bolt embedment*

$b = 54.00\cdot in$ *shaft diameter*

$$r_b := \frac{Diameter_{boltcircle.pole}}{2} \qquad r_b = 13.50\cdot in$$

$$r := \frac{b}{2} \qquad r = 27.00\cdot in$$

$c_{a1} := \dfrac{\sqrt{r_b^{\,2} + 3.25 \cdot \left(r^2 - r_b^{\,2}\right)} - r_b}{3.25}$ $\quad c_{a1} = 9.47 \cdot in$

adjusted cover

UF Report Eqn 3-2

$L_e := \min\left(8 \cdot d_{bolt.pole}, L_{embedment.rod}\right)$ $\quad L_e = 16.00 \cdot in$

load bearing length of anchor for shear

ACI D.6.2.2

$V_b := 13 \cdot \left(\dfrac{L_e}{d_{bolt.pole}}\right)^{0.2} \cdot \sqrt{\dfrac{d_{bolt.pole}}{in}} \cdot \sqrt{\dfrac{f_c}{psi}} \left(\dfrac{c_{a1}}{in}\right)^{1.5} \cdot lbf$

shear break-out strength (single anchor)

UF Report Eqn 2-11

$V_b = 51.3 \cdot kip$

$A := \dfrac{(360 \cdot deg)}{\#AnchorRods}$ $\quad A = 60 \cdot deg$

UF Report Fig 3-7

$alpha := 2\,asin\left[\dfrac{\left(1.5 \cdot c_{a1}\right)}{r}\right]$ $\quad alpha = 63.5 \cdot deg$

OverlapTest := if(A ≤ alpha, "Overlap of Failure Cones" , "No Overlap of Failure Cones")

OverlapTest = "Overlap of Failure Cones"

$chord := 2 \cdot r \cdot \sin\left(\dfrac{A}{2}\right)$ $\quad chord = 27 \cdot in$

UF Report Fig 3-7

$A_{Vco} := 4.5 \cdot c_{a1}^{\,2}$ $\quad A_{Vco} = 403.2 \cdot in^2$

projected concrete failure area (single anchor)

ACI Eqn D-23

$A_{Vc} := chord \cdot 1.5 \cdot c_{a1}$ $\quad A_{Vc} = 383.4 \cdot in^2$

projected concrete failure area (group)

ACI D.6.2.1

$A_{Vc} := if\left(A_{Vc} > A_{Vco}, A_{Vco}, A_{Vc}\right)$ $\quad A_{Vc} = 383.4 \cdot in^2$

$\psi_{ecV} := \mathbf{1.0}$	*eccentric load modifier*	***ACI D.6.2.5***	
$\psi_{edV} := \mathbf{1.0}$	*edge effect modifier*	***ACI D.6.2.6***	
$\psi_{cV} := \mathbf{1.4}$	*cracked section modifier*	***ACI D.6.2.7***	*(stirrup spacing <= 4)'*
$\psi_{hV} := \mathbf{1.0}$	*member thickness modifier*	***ACI D.6.2.8***	
$\phi_{breakout} := \mathbf{0.75}$	*strength reduction factor*	***ACI D.4.4.c.i***	*(shear breakout, condition A)*

$V_{cbg} := \#AnchorRods \cdot \left(\frac{A_{Vc}}{A_{Vco}} \right) \cdot \left(\psi_{ecV} \cdot \psi_{edV} \cdot \psi_{cV} \cdot \psi_{hV} \right) \cdot V_b$ $V_{cbg} = 409.9 \cdot kip$ *concrete breakout strength - shear*

ACI Eqn D-22 *Shear force ⊥ to edge*

$V_{cbg\_parallel} := 2 \cdot V_{cbg}$ $V_{cbg\_parallel} = 819.8 \cdot kip$ ***ACI D.6.2.1.c*** *Shear force || to edge*

$T_{n.breakout} := V_{cbg\_parallel} \cdot r_b$ $T_{n.breakout} = 922.3 \cdot kip \cdot ft$ *concrete breakout strength - torsion*

$\phi_{breakout} \cdot T_{n.breakout} = 691.7 \cdot kip \cdot ft$

$T_u = 230 \cdot kip \cdot ft$

$BreakoutTest := if\left(\phi_{breakout} \cdot T_{n.breakout} \geq T_u, \text{"OK"}, \text{"No Good"} \right)$ $BreakoutTest = \text{"OK"}$

$OverlapDesign := if(A \leq \alpha, \text{"Based on Overlap of Failure Cones"}, \text{"Based on No Overlap of Failure Cones"})$

$OverlapDesign = \text{"Based on No Overlap of Failure Cones"}$

$M_{x.polebase} = \begin{pmatrix} 0.0 \\ 117.6 \\ 117.6 \end{pmatrix} \cdot ki$ $M_{y.polebase} = \begin{pmatrix} 176.9 \\ 0.0 \\ 176.9 \end{pmatrix} \cdot kip \cdot$ $M_{z.polebase} = \begin{pmatrix} 0.0 \\ 60.2 \\ 60.2 \end{pmatrix} \cdot kip \cdot ft$

maximum torsion (Mx & Mz not used)
maximum overturning (My not used)
maximum CSR

Analyze Foundation

Summary - Soil Properties and Drilled Shaft Geometry

$SoilType = 1$ *0 - clay* *1 - sand* $\phi_{soil} = 28 \cdot deg$ $c_{soil} = 2000 \cdot psf$ $\gamma_{soil} = 37.6 \cdot pcf$

$Diameter_{shaft} = 4.5\,ft$ $L_{shaft} = 15\,ft$ $L_{embedment.rod} = 40 \cdot in$ $L_{anchor.rod} = 48.00 \cdot in$

$\#BarsProvided = 15$ $d_{bar} = 1.41 \cdot in$

Foundation Performance Ratios

$PR_{foundation} = 0.924$

Fatigue Analysis

DataFile = "E5T3.dat" WindSpeed = 130·mph

Use the member cross section adjacent to the weld toe to compute the nominal stress range. **LTS 11.9**

$FatigueCategory := 2$ **SM V9 11.6**

▼ Analyze Structure for Fatigue

Fatigue Importance Factors

LTS Table 11-1

Galloping: $I_{F.g} := if(FatigueCategory = 1, 1.0, if(FatigueCategory = 2, 0.65, 0.3)) = 0.65$

Natural Wind Gusts: $I_{F.nw} := if(FatigueCategory = 1, 1.0, if(FatigueCategory = 2, 0.80, 0.55)) = 0.80$

Vortex Shedding: No check. **LTS Table 11-1**

Truck Gust: No check. **LTS 11.7.4**

Constant Amplitude Fatigue Threshold

LTS Table 11-3

$CAFT_A := 24 \cdot ksi$

$CAFT_B := 16 \cdot ksi$ $CAFT_{B'} := 12 \cdot ksi$

$CAFT_C := 10 \cdot ksi$

$CAFT_D := 7 \cdot ksi$

$CAFT_E := 4.5 \cdot ksi$ $CAFT_{E'} := 2.6 \cdot ksi$

$CAFT_{ET} := 1.2 \cdot ksi$

$CAFT_{K2} := 1.0 \cdot ksi$

Galloping

LTS 11.7.1

Pressure: $Pressure_{galloping} := (21 \cdot psf) \cdot I_{F.g} = 13.65 \cdot psf$

Natural Wind Gust

LTS 11.7.3

$C_{d.nwg.tube} := 1.2$

Pressure: coefficient of drag will be added with each component $Pressure_{natural.wind.gust} := (5.2 \cdot psf) \cdot I_{F.nw} = 4.16 \cdot psf$

Arm and Pole Welds

*NOTE: *LTS = proposed for 2012*

***LTS 11.9.3.1**

$$^{**}\; b_{conn.plate} = \begin{pmatrix} 28.00 \\ 0.00 \end{pmatrix} \cdot in$$

***NOTE: For Standard Mastarms check Design Standard 17743 for arm plate width FJ.*

$D_{BC.arm1} := b_{conn.plate_0} - 4 \cdot d_{bolt.conn_0} = 23.00 \cdot in$ $D_{OP.arm1} := max(Diameter_{base.arm1}) - 4 \cdot in = 10.00 \cdot in$

$D_{T.arm1} := max(Diameter_{base.arm1}) = 14.00 \cdot in$

$D_{BC.arm2} := b_{conn.plate_1} - 4 \cdot d_{bolt.conn_1} = 0.00 \cdot in$ $D_{OP.arm2} := if[(L_{total.arm2} = 0 \cdot ft), 10 \cdot in, max(Diameter_{base.arm2}) - 4 \cdot in] = 10.00 \cdot in$

$D_{T.arm2} := if[(L_{total.arm2} = 0 \cdot ft), 14 \cdot in, max(Diameter_{base.arm2})] = 14.00 \cdot in$

$D_{BC.pole} := Diameter_{boltcircle.pole} = 27.00\cdot in$ $D_{OP.pole} := Diameter_{base.pole} - 4\cdot in = 15.00\cdot in$ $D_{T.pole} := Diameter_{base.pole} = 19.00\cdot in$

$C_{BC.arm1} := \dfrac{D_{BC.arm1}}{D_{T.arm1}} = 1.64$ $C_{OP.arm1} := \dfrac{D_{OP.arm1}}{D_{T.arm1}} = 0.71$ $t_{T.arm1} := \max\left(t_{wall.arm1}\right) = 0.375\cdot in$

$t_{TP.arm1} := t_{baseplate.arm_0} + t_{conn.plate_0} = 4.375\cdot in$

$C_{BC.arm2} := \dfrac{D_{BC.arm2}}{D_{T.arm2}} = 0.00$ $C_{OP.arm2} := \dfrac{D_{OP.arm2}}{D_{T.arm2}} = 0.71$ $t_{T.arm2} := if\left[\left(L_{total.arm2} = 0\cdot ft\right), 0.1\cdot in, \max\left(t_{wall.arm2}\right)\right] = 0.1\cdot in$

$t_{TP.arm2} := if\left[\left(L_{total.arm2} = 0\cdot ft\right), 0.1\cdot in, t_{baseplate.arm_1} + t_{conn.plate_1}\right] = 0.1\cdot in$

$C_{BC.pole} := \dfrac{D_{BC.pole}}{D_{T.pole}} = 1.42$ $C_{OP.pole} := \dfrac{D_{OP.pole}}{D_{T.pole}} = 0.79$ $t_{T.pole} := t_{wall.pole} = 0.375\cdot in$ $t_{TP.pole} := t_{baseplate.pole} = 2.5\cdot in$

LTS Table 11-3, Eqn 11-13

valid for:

$0.179\cdot in \le t_T \le 0.625\cdot in$

$8\cdot in \le D_T \le 50\cdot in$

$2\cdot in \le t_{TP} \le 4\cdot in$

$\le C_{BC} \le 2.5$

$0.3 \le C_{OP} \le 0.9$

$$K_{F.arm1} := 1.35 + 16\cdot\left(15\cdot\frac{t_{T.arm1}}{in} + 1\right)\cdot\left(\frac{D_{T.arm1}}{in} - 5\right)\cdot\left(\frac{C_{BC.arm1}{}^{0.02} - 1}{4\cdot C_{OP.arm1}{}^{-0.7} - 3}\right)\cdot\left(\frac{t_{TP.arm1}}{in}\right)^{-2} = 1.59$$

$$K_{F.arm2} := 1.35 + 16\cdot\left(15\cdot\frac{t_{T.arm2}}{in} + 1\right)\cdot\left(\frac{D_{T.arm2}}{in} - 5\right)\cdot\left(\frac{C_{BC.arm2}{}^{0.02} - 1}{4\cdot C_{OP.arm2}{}^{-0.7} - 3}\right)\cdot\left(\frac{t_{TP.arm2}}{in}\right)^{-2} = -1.75\times 10^{4}$$

$$K_{F.pole} := 1.35 + 16\cdot\left(15\cdot\frac{t_{T.pole}}{in} + 1\right)\cdot\left(\frac{D_{T.pole}}{in} - 5\right)\cdot\left(\frac{C_{BC.pole}{}^{0.02} - 1}{4\cdot C_{OP.pole}{}^{-0.7} - 3}\right)\cdot\left(\frac{t_{TP.pole}}{in}\right)^{-2} = 2.32$$

$$K_{I.arm1} := \left[\left(1.76 + 1.83\cdot\frac{t_{T.arm1}}{in}\right) - 4.76\cdot 0.22^{K_{F.arm1}}\right]\cdot K_{F.arm1} = 3.21$$

$$K_{I.arm2} := if\left[\left(L_{total.arm2} = 0\cdot ft\right), 100, \left[\left(1.76 + 1.83\cdot\frac{t_{T.arm2}}{in}\right) - 4.76\cdot 0.22^{K_{F.arm2}}\right]\cdot K_{F.arm2}\right] = 100.00$$

$$K_{I.pole} := \left[\left(1.76 + 1.83\cdot\frac{t_{T.pole}}{in}\right) - 4.76\cdot 0.22^{K_{F.pole}}\right]\cdot K_{F.pole} = 5.36$$

LTS Table 11-2, Detail 4.5

$CAFT_{fullpengroove.weld.arm1} := if\left(K_{I.arm1} < 3.0, 10.0\cdot ksi, if\left(K_{I.arm1} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 7.00\cdot ksi$

$CAFT_{fullpengroove.weld.arm2} := if\left(K_{I.arm2} < 3.0, 10.0\cdot ksi, if\left(K_{I.arm2} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 4.50\cdot ksi$

$CAFT_{fullpengroove.weld.pole} := if\left(K_{I.pole} < 3.0, 10.0\cdot ksi, if\left(K_{I.pole} < 4.0, 7.0\cdot ksi, 4.5\cdot ksi\right)\right) = 4.50\cdot ksi$

Galloping Moment: base1 = 20 base2 = 20 polebase = 10

$$M_{galloping.arm1.base} := \left(\frac{M_{wl.signal.arm1_{base1}}}{C_{d.signal}} + \frac{M_{wl.panel.arm1_{base1}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 30.72\cdot kip\cdot ft$$

$$M_{galloping.arm2.base} := \left(\frac{M_{wl.signal.arm2_{base2}}}{C_{d.signal}} + \frac{M_{wl.panel.arm2_{base2}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 0.00\cdot kip\cdot ft$$

$$M_{galloping.pole.base} := \max\left(M_{galloping.arm1.base}, M_{galloping.arm2.base}\right) = 30.72\cdot kip\cdot ft$$

Galloping Shear:

$$V_{galloping.arm1.base} := \left(\frac{V_{wl.signal.arm1_{base1}}}{C_{d.signal}} + \frac{V_{wl.panel.arm1_{base1}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 0.83\cdot kip$$

$$V_{galloping.arm2.base} := \left(\frac{V_{wl.signal.arm2_{base2}}}{C_{d.signal}} + \frac{V_{wl.panel.arm2_{base2}}}{C_{d.panel}}\right)\cdot\left(\frac{Pressure_{galloping}}{Pressure\cdot K_{z.arm}}\right) = 0\cdot kip$$

Galloping Bending Stress

$$\phi := \frac{180\cdot deg}{Sides} = 15.00\cdot deg$$

$$f_{b.galloping.arm1.base} := \frac{M_{galloping.arm1.base}\cdot\left(\frac{a_{od.arm1_{base1}}}{2\cdot\sin(\phi)}\right)}{I_{arm1_{base1}}} = 6.85\cdot ksi$$

$$f_{b.galloping.arm2.base} := \text{if}\left[I_{arm2_{base2}} > 0\cdot in^4, \frac{M_{galloping.arm2.base}\cdot\left(\frac{a_{od.arm2_{base2}}}{2\cdot\sin(\phi)}\right)}{I_{arm2_{base2}}}, 0\cdot ksi\right] = 0.00\cdot ksi$$

$$f_{b.galloping.pole.base} := \frac{M_{galloping.pole.base}\cdot\left(\frac{a_{od.pole_{polebase}}}{2\cdot\sin(\phi)}\right)}{I_{pole_{polebase}}} = 3.64\cdot ksi$$

Galloping Shear Stress:

$$f_{v.galloping.arm1.base} := 2.025\cdot\frac{V_{galloping.arm1.base}}{A_{arm1_{base1}}} = 0.10\cdot ksi$$

$$f_{v.galloping.arm2.base} := \text{if}\left(A_{arm2_{base2}} > 0\cdot in^2, 2.025\cdot\frac{V_{galloping.arm2.base}}{A_{arm2_{base2}}}, 0\cdot ksi\right) = 0.00\cdot ksi$$

Check Galloping Stress:

$$f_{galloping.arm1} := \sqrt{f_{b.galloping.arm1.base}^2 + f_{v.galloping.arm1.base}^2} = 6.85\cdot ksi \qquad CAFT_{fullpengroove.weld.arm1} = 7.00\cdot ksi$$

$$Check_{galloping.arm1} := \text{if}\left(CAFT_{fullpengroove.weld.arm1} \geq f_{galloping.arm1}, \text{"OK"}, \text{"No Good"}\right) \qquad Check_{galloping.arm1} = \text{"OK"}$$

$$f_{galloping.arm2} := \sqrt{f_{b.galloping.arm2.base}^2 + f_{v.galloping.arm2.base}^2} = 0.00\cdot ksi \qquad CAFT_{fullpengroove.weld.arm2} = 4.50\cdot ksi$$

$$f_{galloping.arm2} := \text{if}\left(L_{total.arm2} = 0\cdot ft, 0\cdot ksi, f_{galloping.arm2}\right) = 0.00\cdot ksi$$

$$Check_{galloping.arm2} := \text{if}\left(CAFT_{fullpengroove.weld.arm2} \geq f_{galloping.arm2}, \text{"OK"}, \text{"No Good"}\right)$$

$$Check_{galloping.arm2} := \text{if}\left(L_{total.arm2} = 0\cdot ft, \text{"NA"}, Check_{galloping.arm2}\right) \qquad Check_{galloping.arm2} = \text{"NA"}$$

$$f_{galloping.pole} := f_{b.galloping.pole.base} = 3.64\cdot ksi \qquad CAFT_{fullpengroove.weld.pole} = 4.50\cdot ksi$$

$$Check_{galloping.pole} := \text{if}\left(CAFT_{fullpengroove.weld.pole} \geq f_{galloping.pole}, \text{"OK"}, \text{"No Good"}\right) \qquad Check_{galloping.pole} = \text{"OK"}$$

Natural Wind Gust Moment: $base1 = 20$ $base2 = 20$ $polebase = 10$

$$M_{nwg.arm1.base} := \left(M_{wl.signal.arm1_{base1}} + M_{wl.panel.arm1_{base1}} + M_{wl.tube.arm1_{base1}}\cdot\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}} = 17.1\cdot kip\cdot f$$

$$M_{nwg.arm2.base} := \left(M_{wl.signal.arm2_{base2}} + M_{wl.panel.arm2_{base2}} + M_{wl.tube.arm2_{base2}}\cdot\frac{C_{d.nwg.tube}}{C_{d.segment.arm2_{base2}}}\right)\cdot\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}} = 0\cdot kip\cdot ft$$

$$M_{nwg.pole.base} := \max(M_x)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right)\cdot\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}} = 17.32\cdot kip\cdot ft$$

$$M_{x.connect_{\beta}} := M_{x_{\beta,0}}$$

$$M_{nwg.pole.connect} := \max(M_{x.connect})\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}} = 7.29\times 10^{-3}\cdot kip\cdot ft$$

$$M_{nwg.pole.torsion} := \max\left(M_y\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right)\cdot\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}} = 26.05\cdot kip\cdot ft$$

Natural Wind Gust Shear:

$$V_{nwg.arm1.base} := \left(V_{wl.signal.arm1_{base1}} + V_{wl.panel.arm1_{base1}} + V_{wl.tube.arm1_{base1}}\cdot\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 0.55\cdot kip$$

$$V_{nwg.arm2.base} := \left(V_{wl.signal.arm2_{base2}} + V_{wl.panel.arm2_{base2}} + V_{wl.tube.arm2_{base2}}\cdot\frac{C_{d.nwg.tube}}{C_{d.segment.arm2_{base2}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 4.99 \times 10$$

$$V_{nwg.pole.base} := \max\left(V_z\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.pole_{polebase}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.pole_{polebase}}}\right) = 0.92\cdot kip$$

$$V_{x.connect_{\beta}} := V_{x_{\beta,0}}$$

$$V_{nwg.pole.connect} := \max\left(V_{x.connect}\right)\cdot\left(\frac{C_{d.nwg.tube}}{C_{d.segment.arm1_{base1}}}\right)\cdot\left(\frac{Pressure_{natural.wind.gust}}{Pressure\cdot K_{z.arm}}\right) = 1.94 \times 10^{-3}\cdot kip$$

Natural Wind Gust Bending Stress:

$$f_{b.nwg.arm1.base} := \frac{M_{nwg.arm1.base}\cdot\left(\frac{a_{od.arm1_{base1}}}{2\cdot\sin(\phi)}\right)}{I_{arm1_{base1}}} = 3.82\cdot ksi$$

$$f_{b.nwg.arm2.base} := \mathrm{if}\left[I_{arm2_{base2}} > 0\cdot in^4, \frac{M_{nwg.arm2.base}\cdot\left(\frac{a_{od.arm2_{base2}}}{2\cdot\sin(\phi)}\right)}{I_{arm2_{base2}}}, 0\cdot ksi\right] = 0.00\cdot ksi$$

$$f_{b.nwg.pole.base} := \frac{M_{nwg.pole.base}\cdot\left(\frac{a_{od.pole_{polebase}}}{2\cdot\sin(\phi)}\right)}{I_{pole_{polebase}}} = 2.05\cdot ksi$$

$$f_{b.nwg.pole.connect} := \frac{M_{nwg.pole.connect}\cdot\left(\frac{a_{od.pole_0}}{2\cdot\sin(\phi)}\right)}{I_{pole_0}} = 1.21 \times 10^{-3}\cdot ksi$$

Natural Wind Gust Shear Stress:

$$f_{v.nwg.arm1.base} := 2.025 \cdot \frac{V_{nwg.arm1.base}}{A_{arm1_{base1}}} = 0.07 \cdot ksi$$

$$f_{v.nwg.arm2.base} := if\left(A_{arm2_{base2}} > 0 \cdot in^2, 2.025 \cdot \frac{V_{nwg.arm2.base}}{A_{arm2_{base2}}}, 0 \cdot ksi\right) = 0.00 \cdot ksi$$

$$f_{v.nwg.pole.base.shear} := 2.025 \cdot \frac{V_{nwg.pole.base}}{A_{pole_{polebase}}} = 0.08 \cdot ksi$$

$$f_{v.nwg.pole.connect.shear} := 2.025 \cdot \frac{V_{nwg.pole.connect}}{A_{pole_0}} = 2.07 \times 10^{-4} \cdot ksi$$

$$f_{v.nwg.pole.base.torsion} := \frac{M_{nwg.pole.torsion} \cdot k_{t_{polebase}}}{6.43 \cdot \left(R_{b_{polebase}}\right)^2 \cdot t_{pole}} = 1.53 \cdot ksi$$

$$f_{v.nwg.pole.connect.torsion} := \frac{M_{nwg.pole.torsion} \cdot k_{t_0}}{6.43 \cdot \left(R_{b_0}\right)^2 \cdot t_{pole}} = 2.12 \cdot ksi$$

$$f_{v.nwg.pole.base} := \sqrt{f_{v.nwg.pole.base.shear}{}^2 + f_{v.nwg.pole.base.torsion}{}^2} = 1.53 \cdot ksi$$

$$f_{v.nwg.pole.connect} := \sqrt{f_{v.nwg.pole.connect.shear}{}^2 + f_{v.nwg.pole.connect.torsion}{}^2} = 2.12 \cdot ksi$$

Check Natural Wind Gust Stress:

$$f_{nwg.arm1} := \sqrt{f_{b.nwg.arm1.base}{}^2 + f_{v.nwg.arm1.base}{}^2} = 3.82 \cdot ksi$$

$CAFT_{fullpengroove.weld.arm1} = 7.00 \cdot ksi$

$Check_{nwg.arm1} := if\left(CAFT_{fullpengroove.weld.arm1} \geq f_{nwg.arm1}, \text{"OK"}, \text{"No Good"}\right)$

$Check_{nwg.arm1} = \text{"OK"}$

$$f_{nwg.arm2} := \sqrt{f_{b.nwg.arm2.base}{}^2 + f_{v.nwg.arm2.base}{}^2} = 0.00 \cdot ksi$$

$CAFT_{fullpengroove.weld.arm2} = 4.50 \cdot ksi$

$f_{nwg.arm2} := if\left(L_{total.arm2} = 0 \cdot ft, 0 \cdot ksi, f_{nwg.arm2}\right) = 0.00 \cdot ksi$

$Check_{nwg.arm2} := if\left(CAFT_{fullpengroove.weld.arm2} \geq f_{nwg.arm2}, \text{"OK"}, \text{"No Good"}\right)$

$\text{Check}_{\text{nwg.arm2}} := \text{if}\left(L_{\text{total.arm2}} = 0\cdot\text{ft}, \text{"NA"}, \text{Check}_{\text{nwg.arm2}}\right)$ $\text{Check}_{\text{nwg.arm2}} = \text{"NA"}$

$f_{\text{nwg.pole.base}} := \sqrt{f_{\text{b.nwg.pole.base}}^{2} + f_{\text{v.nwg.pole.base}}^{2}} = 2.56\cdot\text{ksi}$

$f_{\text{nwg.pole.connect}} := \sqrt{f_{\text{b.nwg.pole.connect}}^{2} + f_{\text{v.nwg.pole.connect}}^{2}} = 2.12\cdot\text{ksi}$

$f_{\text{nwg.pole}} := \text{if}\left(f_{\text{nwg.pole.connect}} > f_{\text{nwg.pole.base}}, f_{\text{nwg.pole.connect}}, f_{\text{nwg.pole.base}}\right) = 2.56\cdot\text{ksi}$

$\text{CAFT}_{\text{fullpengroove.weld.pole}} = 4.50\cdot\text{ksi}$

$\text{Check}_{\text{nwg.pole}} := \text{if}\left(\text{CAFT}_{\text{fullpengroove.weld.pole}} \geq f_{\text{nwg.pole}}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{\text{nwg.pole}} = \text{"OK"}$

A325 Connection Bolts

$\text{CAFT}_{\text{conn.bolt}} := \text{CAFT}_{\text{B}} = 16.00\cdot\text{ksi}$ ***LTS Table 11-2, Detail 3***

Galloping

$M_{\text{galloping.arms}_0} := M_{\text{galloping.arm1.base}}$

$M_{\text{galloping.arms}_1} := M_{\text{galloping.arm2.base}}$

$$T_{\text{g.conn}_j} := \frac{M_{\text{galloping.arms}_j}}{RC_j + \text{CompForceOffset}_j + t_{\text{arm}_j}} \qquad T_{\text{g.conn}} = \begin{pmatrix} 13.0 \\ 1.9 \times 10^{-4} \end{pmatrix}\cdot\text{kip}$$

$$T_{\text{g.bolt.max}_j} := \text{if}\left[\#\text{ConnBolts}_j = 0, 0\cdot\text{ksi}, \frac{T_{\text{g.conn}_j}}{0.5\cdot\#\text{ConnBolts}_j} + \frac{\text{DistA}_j\cdot\tan\left(\theta_j\right)\cdot T_{\text{g.conn}_j}\cdot\left(\#\text{ConnBolts}_j\cdot 0.25 - 0.5\right)\cdot\text{Spacing}_{\text{bolts.conn}_j}}{\displaystyle\sum_{n=0}^{\text{floor}\left(0.25\cdot\#\text{ConnBolts}_j\right)} \left[\frac{\left[\left(\#\text{ConnBolts}_j\cdot 0.5\right) - 1\right] - 2\cdot n}{2}\cdot\text{Spacing}_{\text{bolts.conn}_j}\right.}\right.$$

$$T_{\text{g.bolt.max}} = \begin{pmatrix} 6.1 \\ 0.0 \end{pmatrix}\cdot\text{kip}$$

$$f_{\text{t.g.bolt}_j} := \frac{T_{\text{g.bolt.max}_j}}{A_{\text{gross.bolt}_j}} \qquad \textit{Bolt Tensile Stress} \qquad f_{\text{t.g.bolt}} = \begin{pmatrix} 5.0 \\ 0.0 \end{pmatrix}\cdot\text{ksi}$$

$\text{Check}_{\text{g.conn.bolt}_j} := \text{if}\left(\text{CAFT}_{\text{conn.bolt}} \geq f_{\text{t.g.bolt}_j}, \text{"OK"}, \text{"No Good"}\right)$ $\text{Check}_{\text{g.conn.bolt}} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

Natural wind gust

$M_{\text{nwg.arms}_0} := M_{\text{nwg.arm1.base}}$

$M_{nwg.arms_1} := M_{nwg.arm2.base}$

$$T_{nwg.conn_j} := \frac{M_{nwg.arms_j}}{RC_j + CompForceOffset_j + t_{arm_j}}$$

$$T_{nwg.conn} = \begin{pmatrix} 7.2 \\ 7.0 \times 10^{-5} \end{pmatrix} \cdot kip$$

$$T_{nwg.bolt.max_j} := if\left[\#ConnBolts_j = 0, 0 \cdot ksi, \frac{T_{nwg.conn_j}}{0.5 \cdot \#ConnBolts_j} + \frac{DistA_j \cdot \tan(\theta_j) \cdot T_{nwg.conn_j} \cdot (\#ConnBolts_j \cdot 0.25 - 0.5) \cdot Spacing_{bolts.co}}{\sum_{n=0}^{floor(0.25 \cdot \#ConnBolts_j)} \left[\frac{\left[(\#ConnBolts_j \cdot 0.5) - 1 \right] - 2 \cdot n}{2} \cdot Spacing_{bolts.co} \right.} \right.$$

$$T_{nwg.bolt.max} = \begin{pmatrix} 3.4 \\ 0.0 \end{pmatrix} \cdot kip$$

$$f_{t.nwg.bolt_j} := \frac{T_{nwg.bolt.max_j}}{A_{gross.bolt_j}}$$ *Bolt Tensile Stress*

$$f_{t.nwg.bolt} = \begin{pmatrix} 2.8 \\ 0.0 \end{pmatrix} \cdot ksi$$

$Check_{nwg.conn.bolt_j} := if\left(CAFT_{conn.bolt} \ge f_{t.nwg.bolt_j}, "OK", "No Good"\right)$

$$Check_{nwg.conn.bolt} = \begin{pmatrix} "OK" \\ "OK" \end{pmatrix}$$

Anchor Bolts

$CAFT_{anchor.rods} := CAFT_D = 7.00 \cdot ksi$ ***LTS Table 11-2, Detail 5***

Galloping

$$T_{g.rod} := \frac{M_{galloping.arm1.base}}{S_{rod.group}}$$ $T_{g.rod} = 9.1 \cdot kip$

$$f_{t.g.rod} := \frac{T_{g.rod}}{A_{net.rod}}$$ $f_{t.g.rod} = 3.76 \cdot ksi$

$Check_{g.rod} := if\left(CAFT_{anchor.rods} \ge f_{t.g.rod}, "OK", "No Good"\right)$ $Check_{g.rod} = "OK"$

Natural Wind Gust

$$T_{nwg.rod} := \frac{M_{nwg.pole.base}}{S_{rod.group}}$$ $T_{nwg.rod} = 5.1 \cdot kip$

$$f_{t.nwg.rod} := \frac{T_{nwg.rod}}{A_{net.rod}}$$ $f_{t.nwg.rod} = 2.12 \cdot ksi$

$Check_{nwg.rod} := if\left(CAFT_{anchor.rods} \ge f_{t.nwg.rod}, "OK", "No Good"\right)$ $Check_{nwg.rod} = "OK"$

Longitudinal Seam Weld on Arm and Upright Tubes

$\mathrm{CAFT}_{\mathrm{seam.weld}} := \mathrm{CAFT}_{\mathrm{B'}} = 12.00 \cdot \mathrm{ksi}$ **LTS Table 11-2, Detail 8**

$CAFT_{seam.weld}$ > galloping or natural wind gust stress. No check.

Arm Telescopic Splice

$\mathrm{CAFT}_{\mathrm{splice}} := \mathrm{CAFT}_{\mathrm{B}} = 16.00 \cdot \mathrm{ksi}$ **LTS Table 11-2, Detail 2**

$CAFT_{splice}$ > galloping or natural wind gust stress. No check.

Reinforced Handhole

$\mathrm{CAFT}_{\mathrm{handhole}} := 7 \cdot \mathrm{ksi}$ ***LTS Table 11-2, Detail 3.2**

$CAFT_{handhole}$ > galloping or natural wind gust stress. No check.

$\mathrm{CAFT}_{\mathrm{fullpengroove.weld.arm2}} := \mathrm{if}\left(\mathrm{L}_{\mathrm{total.arm2}} = 0 \cdot \mathrm{ft}, \text{"NA"}, \mathrm{CAFT}_{\mathrm{fullpengroove.weld.arm2}}\right)$

Analyze Structure for Fatigue

Arm and Pole Welds

$\mathrm{f}_{\mathrm{galloping.arm1}} = 6.85 \cdot \mathrm{ksi}$ $\mathrm{CAFT}_{\mathrm{fullpengroove.weld.arm1}} = 7.00 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{galloping.arm1}} = \text{"OK"}$

$\mathrm{f}_{\mathrm{galloping.arm2}} = 0.00 \cdot \mathrm{ksi}$ $\mathrm{CAFT}_{\mathrm{fullpengroove.weld.arm2}} = \text{"NA"} \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{galloping.arm2}} = \text{"NA"}$

$\mathrm{f}_{\mathrm{galloping.pole}} = 3.64 \cdot \mathrm{ksi}$ $\mathrm{CAFT}_{\mathrm{fullpengroove.weld.pole}} = 4.50 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{galloping.pole}} = \text{"OK"}$

$\mathrm{f}_{\mathrm{nwg.arm1}} = 3.82 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{nwg.arm1}} = \text{"OK"}$

$\mathrm{f}_{\mathrm{nwg.arm2}} = 0.00 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{nwg.arm2}} = \text{"NA"}$

$\mathrm{f}_{\mathrm{nwg.pole}} = 2.56 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{nwg.pole}} = \text{"OK"}$

A325 Connection Bolts

$\mathrm{f}_{\mathrm{t.g.bolt}} = \begin{pmatrix} 5.0 \\ 0.0 \end{pmatrix} \cdot \mathrm{ksi}$ $\mathrm{CAFT}_{\mathrm{conn.bolt}} = 16.00 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{g.conn.bolt}} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

$\mathrm{f}_{\mathrm{t.nwg.bolt}} = \begin{pmatrix} 2.8 \\ 0.0 \end{pmatrix} \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{nwg.conn.bolt}} = \begin{pmatrix} \text{"OK"} \\ \text{"OK"} \end{pmatrix}$

Anchor Bolts

$\mathrm{f}_{\mathrm{t.g.rod}} = 3.76 \cdot \mathrm{ksi}$ $\mathrm{CAFT}_{\mathrm{anchor.rods}} = 7.00 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{g.rod}} = \text{"OK"}$

$\mathrm{f}_{\mathrm{t.nwg.rod}} = 2.12 \cdot \mathrm{ksi}$ $\mathrm{Check}_{\mathrm{nwg.rod}} = \text{"OK"}$

▶ Summary

Mast Arm Design and Analysis Summary

DataFile = "E5T3.dat" WindSpeed = 130·mph

Subject = "E5-T3 Mast Arm" **DesignedBy** = "MAV" **PoleLocation** = "ID No.4"

ProjectNo = "00193008015" **CheckedBy** = "FDOT" **Date** = "12/5/2012"

1st Mast Arm

$\#Signals_{arm1} = 4$ $\#Panels_{arm1} = 3$

$X_{signal.arm1} = \begin{pmatrix} 21 \\ 29 \\ 40 \\ 52 \end{pmatrix} ft$ $Sections_{signal.arm1} = \begin{pmatrix} 3 \\ 3 \\ 3 \\ 5 \end{pmatrix}$ $Backplate_{signal.arm1} = \begin{pmatrix} 1 \\ 1 \\ 1 \\ 1 \end{pmatrix}$

$X_{panel.arm1} = \begin{pmatrix} 35 \\ 44 \\ 22 \end{pmatrix} ft$ $Area_{panel.arm1} = \begin{pmatrix} 9 \\ 5 \\ 1.56 \end{pmatrix} ft^2$

$L_{total.arm1} = 54\,ft$ $L_{splice.provided.arm1} = 24 \cdot in$

'FA'= 'FE'= $L_{arm1} = \begin{pmatrix} 30 \\ 26 \end{pmatrix} \cdot ft$ 'FB'= 'FF'= $Diameter_{tip.arm1} = \begin{pmatrix} 6.94 \\ 10.36 \end{pmatrix} \cdot in$ 'FC'= 'FG'= $Diameter_{base.arm1} = \begin{pmatrix} 11.14 \\ 14 \end{pmatrix} \cdot in$

'FD'= 'FH'= $t_{wall.arm1} = \begin{pmatrix} 0.25 \\ 0.375 \end{pmatrix} \cdot in$ $\max(\Delta_{arm1}) = 8.72 \cdot in$ $\max(CSR_{arm1}) = 0.945$

2nd Mast Arm

$\#Signals_{arm2} = 0$ $\#Panels_{arm2} = 1$

$X_{signal.arm2} = (0)\,ft$ $Sections_{signal.arm2} = (0)$ $Backplate_{signal.arm2} = (0)$

$X_{panel.arm2} = (0.1)\,ft$ $Area_{panel.arm2} = (0.1)\,ft^2$

$L_{total.arm2} = 0\,ft$ $L_{splice.provided.arm2} = 24 \cdot in$ 'UF'= $\alpha = 0 \cdot deg$ **(Angle Between Arms)**

'SA'= 'SE'= $L_{arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot ft$ 'SB'= 'SF'= $Diameter_{tip.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ 'SC'= 'SG'= $Diameter_{base.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$

'SD'= 'SH'= $t_{wall.arm2} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \cdot in$ $\max(\Delta_{arm2}) = 0 \cdot in$ $\max(CSR_{arm2}) = 0$

Luminaire Arm and Connection

DataFile = "E5T3.dat"

WindSpeed = 130·mph

(use MC10x33.6 channel for connection)

'LA'= $Y_{luminaire} = 0\ ft$

'LB'= $X_{luminaire} = 0\ ft$

'LC'= $Diameter_{base.lumarm} = 0 \cdot in$

'LD'= $t_{wall.lumarm} = 0 \cdot in$

'LE'= $Slope_{lumarm} = 0$

'LF'= $r_{lumarm} = 0\ ft$

'LG'= $d_{bolt.lum} = 0 \cdot in$

'LH'= $t_{baseplate.lum} = 0 \cdot in$

'LJ'= $w_{base.lum} = 0 \cdot in$

'LK'= $w_{channel.lum} = 0 \cdot in$

$CSR_{base.lumarm} = 0$

$PR_{bolt.lum} = 0$

$PR_{baseplate.lum} = 0$

$PR_{conn.plate.lum} = 0$

Upright

'UA'= $Y_{pole} = 22 \cdot ft$

'UB'= $Y_{arm.conn} = 20.5 \cdot ft$

'UC'= $Diameter_{tip.pole} = 15.92 \cdot in$

'UD'= $Diameter_{base.pole} = 19 \cdot in$

'UE'= $t_{wall.pole} = 0.375 \cdot in$

'UF'= $\alpha = 0 \cdot deg$

'UG'= $Y_{lum.conn} = 0\ ft$

$\Delta_{x.dl} = 0.88 \cdot in$

$Slope_x = 0.45 \cdot deg$

$\Delta_{z.dl} = 0 \cdot in$

$Slope_z = 0 \cdot deg$

$C_{a.pole} = 0.997$

$\max\left(CSR_{pole}\right) = 0.689$

1st Arm/Upright Connection

$\#ConnBolts_0 = 6$

'HT'= $h_{conn.plate} = 30 \cdot in$

'FJ'= $b_{conn.plate_0} = 28.00 \cdot in$

'FK'= $t_{baseplate.arm_0} = 2.75 \cdot in$

'FL'= $t_{vertical.plate_0} = 0.75 \cdot in$

'FN'= $w_{vertical.plate_0} = 0.3125 \cdot in$

'FO'= $Offset_{conn_0} = 19.565 \cdot in$

'FP'= $d_{bolt.conn_0} = 1.25 \cdot in$

'FR'= $t_{conn.plate_0} = 1.625 \cdot in$

'FS'= $Spacing_{bolts.conn_0} = 12.5 \cdot in$

'FT'= $w_{conn.plate_0} = 0.3125 \cdot in$

$$\begin{pmatrix} PR_{bolt_0} \\ PR_{t.baseplate.arm_0} \\ PR_{t.connplate.arm_0} \\ CSR_{t.vert.plate_0} \end{pmatrix} = \begin{pmatrix} 0.547 \\ 0.759 \\ 0.993 \\ 0.442 \end{pmatrix}$$

2nd Arm/Upright Connection

$\#ConnBolts_1 = 0$

'HT'= $h_{conn.plate} = 30 \cdot in$

'SJ'= $b_{conn.plate_1} = 0.00 \cdot in$

'SK'= $t_{baseplate.arm_1} = 0 \cdot in$

'SL'= $t_{vertical.plate_1} = 0 \cdot in$

'SN'= $w_{vertical.plate_1} = 0 \cdot in$

'SO'= $Offset_{conn_1} = 0 \cdot in$

'SP'= $d_{bolt.conn_1} = 0 \cdot in$

'SR'= $t_{conn.plate_1} = 0 \cdot in$

'SS'= $Spacing_{bolts.conn_1} = 0 \cdot in$

'ST'= $w_{conn.plate_1} = 0 \cdot in$

$$\begin{pmatrix} PR_{bolt_1} \\ PR_{t.baseplate.arm_1} \\ PR_{t.connplate.arm_1} \\ CSR_{t.vert.plate_1} \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}$$

Pole Baseplate

$DataFile = "E5T3.dat"$

$WindSpeed = 130 \cdot mph$

$\#AnchorRods = 6$

'BA'= $Diameter_{baseplate.pole} = 35 \cdot in$

'BB'= $t_{baseplate.pole} = 2.5 \cdot in$

'BC'= $d_{bolt.pole} = 2.00 \cdot in$

'BF'= $L_{embedment.rod} = 40 \cdot in$

$Diameter_{boltcircle.pole} = 27 \cdot in$

$PR_{rod} = 0.405$

$PR_{plate.pole} = 1$

Foundation

'DA'= $L_{shaft} = 15 \cdot ft$

'DB'= $Diameter_{shaft} = 4.5 \cdot ft$

$d_{bar} = 1.41 \cdot in$

'RA'= $round\left(\frac{d_{bar}}{0.125in}\right) = 11$

'RB'= $\#BarsProvided = 15$

$Diameter_{rebar.circle} = 3.2783\ ft$

'RC'= $NumSpaces_{v.bar} = 12$

'RD'= $s_{v2} = 9 \cdot in$

$PR_{foundation} = 0.924$

▼ WRITEPRN to Line 1-2-3

WRITEPRN statements create three ASCII files (LINE1.PRN, LINE2.PRN, LINE3.PRN) for use in Mastarm Data Table 17745.

$PRNPRECISION := 3 \quad PRNCOLWIDTH := 6$

$lineone_0 := \frac{L_{arm1_0}}{ft}$

$lineone_1 := \frac{Diameter_{tip.arm1_0}}{in}$

$lineone_2 := \frac{Diameter_{base.arm1_0}}{in}$

$lineone_3 := \frac{t_{wall.arm1_0}}{in}$

$lineone_4 := \frac{L_{arm1_1}}{ft}$

$lineone_5 := \frac{Diameter_{tip.arm1_1}}{in}$

$lineone_6 := \frac{Diameter_{base.arm1_1}}{in}$

$lineone_7 := \frac{t_{wall.arm1_1}}{in}$

$lineone_8 := \frac{L_{arm2_0}}{ft}$

$lineone_9 := \frac{Diameter_{tip.arm2_0}}{in}$

$lineone_{10} := \frac{Diameter_{base.arm2_0}}{in}$

$lineone_{11} := \frac{t_{wall.arm2_0}}{in}$

$lineone_{12} := \frac{L_{arm2_1}}{ft}$

$lineone_{13} := \frac{Diameter_{tip.arm2_1}}{in}$

$lineone_{14} := \frac{Diameter_{base.arm2_1}}{in}$

$lineone_{15} := \frac{t_{wall.arm2_1}}{in}$

$lineone_{16} := \frac{Y_{pole}}{ft}$

$lineone_{17} := \frac{Y_{arm.conn}}{ft}$

$lineone_{18} := \frac{Diameter_{tip.pole}}{in}$

$lineone_{19} := \frac{Diameter_{base.pole}}{in}$

$lineone_{20} := \frac{t_{wall.pole}}{in}$

$lineone_{21} := \frac{\alpha}{deg}$

$lineone_{22} := \frac{Y_{lum.conn}}{ft}$

$linetwo_0 := \#ConnBolts_0$

$linetwo_{11} := \#ConnBolts_1$

$linetwo_1 := \frac{h_{conn.plate}}{in}$

$linetwo_2 := \frac{b_{conn.plate_0}}{in}$

$linetwo_3 := \frac{t_{baseplate.arm_0}}{in}$

$linetwo_4 := \frac{t_{vertical.plate_0}}{in}$

$linetwo_5 := \frac{w_{vertical.plate_0}}{in}$

$linetwo_6 := \frac{Offset_{conn_0}}{in}$

$linetwo_7 := \frac{d_{bolt.conn_0}}{in}$

$linetwo_8 := \frac{t_{conn.plate_0}}{in}$

$linetwo_9 := \frac{Spacing_{bolts.conn_0}}{in}$

$linetwo_{10} := \frac{w_{conn.plate_0}}{in}$

$linetwo_{12} := \frac{h_{conn.plate}}{in}$

$linetwo_{13} := \frac{b_{conn.plate_1}}{in}$

$linetwo_{14} := \frac{t_{baseplate.arm_1}}{in}$

$linetwo_{15} := \frac{t_{vertical.plate_1}}{in}$

$linetwo_{16} := \frac{w_{vertical.plate_1}}{in}$

$linetwo_{17} := \frac{Offset_{conn_1}}{in}$

$linetwo_{18} := \frac{d_{bolt.conn_1}}{in}$

$linetwo_{19} := \frac{t_{conn.plate_1}}{in}$

$linetwo_{20} := \frac{Spacing_{bolts.conn_1}}{in}$

$linetwo_{21} := \frac{w_{conn.plate_1}}{in}$

$linethree_0 := \#AnchorRods$

$linethree_1 := \frac{Diameter_{baseplate.pole}}{in}$

$linethree_2 := \frac{t_{baseplate.pole}}{in}$

$linethree_3 := \frac{d_{bolt.pole}}{in}$

$linethree_5 := \frac{L_{shaft}}{ft}$

$linethree_6 := \frac{Diameter_{shaft}}{ft}$

$linethree_7 := round\left(\frac{d_{bar}}{0.125in}\right)$

$linethree_8 := \#BarsProvided$

$linethree_{11} := \frac{Y_{luminaire}}{ft}$

$linethree_{12} := \frac{X_{luminaire}}{ft}$

$linethree_{13} := \frac{Diameter_{base.lumarm}}{in}$

$linethree_{14} := \frac{t_{wall.lumarm}}{in}$

$\text{linethree}_4 := \frac{L_{embedment.rod}}{in}$

$\text{linethree}_9 := \text{NumSpaces}_{v.bar}$

$\text{linethree}_{10} := \frac{s_{v2}}{in}$

$\text{linethree}_{15} := \text{Slope}_{lumarm}$

$\text{linethree}_{16} := \frac{r_{lumarm}}{ft}$

$\text{linethree}_{17} := \frac{d_{bolt.lum}}{in}$

$\text{linethree}_{18} := \frac{t_{baseplate.lum}}{in}$

$\text{linethree}_{19} := \frac{w_{base.lum}}{in}$

$\text{linethree}_{20} := \frac{w_{channel.lum}}{in}$

$x := 0$ $\quad y1 := 0, 1 .. 22$ $\quad \text{line1}_{x,y1} := \text{lineone}_{y1}$

$y2 := 0, 1 .. 21$ $\quad \text{line2}_{x,y2} := \text{linetwo}_{y2}$

$y3 := 0, 1 .. 20$ $\quad \text{line3}_{x,y3} := \text{linethree}_{y3}$

WRITEPRN("line1.prn") := line1

WRITEPRN("line2.prn") := line2

WRITEPRN("line3.prn") := line3

PRNPRECISION := 8

WRITEPRN to Line 1-2-3

Mast Arm Tip Deflection

Compare Mast Arm deflection of each arm to a proposed camber

$\text{Camber}_{arm1} := 2 \cdot deg$ $\qquad \text{Camber}_{arm2} := 2 \cdot deg$

$L_{arm1} := \sum L_{arm1} - \text{if}\left[\left(L_{arm1_1} = 0 \cdot ft\right), 0 \cdot ft, 2 \cdot ft\right]$

$L_{arm2} := \sum L_{arm2} - \text{if}\left[\left(L_{arm2_1} = 0 \cdot ft\right), 0 \cdot ft, 2 \cdot ft\right]$

$\text{Deflection}_{arm1} := \text{Slope}_x \cdot L_{arm1} + \max(\Delta_{arm1})$ $\text{Deflection}_{arm1} = 13.77 \cdot in$

$\text{CamberArm1}_{upward} := \sin(\text{Camber}_{arm1}) \cdot L_{arm1}$ $\text{CamberArm1}_{upward} = 22.61 \cdot in$

$\text{Deflection}_{arm2} := \left[\text{Slope}_z \cdot L_{arm2} \cdot (\sin(\alpha))\right] + \text{Slope}_x \cdot L_{arm2} \cdot \cos(\alpha) + \max(\Delta_{arm2})$ $\text{Deflection}_{arm2} = 0 \cdot in$

$\text{CamberArm2}_{upward} := \sin(\text{Camber}_{arm2}) \cdot L_{arm2}$ $\text{CamberArm2}_{upward} = 0 \cdot in$

Check Clearance Between Connection Plates *(for Two Arm Structures only)*

$\alpha = 0.00 \cdot deg$ $\alpha := \text{if}[(\alpha > 180 \cdot deg), (360 \cdot deg - \alpha), \alpha]$

$\text{Offset}_{conn_0} = 19.56 \cdot in$ $b_{conn.plate_0} = 28.00 \cdot in$ $h_{conn.plate} = 30.00 \cdot in$ $\alpha = 0.00 \cdot deg$

$\text{Offset}_{conn_1} = 0.00 \cdot in$ $b_{conn.plate_1} = 0.00 \cdot in$

$x_1 := \text{Offset}_{conn_0} - t_{conn.plate_0} - h_{conn.plate} \cdot \frac{\sin(\text{Camber}_{arm1})}{2}$ $y_1 := \frac{b_{conn.plate_0}}{2}$ $x_1 = 17.42 \cdot in$ $y_1 = 14 \cdot in$

$$x_2 := \left(\text{Offset}_{conn_1} - t_{conn.plate_1} - h_{conn.plate} \cdot \frac{\sin(\text{Camber}_{arm2})}{2}\right) \cdot \cos(\alpha) + \frac{b_{conn.plate_1}}{2} \cdot \sin(\alpha)$$

$$y_2 := \left(\text{Offset}_{conn_1} - t_{conn.plate_1} - h_{conn.plate} \cdot \frac{\sin(\text{Camber}_{arm2})}{2}\right) \cdot \sin(\alpha) - \frac{b_{conn.plate_1}}{2} \cdot \cos(\alpha)$$

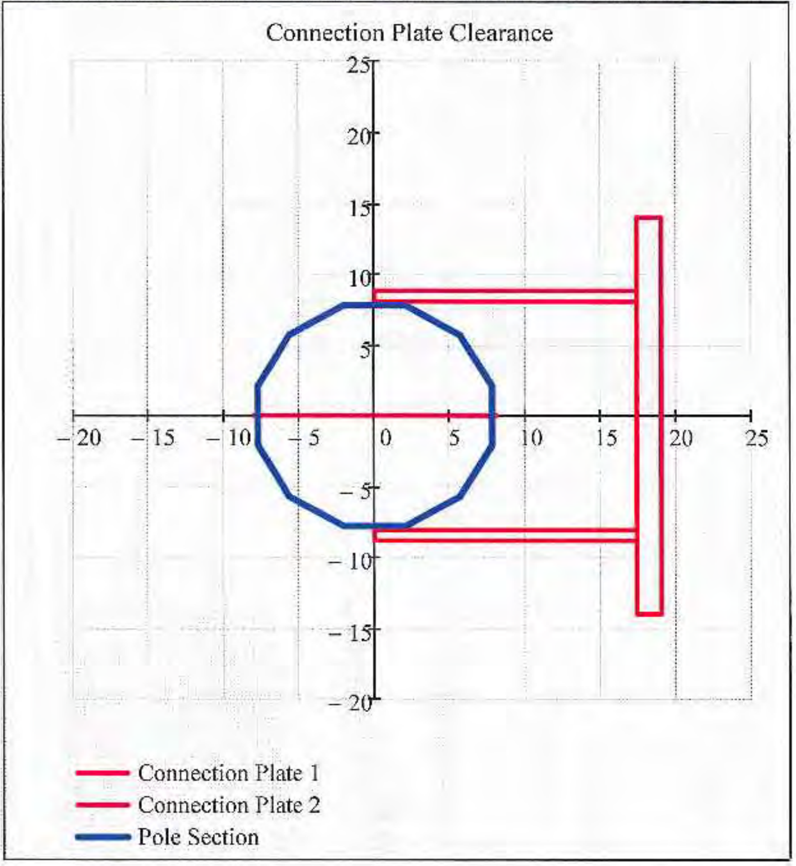
$x_2 = -0.52 \cdot in$ $y_2 = 0 \cdot in$

$\text{Clearance} := \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$ $\text{Clearance} := \text{if}\left[(y_2 \le y_1), \text{if}\left[(x_1 > x_2), \text{Clearance}, 0 \cdot in\right], \text{Clearance}\right]$ $\text{Clearance} = 22.76 \cdot in$

(if Clearance equals 0, then Connection Plates intersect and redesign is required.

Plan View - Connection Plate Clearance for Two Arm Connections

Coordinates for Drawings



$\text{Clearance} = 22.76 \cdot \text{in}$

$\text{Diameter}_{\text{conn.pole}} = 16.13 \cdot \text{in}$

$t_{\text{conn.plate}_0} = 1.625 \cdot \text{in}$

$b_{\text{conn.plate}_0} = 28 \cdot \text{in}$

$t_{\text{vertical.plate}_0} = 0.75 \cdot \text{in}$

$\text{Offset}_{\text{conn}_0} = 19.565 \cdot \text{in}$

$\text{Gap}_0 = 11.5 \cdot \text{in}$

$t_{\text{conn.plate}_1} = 0 \cdot \text{in}$

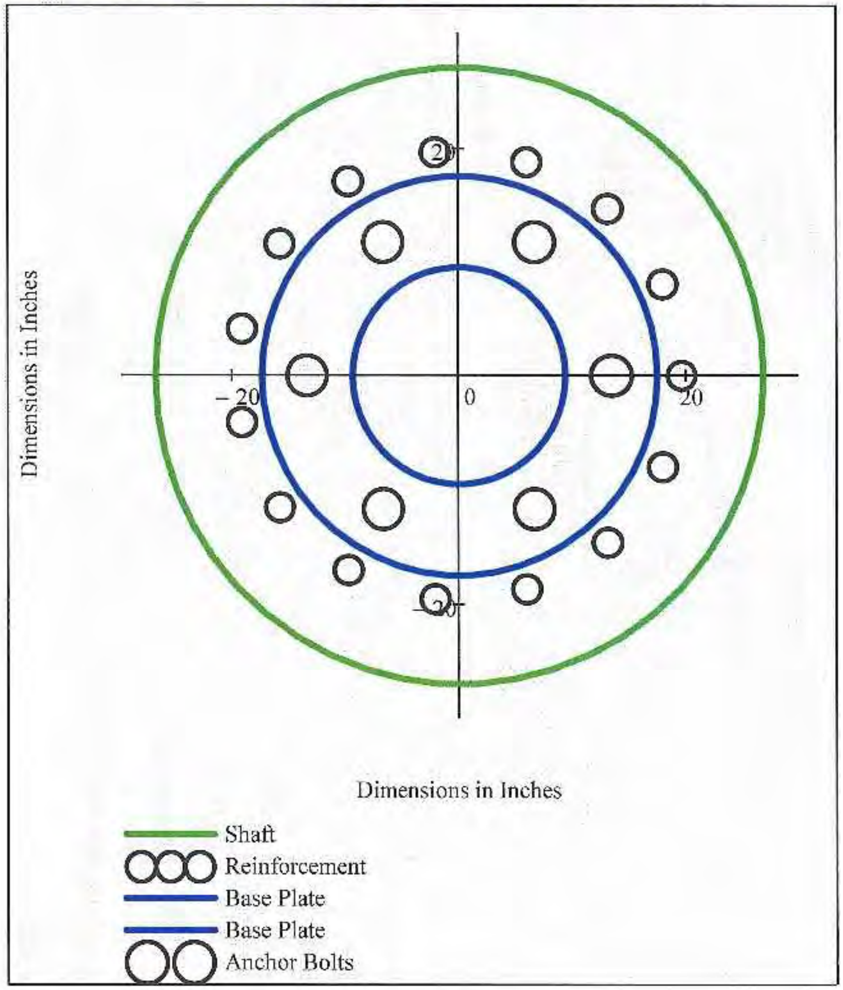
$b_{\text{conn.plate}_1} = 0 \cdot \text{in}$

$t_{\text{vertical.plate}_1} = 0 \cdot \text{in}$

$\text{Offset}_{\text{conn}_1} = 0 \cdot \text{in}$

$\text{Gap}_1 = 0 \cdot \text{in}$

Plan View - Drilled Shaft, Base Plate, Anchor Bolts, & Reinforcing Steel



$Diameter_{base.pole} = 19 \cdot in$

$Diameter_{baseplate.pole} = 35 \cdot in$

$Diameter_{shaft} = 54 \cdot in$

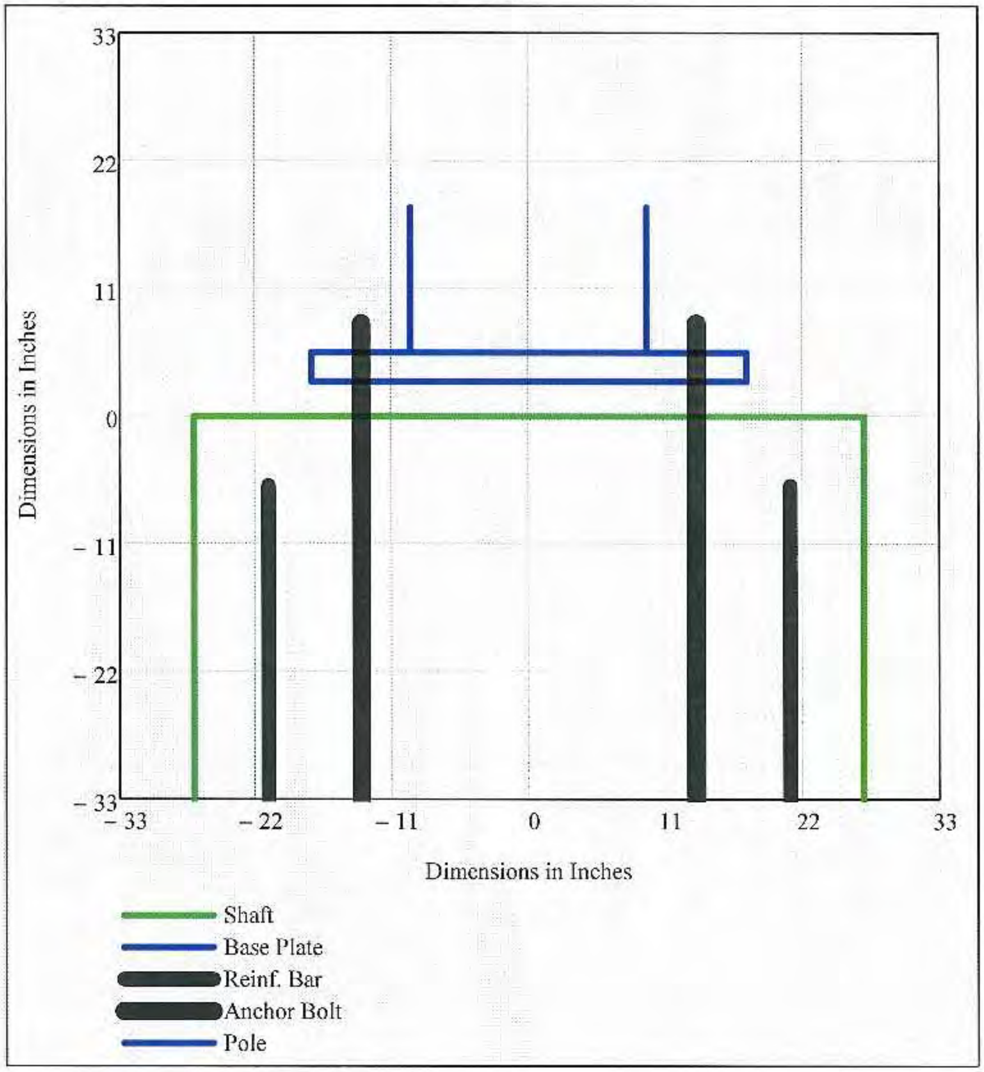
$Diameter_{boltcircle.pole} = 27 \cdot in$

$Diameter_{rebar.circle} = 39.34 \cdot in$

#AnchorRods = 6

#BarsProvided = 15

Elevation View - Drilled Shaft, Base Plate, Anchor Bolts, & Reinforcing Steel



$\text{Diameter}_{\text{base.pole}} = 19.00 \cdot \text{in}$

$\text{Diameter}_{\text{baseplate.pole}} = 35.00 \cdot \text{in}$

$t_{\text{baseplate.pole}} = 2.50 \cdot \text{in}$

$\text{Diameter}_{\text{shaft}} = 4.50 \cdot \text{ft}$

$\text{Diameter}_{\text{boltcircle.pole}} = 27.00 \cdot \text{in}$

$\text{Diameter}_{\text{rebar.circle}} = 39.3 \cdot \text{in}$

Section 6: Table of Variables

STANDARD MAST ARM ASSEMBLIES DATA TABLE

Table Date 01-01-12

STRUCTURE ID NUMBERS	ASSEMBLY NUMBERS (1)	FIRST ARM			SECOND ARM			UF (deg)	LL (deg)	POLE				SPECIAL DRILLED SHAFT (4)					
		ARM TYPE	FAA(2) (ft.)	FBA(2) (in.)	ARM TYPE	FAA(2) (ft.)	FBA(2) (in.)			POLE TYPE	UAA(3) (ft.)	UB (ft.)	UCA(3) (in.)	DA (ft.)	DB (ft.)	RA	RB	RC	RD (in.)
1-1	E1-T1	E1	–	–	–	–	–	–	–	T1	21.5	20.0	10.99	13.0	4.0	11	12	7	12
1-2	E7-T6	E7	38	7.72	–	–	–	–	–	T6	22.0	20.5	18.92	19.0	4.5	11	15	20	8
1-3	E1-T1	E1	–	–	–	–	–	–	–	T1	22.0	20.5	10.92	13.0	4.0	11	12	7	12
1-4	E5-T3	E5	30	6.94	–	–	–	–	–	T3	22.0	20.5	15.92	15.0	4.5	11	15	12	9

TABLE NOTES:

1. Assembly Number Legend

   Single Arm:
   Arm Type – Pole Type = D# – S#
   = E# – T#

   Double Arm:
   First Arm Type – Second Arm Type – Pole Type = D# – D# – S#
   = E# – E# – T#

2. If an entry appears in columns "FAA" and "FBA", a shorter arm is required. This is obtained by removing length from the arm tip. For these cases the mast arm length shall be shortened from "FA" to "FAA" and the tip diameter shall be increased from "FB" to "FBA".

3. If an entry appears in columns "UAA" and "UCA", a shorter pole is required. This is obtained by removing length from the pole tip. For these cases the pole height shall be shortened from "UA" to "UAA" and the pole tip diameter shall be increased from "UC" to "UCA".

4. The foundations for Standard Mast Arm Assemblies have been designed based on geotechnical information provided by Dunkelberger Engineering and Testing, Inc. Values used in design:

   Soil Classification = Cohesionless (Fine Sand)
   Friction Angle = 28 Degrees (26 Degrees Minimum)
   Unit Weight = 37.6 lbs. / cu. ft. (assumed submerged)(Minimum)

GENERAL NOTES:

1. Work this sheet with the Signal Designer's "Mast Arm Tabulation". See "Mast Arm Tabulation" for special instructions that include non-standard Handhole location, paint color, terminal compartment requirement, and pedestrian features.
2. Work with Interim Standard Index No. 17743 and 17745.
3. Design Wind Speed = 130 mph.

MIGUEL A. VILLEGAS
No. 68768

NO.	DESCRIPTION	BY	DATE

MANATEE COUNTY

CORTEZ RD. W. AT 86TH STREET
IMPROVEMENTS
FP ID: 429867-1-58-01

Cardno TBE
380 Park Place Blvd., Suite 300, Clearwater, Florida 33759
www.cardnotbe.com – 727.531.3505
Certificate of Authorization No. 3843

1/25/15
MIGUEL A. VILLEGAS, PE
LIC. NO.: 68768 DATE

DESIGNED MAV
DRAWN JJH
Q.C.
APPROVED

TABLE OF VARIABLES FOR
STANDARD MAST ARM
ASSEMBLIES

PROJECT NO.: 00193-008-015
DATE: 01-25-2015
SHEET NO.: T-10