MODIFIED BY EI 83-039
EFFECTIVE 1/12/84 & EI 86-032
EFFECTIVE 2/19/87
SUPERSEDED BY EI 22-011
EFFECTIVE 4/27/22

ENGINEERING INSTRUCTION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

SUBJECT: METHOD FOR CALCULATING THE LOADS APPLIED TO SPAN WIRE TRAFFIC SIGNAL POLES

Subject Code: 7.27-1-680

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APPROVED:

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This method shall be used to determine the pole load for span wire traffic signal poles. It is the same method contained in EI 76-43; but, has been modified to delete the "Min. Load Capacity at Yield" calculation (see EI 79-37).

This method shall apply to traffic signals and/or signs suspended on a cable between poles with attachment points at the same elevation. The length of the poles need not be equal; however, in such cases, the stiffness of the stiffer pole shall be used. The suspension system may include a tether wire strung between the poles.

A. DEAD LOADS

The method used for dead load on the pole (H) is the conventional simple beam analogy and is as follows:

After determining the individual dead loads and points of application, find the left and right reactions, as a simple beam, and solve for the load on the pole (H) by taking moments at the point of zero shear. The sag is made equal to 5% of the span.

Step 1. Determine the location of, and magnitude of the dead loads on the cable, the sag of the cable and the span. Include a portion of the weight of the cable in each load.

Step 2. Resolve the moments of the dead loads at each pole attachment point and determine the left and right reactions.

Step 3. Determine the point of zero shear of the dead loads on the cable.

Step 4. Resolve moments of the dead loads about the point of zero shear and determine the value of the horizontal reaction (H) at the attachment point on the pole.

B. WIND LOADS

To determine the wind load on a pole, an equivalent cable system is developed with a single concentrated load at the center of an imaginary cable. (known as the modified Nebraska method). An equivalent system is used because it is much easier to deal with than the actual loading and provides acceptable accuracy. The concentrated load in the imaginary cable is determined using the horizontal sag caused by the deflection of the pole and the strain of the cable. The load used on the imaginary cable is the total horizontal wind load reduced by a factor. The factor is determined using the dead loads and the dead load cable configuration. It involves computing the single concentrated dead load which will cause a cable dead load equal to the actual cable dead load. The factor is equal to the equivalent concentrated dead load divided by the actual total dead load. This method is outlined below:

Step 5. Determine the wind pressure on the signals and/or signs by formula:

Pressure = $.00256\ (1.3V)^2\ C_d\ C_h$

Where V = Wind velocity from §724-03 (Standard Spec. Book)

C_d = Shape coefficient from AASHTO

C_h = Height coefficient from AASHTO

SHAPE AND HEIGHT COEFFICIENTS
PER AASHTO

Height Coefficient (C_h)

Height(ft)	Ch
0-15	0.80
15-30	1.00
30-50	1.10

Shape Coefficient (C_d)

Type of Member	Cd
Traffic Signals	1.2
Sign Panel-L/W	
1.0	1.12
2.0	1.19
5.0	1.20
Cable	1.10

Step 6. Determine the location of, and magnitude of the wind loads on the cable. Include the wind on the cable. (See page 7).

Step 7. Determine the total wind load (W) by taking the summation of the individual wind loads on the cable.

Step 8. Compute the reduction factor from dead loads by using formula:

$$\text{Reduction Factor} = \frac{4\ P_{CZ}\ Z}{X_i\ P_{d1}}$$

Where

P_{CZ} = Cable dead load

Z = Sag

X_i = Span

P_{d1} = Total dead load $R_L + R_R$

Step 9. Determine P_y = W x Reduction Factor and solve for

$$PC_y = 3\sqrt{\frac{75\ X_i\ P_y^2}{d_p + d_c}}$$, the load on the pole.

Where

P_y = Equivalent wind load

X_i = Span

d_p = Deflection rate of pole (in/100 lbs)

d_c = Deflection rate of cable (in/100 lbs)

C. ICE LOADS

The ice load on the pole shall be determined by the same method as for dead load using ice as 3#/s.f/ on all sides and top of signals and cable and 3#/s.f. on one side of signs.

Step 10. Determine horizontal load (H) due to ice in the same manner used to compute dead load H (Steps 1-4).

D. APPLICATION OF LOADS

The loads (dead, wind, ice) shall be combined in groups as per Table 1.2.6-Group Loading of AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires and Traffic Signals to analyze a pole and its components. Determine which of the group loads is critical.

REFERENCE: STANDARD SPECIFICATIONS FOR STRUCTURAL SUPPORTS FOR HIGHWAY SIGNS, LUMINAIRES AND TRAFFIC SIGNALS. AASHTO, 1975

An example of this method using hand calculations is given on pages 4-14. Additionally, this method can be performed using the TI 59 calculator and programmed cards. Five programmed cards and a manual entitled "Span Wire Analysis for Traffic Signals" were distributed separately to Regional Design Engineers on June 14, 1983.

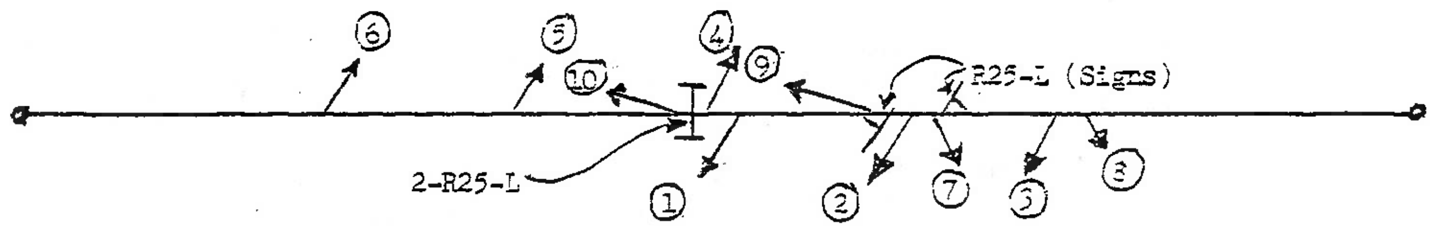
SIGNAL & SIGN LAYOUT

WEIGHT:

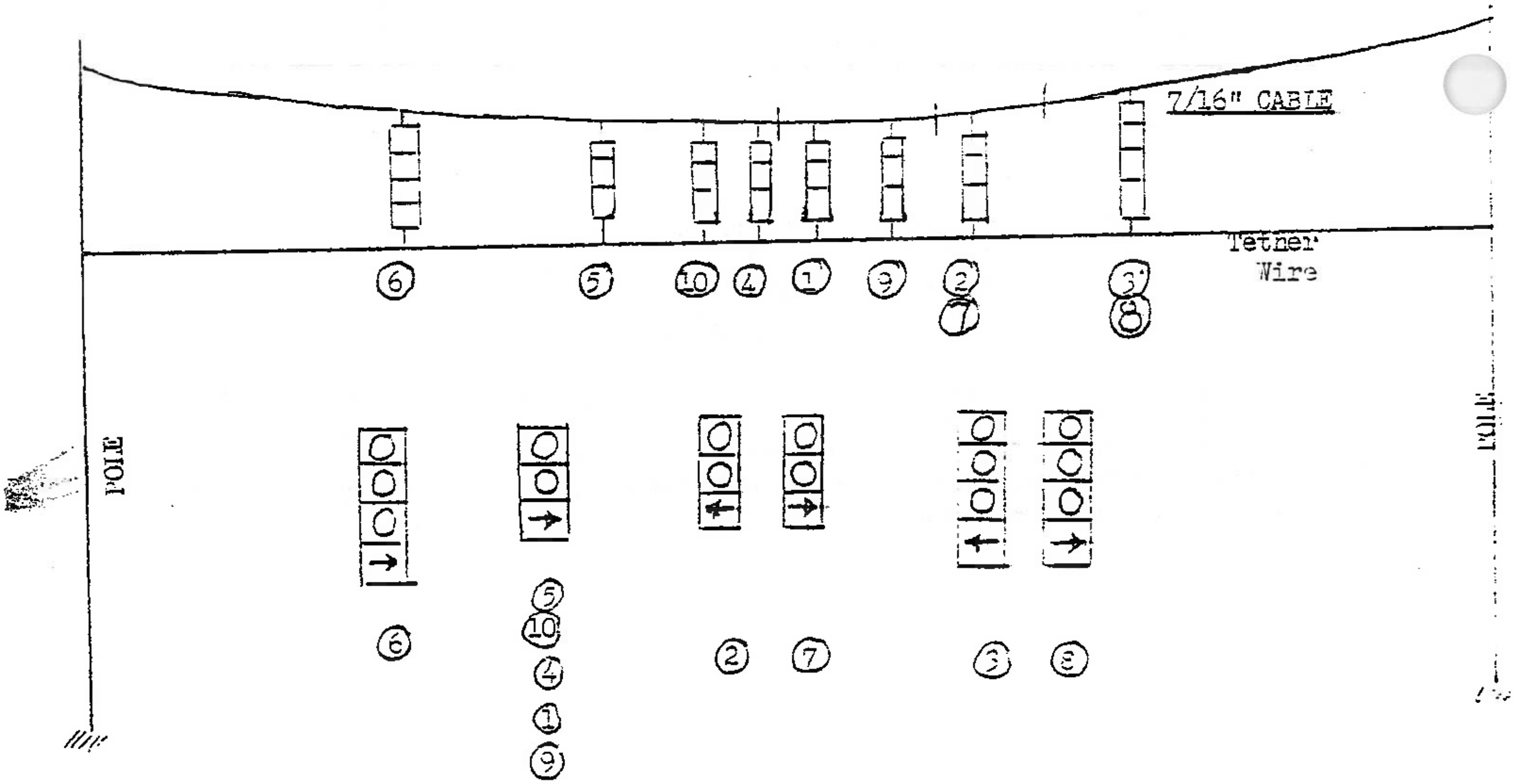
SIGNAL = 14#
HANGER = 8#

KEY:

SIGNAL →
SIGN ⊢



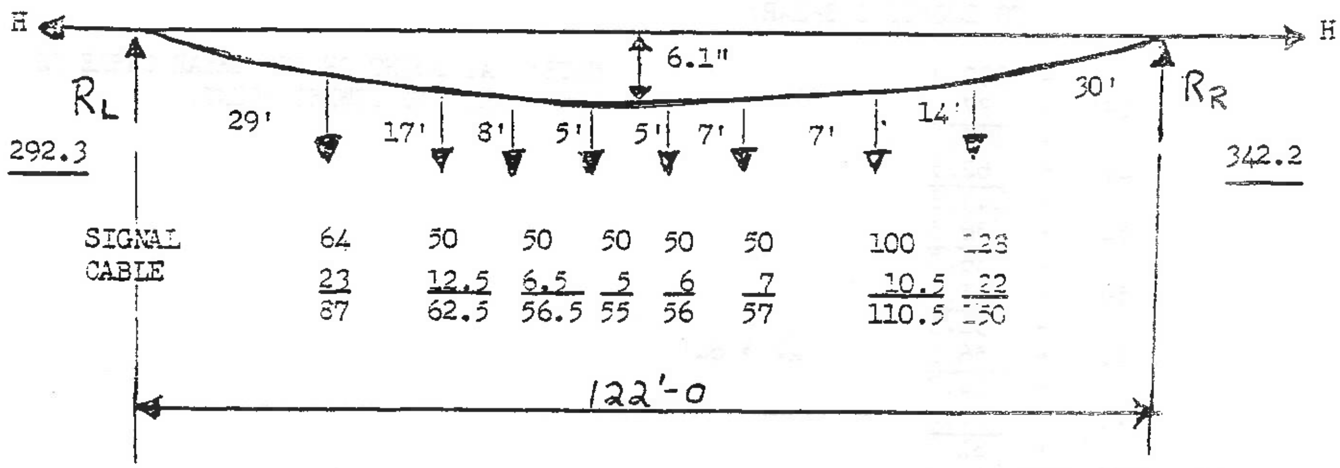
PLAN



D.L. HD.	4 x 14 = 56	3 x 14 = 42	3 x 14 = 42 3 x 14 = 42	4 x 14 = 56 4 x 14 = 56
HANGER	1 x 8 = 8	1 x 8 = 8	1 x 8 = 8 1 x 8 = 8	2 x 8 = 16
	64#	50#	100#	128#
WIND	4 x 23 = 92#	3 x 23 = 69#	6 x 23 = 138#	8 x 23 = 184#

NOTE: DEAD LOAD OF SIGNS ASSUMED TO BE INSIGNIFICANT FOR THIS DESIGN.

DEAD LOAD OF SIGNALS



SAG = 5% = 6.1'
D.L CABLE = 1.0#/FT.
D.L. HEADS FROM REGION

$$\Sigma M_L = 87 \times 29 + 62.5 \times 46 + 56.5 \times 54 + 55 \times 59 + 56 \times 64 + 57 \times 71 + 110.5 \times 78 + 150 \times 92$$

$$- R_R \times 122' = 0$$

$$R_R \times 122 = 2523 + 2875 + 3051 + 3245 + 3584 + 4047 + 8619 + 13{,}800$$

$$R_R = \frac{41744}{122} = \underline{342.2\#}$$

$$\Sigma M_R = R_L \times 122' - 87 \times 93 - 62.5 \times 76 - 56.5 \times 68 - 55 \times 63 - 56 \times 58 - 57 \times 51 - 110.5 \times 44$$

$$-150 \times 30 = 0$$

$$= R_L \times 122 - 8091 - 4750 - 3842 - 3465 - 3248 - 2907 - 4862 - 4500$$

$$R_L = \frac{35665}{122} = \underline{292.3\#}$$

NOTE: AT POINT OF "O" SHEAR CABLE IS AT ITS LOWEST POINT.

TO LOCATE O SHEAR:

	-	292.3	
29'	+	87.	
	-	205.3	
46'	+	62.5	
	-	142.8	
54'	+	56.5	
	-	86.3	
59'	+	55.	
	-	31.3	
64'	+	56.0	AV @ 64'
	+	24.7	
71'	+	57.0	
	+	81.7	
78'	+	11[illegible]5	
	+	192.2	
92'	+	150.	
	+	342.2	OK
122'			

$$\Sigma M_{64} = 55 \times 5' + 56.5 \times 10' + 62.5 \times 18' + 87 \times 35' - 292.3 \cdot 64' + H6.1 = 0$$

$$= 275 + 565 + 1125 + 3045 - 18707.2 + H \times 6.1$$

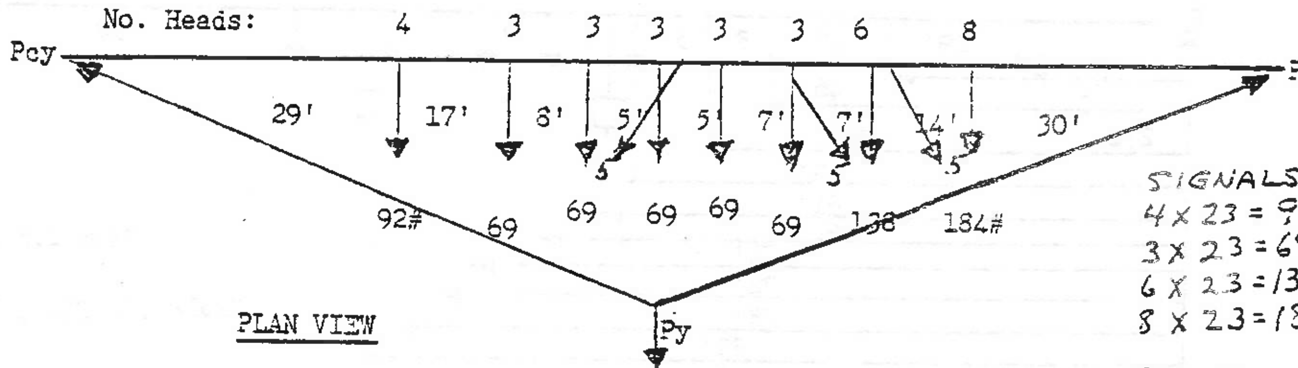
$$H = \frac{18707.2 - 5010}{6.1} = \underline{2245}^{\#}$$

SIGNALS
4 x 23 = 92
3 x 23 = 69
6 x 23 = 138
8 x 23 = 184

SIGNS
2.5x3x23 = 172

WIND LOAD

ASSUME: 23 #/S.F.



SIGNALS
4 x 23 = 92
3 x 23 = 69
6 x 23 = 138
8 x 23 = 184

SIGNS
2.5 x 3 x 23 = 172.

WIND ON CABLE = 4.88 S.F. x 15 #/S.F. = 73.2#

TOTAL WIND LOAD ΣW = 92 + 5·(69) + 3·(172.5) x .707 + 138 + 184 + 73.2 =

92 + 345 + 365.9 + 138 + 184 + 73.2 = 1198.1# = Py   Pw   Terry Hale

$$Py = \Sigma W \times \text{REDUCTION FACTOR}$$

* REDUCTION FACTOR = $\dfrac{4\ Pcz\ S}{X_i \times Pdl} = \dfrac{4 \times 2271 \cdot 6.1}{122 \times 634.5} = .7158$

$$Pcz = \sqrt{H^2 + R^2_{MAX}} = \sqrt{2245^2 + 342.2^2} = 2271\#\ \ D.L.$$

$$Py = 1198.1 \times .7158 = 857.6\#$$

* $Pcy = \sqrt[3]{\dfrac{75\ X_i\ Py^2}{d_p + d_c}} = \sqrt[3]{\dfrac{75 \cdot 122 \cdot 857.6^2}{.19 + .03}} = 3210\#$

* SEE DERIVATION OF THESE FORMULAE, PAGE 10-11.

X_i = SPAN

Pcz = FORCE IN CABLE DUE TO WT. OF SIGNALS, SIGNS, & CABLE

d_p = DEFLECTION RATE OF POLE ("/100#) = $\dfrac{\text{MAX DEFL.} \times 100}{Pcz \times 2.5} \times .7$

d_c = DEFLECTION RATE (STRAIN) OF CABLE ("/100#)

Pdl = TOTAL WT. OF SIGNALS, SIGNS AND CABLE = $R_1 + R_2$.

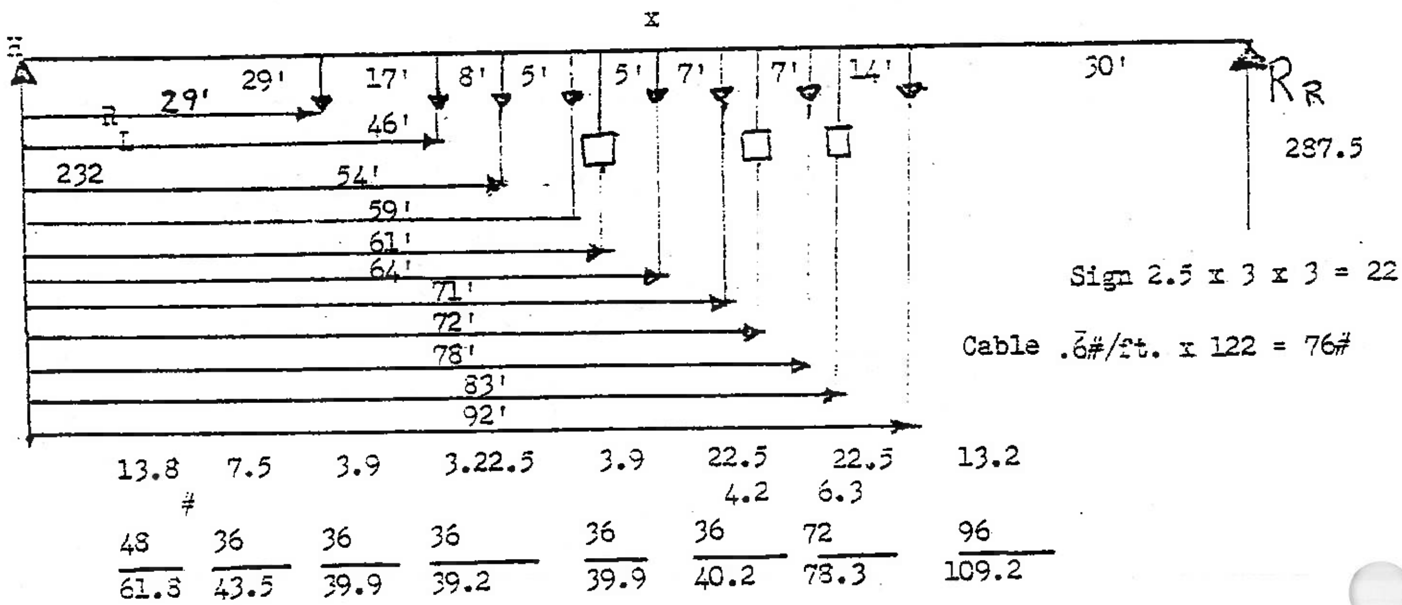
Subject: METHOD FOR CALCULATING THE LOADS APPLIED TO SPAN WIRE TRAFFIC SIGNAL POLES

ICE LOAD

3#/sf - ALL SIDES OF SIGNALS

3#/sf - ONE SIDE OF SIGNS

6.1' SAG



ΣM_L = 61.8 x 29 + 43.5 · 46 + 39.9 · 54 + 39.2 · 59 + 39.9 · 64 + 40.2 · 71 - 78.3 · 78 + 109.2 x 92 + 22.5 (61 + 72 + 83) — R_R · 122' = 0

R_R = 287.5#

R_L = 519.5 - 287.5 = 232#

POINT OF 0 SHEAR IS AT 64' FROM LEFT (See Next Page)

ΣM_{64} = 22.5 x 3 + 39.2 x 5 + 39.9 x 10 + 43.5 x 13 - 61.8 x 35 - 232 x 64 + H x 6.1 = 0

-H x 6.1 = 67.5 + 196 + 399 - 783 + 2163 - 14848

= 3608.5 - 14,848 = -11,239.5

H = 1842.5 DUE TO ICE ONLY

ICE LOAD (CONTINUED)

TO LOCATE O SHEAR

	- 232.2	
29'	+ 61.8	
	- 170.2	
46'	+ 43.5	
	- 126.7	
54'	+ 39.9	
	- 86.8	
59'	+ 39.2	
	- 47.6	
61'	+ 22.5	
	- 25.1	
64'	39.9	O SHEAR
	+ 14.8	

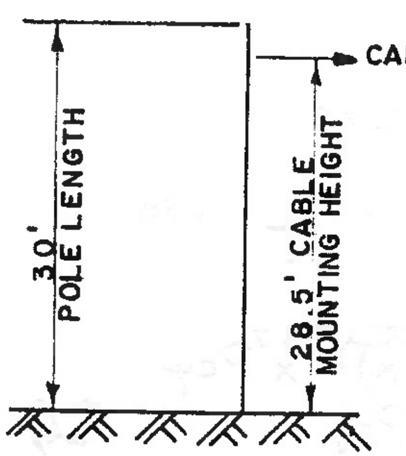
GROUP LOADING (AASHTO)

GROUP I = D.L. H = 2245 #

GROUP II = D.L. + WIND H = 2245 + 3210 = 5455#

GROUP III = D.L. + ICE + ½ WIND H = 2245 + 1842.5 + $\frac{3210}{2}$ = 5692.5

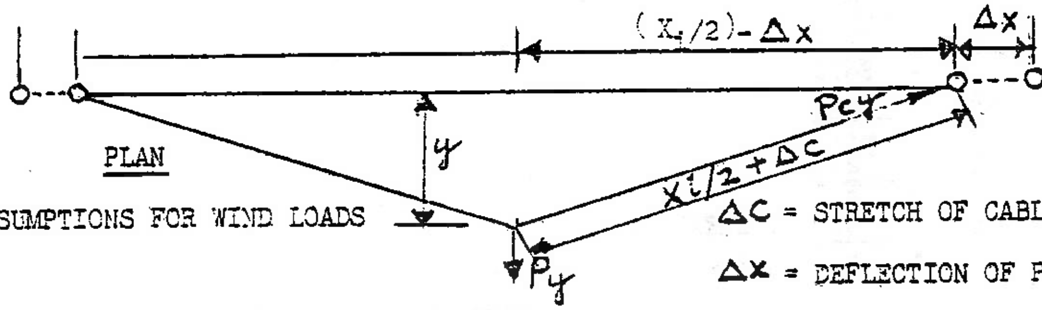
The greater of either the Group II or Group III loading rounded up to the next higher thousand pounds should be used to design the pole and footing. Therefore, in this example the Group III loading would be the design load rounded upward to 6,000 pounds. This load should be the load coded into the pay item for the pole and used in conjunction with the height of the cable attachment point to compute the moment at the footing.



M base = 6,000 X 28.5 = 171,000 ft. lbs.

DERIVATION OF FORMULA
FOR WIND LOAD

DESIGN ANALYSIS FOR SPAN WIRE TRAFFIC SIGNAL SUPPORT



ASSUMPTIONS FOR WIND LOADS

ΔC = STRETCH OF CABLE

Δx = DEFLECTION OF POLE

Pcy = LOAD ON CABLE

$$y = \sqrt{\left(\frac{xi}{2} + \Delta c\right)^2 - \left(\frac{xi}{2} - \Delta x\right)^2}$$

$$= \sqrt{\left(\frac{xi^2}{4} + xi\,\Delta c + \Delta c^2\right) - \frac{xi^2}{4} + xi\,\Delta x - \Delta x^2}$$

$$= \sqrt{xi\,\Delta c + xi\,\Delta x + \cancel{\Delta c^2} - \cancel{\Delta x^2}}$$

Δc^2 & Δx^2 SMALL ENOUGH TO BE NEGLECTED.

Pcy = CABLE LOAD DUE TO WIND

Py = SUMMATION OF THE WIND LOADS x F = P_w x F

$$Py = 2 \cdot Pcy \cdot \frac{y}{X_i/2} = \frac{4y}{X_i} \times Pcy$$

SUBSTITUTE FORMULA FOR y

$$Py = \frac{4}{xi}\left(xi\,\Delta c + xi\,\Delta x\right)^{1/2} \times Pcy$$

$$= 4\left(\frac{\Delta c}{xi} + \frac{\Delta x}{xi}\right)^{1/2} \times Pcy \qquad (2)$$

LET d_p = DEFLECTION RATE FOR POLES ("/100#)

THEN $\Delta x = \dfrac{d_p\ Pcy}{1200}$

LET d_c = DEFLECTION RATE FOR CABLE ("/100#)

THEN $\Delta c = \dfrac{d_c \; Pcy}{1200}$

SUBSTITUTE Δc & Δx IN FORMULA (2)

$$Py = 4\left(\frac{d_p \times Pcy^3}{1200\, X_i} + \frac{d_c \; Pcy^3}{1200\, X_i}\right)^{1/2}$$

$$Py^2 = 16\left(\frac{d_p \; Pcy^3}{1200\, X_i} + \frac{d_c \; Pcy^3}{1200\, X_i}\right)$$

$$Py^2 = \frac{16\; Pcy^3}{1200\, X_i}\left(d_p + d_c\right)$$

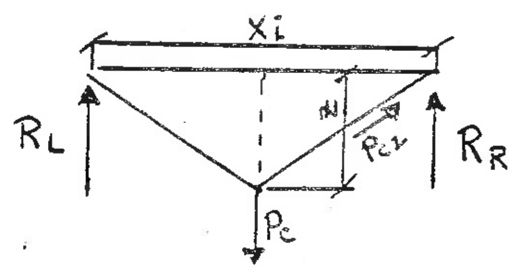
$$Pcy^3 = \frac{1200\, X_i\; Py^2}{16\,(d_p + d_c)}$$

$$Pcy = \sqrt[3]{\frac{75\, X_i\; Py^2}{d_p + d_c}}$$

<u>DERIVATION OF REDUCTION FACTOR - F</u>
<u>(Based on Dead Load Configuration)</u>

$$\frac{\frac{1}{2}\, Pe}{Z} = \frac{Pcz}{X_i/2}$$

$$Pc = \frac{4\; Z\; Pcz}{X_i}$$



$$\text{REDUCTION FACTOR} = \frac{Pe}{Pdl} = \frac{4\; Z\; Pcz}{X_i\; Pdl} = F$$

WHERE X_i = CABLE SPAN
Z = CABLE SAG
(CONTINUED)

P_{cz} = FORCE IN CABLE DUE TO THE WEIGHT OF THE SIGNALS, SIGNS, AND CABLE.

P_e = SINGLE CONCENTRATED LOAD AT THE CENTER OF SPAN WHICH WILL CAUSE APPROXIMATELY THE SAME CABLE LOAD AS THE WEIGHTS OF THE SIGNALS, SIGNS AND CABLE.

P_{DL} = WEIGHT OF ALL THE SIGNALS, SIGNS, AND CABLE.

P_W = TOTAL WIND LOAD ON SIGNALS, SIGNS, AND CABLE.

Method For Determining
Load To Be Shown On Plans
(Characteristics Of Pole Not Known)

Refer to Page 7 of the Example:

The deflection rate of the cable per 100 lbs. is computed as follows:

$$\text{Strain} = \frac{\text{Stress}}{E} = \frac{100}{AE}$$

$$d_c = \frac{X_1}{2} \times 12 \text{ in.} \times \frac{100}{A\,E} \quad \text{(in/100 lb.)}$$

for 7/16" dia., 7 strand cable $A = .117 \text{ in}^2$
$E = 21{,}000{,}000$

for this example: $d_c = \frac{122}{2} \times 12 \times \frac{100}{.117 \times 21{,}000{,}000} = .03 \text{ in/100 lb.}$

Instead of using a value of d_p (deflection rate of pole), for a particular pole, use the following formula to determine d_p:

$$d_p = \frac{\text{MAX. Allowable DEFLECTION} \times 100}{P_{cz} \times 2.5} \times 0.7$$

Where - Maximum allowable deflection is given in § 724-03.

P_{cz} = Force in cable due to weight of signals, signs, and cable (from Pg. 7, Example).

This will give a conservative value for P_{cy} (wind load on pole) which is used when combining Group II and Group III loads on Page 5, and thus a slightly more conservative design. However, this method eliminates the need to select a pole in order to determine the load.

Example: (Pg. 7)

$$d_p = \frac{15" \times 100}{2245 \times 2.5} \times 0.7 = .19$$

$$P_{cy} = \sqrt{\frac{75.122.357.6^2}{.19 + .03}} = 3210$$

Refer to Page 9 of the Example:

Group Loading (AASHTO)

Group I = DL, H = 2245# (from Page 6)

Group II = DL + WIND, H = 2245 + 3210 = 5455#

Group III = DL + ICE + 1/2 WIND, H = 2245 +1842.5 + $\frac{3210}{2}$ = 5692.5

The Group II or III loading will govern for traffic signal loading. Select the larger of the Group II or III loads increased to the next larger 1000 lb. increment; as the pole design load to be specified in the contract documents.