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ENGINEERING INSTRUCTION

NEW YORK STATE DEPARTMENT OF TRANSPORTATION

SUBJECT: METHOD FOR CALCULATING THE LOADS APPLIED TO TYPE A TRAFFIC SIGNAL POLES CARRYING SUSPENDED CABLES

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Addendum 3 to the Standard Specifications has made it necessary to stipulate the design load for traffic signal poles.

This method shall apply to traffic signals and/or signs suspended on a cable between poles. The method shall apply only when attachment points are 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 wind zone map

C_d = Shape coefficient from AASHTO

C_h = Height coefficient from AASHTO

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

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:

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

Where

P_{CZ} = Cable dead lo

Z = Sag

X_i = Span

P_{dL} = Total dead lo $R_L + R_R$

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

$$PC_y = \sqrt[3]{\frac{75\ X_i\ \ P_y^{\ 2}}{d_p + d_c}}$$, 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.

For an example of the methods, see computations for project PIN 1040.10, latest revision 2/26/76 (9 sheets) and addendum.

For derivation of formulas used, see "Derivation of Formula for Wind Load", latest revision 2/26/76.

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

MDG:WCD:FS

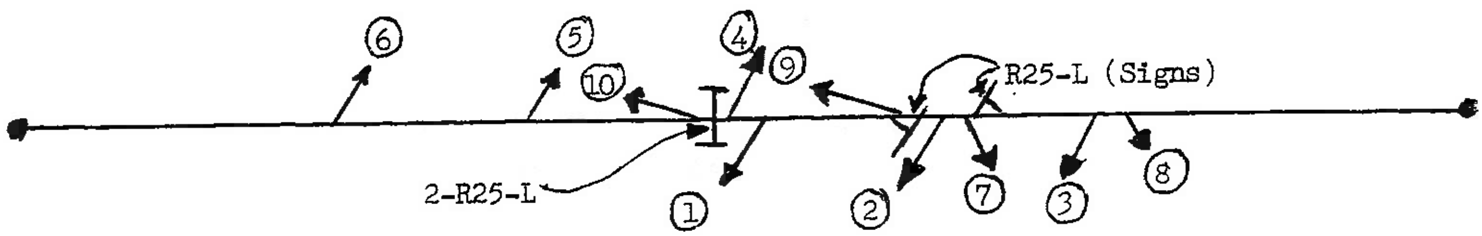
PIN 1040.10

SIGNAL & SIGN LAYOUT

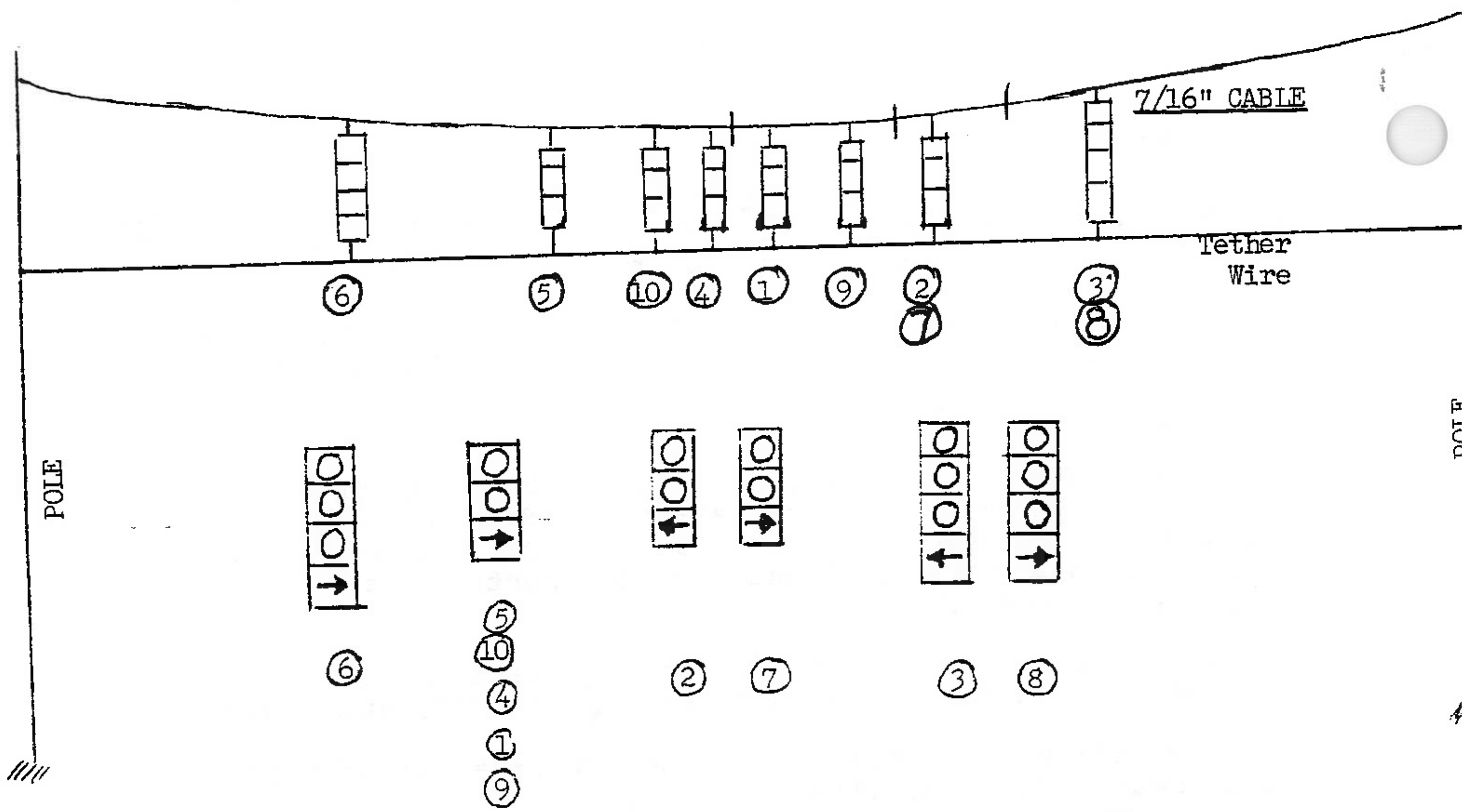
WEIGHT:

SIGNAL = 14#
HANGER = 8#

KEY:
SIGNAL →
SIGN ⊢



PLAN

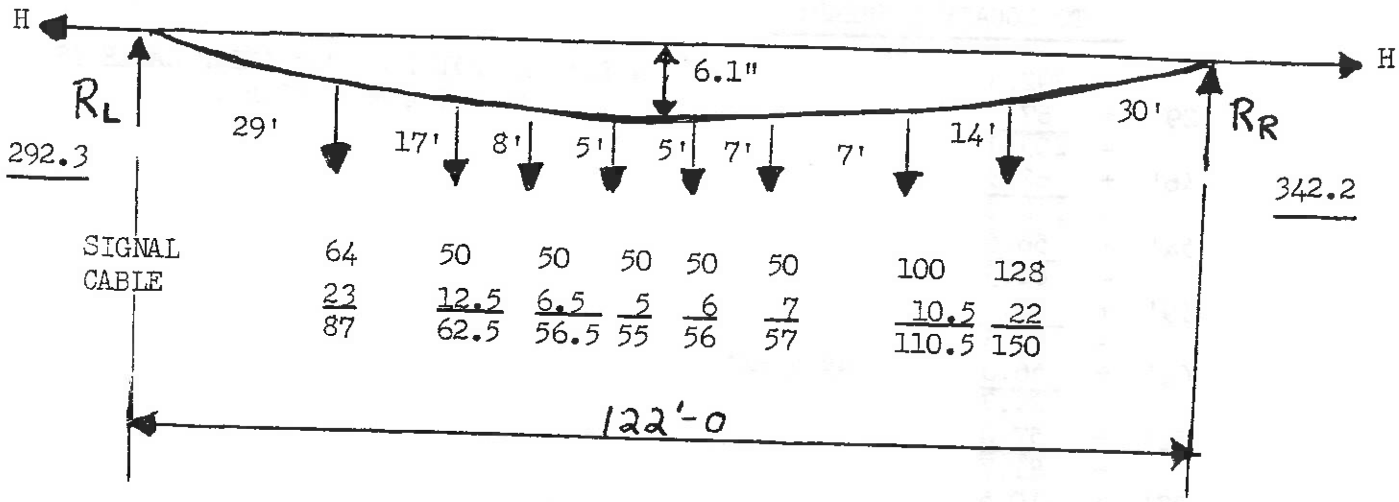


D.L. HD. HANGER	4 x 14 = 56	3 x 14 = 42	3 x 14 = 42	4 x 14 = 56
	1 x 8 = 8	1 x 8 = 8	3 x 14 = 42	4 x 14 = 56
			1 x 8 = 8	2 x 8 = 16
			1 x 8 = 8	
	64#	50#	100#	128#

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

M_L = 87 x 29 + 62.5 x 46 + 56.5 x 54 + 55 x 59 + 56 x 64 + 57 x 71 + 110.5 x 78 + 150 x 92

− R_R x 122' = 0

R_R x 122 = 2523 + 2875 + 3051 + 3245 + 3584 + 4047 + 8619 + 13,800

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

M_R = R_L x 122' − 87 x 93 − 62.5 x 76 − 56.5 x 68 − 55 x 63 − 56 x 58 − 57 x 51 − 110.5 x 44

−150 x 30 = 0

= R_L x 122 − 8091 − 4750 − 3842 − 3465 − 3248 − 2907 − 4862 − 4500

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

TO LOCATE 0 SHEAR:

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

	-	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'	+	110.5	
	+	192.2	
92'	+	150.	
	+	342.2	OK
122'			

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

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

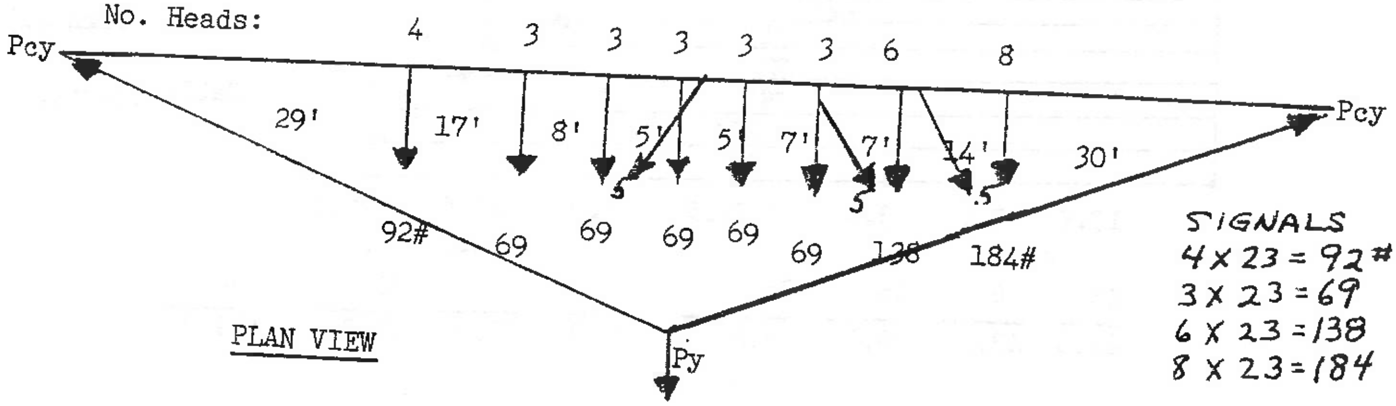
$$H = \frac{18707.2-5010}{6.1} = \underline{2245}^{\#}$$

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

SIGNS
2.5x3x23 = 17

WIND LOAD

ASSUME: 23 #/S.F.



PLAN VIEW

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 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

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

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

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

Py = 1198.1 x .7158 = 857.6#

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

* 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#) = $\frac{\text{MAX DEFL.} \times 100}{Pcz \times 2.5} \times .7$

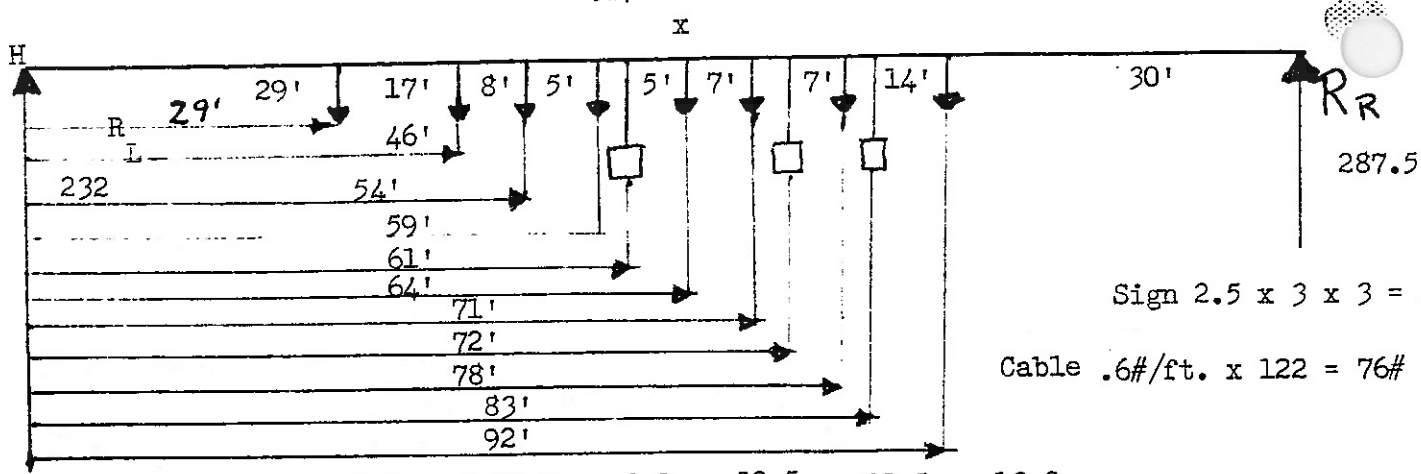
d_c = DEFLECTION RATE (STRAIN) OF CABLE ("/100#)

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

ICE LOAD

3#/sf - ALL SIDES OF SIGNALS
3#/sf - ONE SIDE OF SIGNS

6.1' SAG



Sign 2.5 x 3 x 3 = 2

Cable .6#/ft. x 122 = 76#

13.8 #	7.5	3.9	3.22.5	3.9	22.5 4.2	22.5 6.3	13.2
48	36	36	36	36	36	72	96
61.8	43.5	39.9	39.2	39.9	40.2	78.3	109.2

$$\Sigma M_L = 61.8 \times 29 + 43.5 \cdot 46 + 39.9 \cdot 54 + 39.2 \cdot 59 + 39.9 \cdot 64 + 40.2 \cdot 71 + 78.3$$
$$\cdot 78 + 109.2 \times 92 + 22.5\,(61 + 72 + 83) - R_R \cdot 122' = 0$$

$$R_R = 287.5\#$$

$$R_L = 519.5 - 287.5 = 232\#$$

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

$$\Sigma M_{64} = 22.5 \times 3 + 39.2 \times 5 + 39.9 \times 10 + 43.5 \times 18 + 61.8 \times 35$$
$$- 232 \times 64 + H \times 6.1 = 0$$

$$-H \times 6.1 = 67.5 + 196 + 399 + 783 + 2163 - 14848$$
$$= 3608.5 - 14,848 = -11,239.5$$

H = 1842.5 DUE TO ICE ONLY

ICE LOAD (CONTINUED)

TO LOCATE 0 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	0 SHEAR
	+	14.8	

GROUP LOADING (AASHTO)

GROUP I = D.L.   H = 2245 # (Pg. 2)

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

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

F_A (GROUP I) = .66 x 55,000 = 36,3000 psi   ALLOWABLE

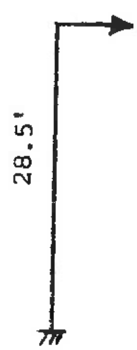
F_A (GROUP II,III) = 1.40 x .66 x 55,000 = 50,820 psi   "

MOMENT ON POLE AT BASE

NOTE: THE EFFECT OF THE TETHER WIRE IS IGNORED IN THE DESIGN.

Cable Force

Applied Here



M_{base} Group I = 2245 x 28.5 = 63,983 ft/lbs

M_{base} Group II = 2245 x 28.5 + 3210 x 28.5 = 155,468 ft/lbs

M_{base} Group III = (2245 + 1843 + 1605) 28.5 = 162,251 ft/lbs

$S_{req.}$ (Group I) = 12 x 63,983/36,300 = 21.2 in.^{3}

$S_{req.}$ (Group II) = 12 x 155,468/50,820 = 36.7 in.^{3}

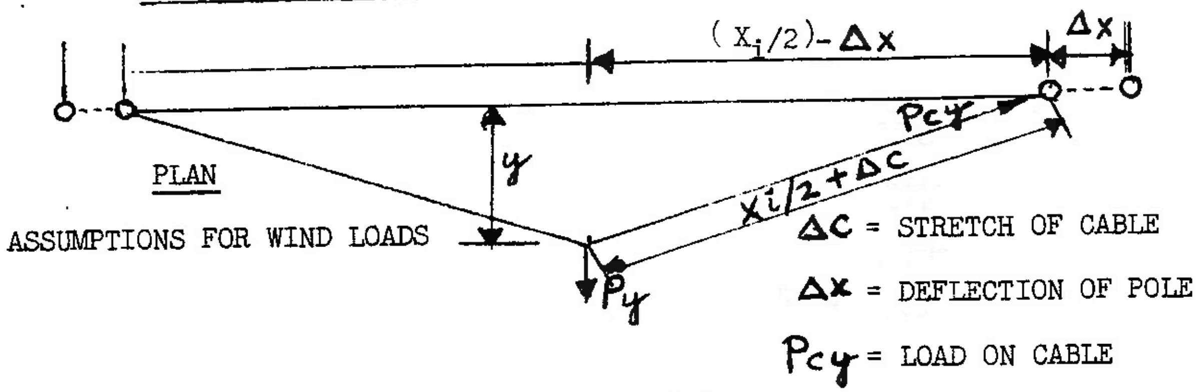
$S_{req.}$ (Group III) = 12 x 162,251/50,820 = 38.3 in.^{3}

Group III is critical load.

∴ Use a 30' long "0" gauge pole (S = 38.6 in.^{3}).

DERIVATION OF FORMULA
FOR WIND LOAD

DESIGN ANALYSIS FOR SPAN WIRE TRAFFIC SIGNAL SUPPORT



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

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

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

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 $$\Delta x = \frac{d_p\,Pcy}{1200}$$

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

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

SUBSTITUTE Δc & Δx IN FORMULA (2)

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

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

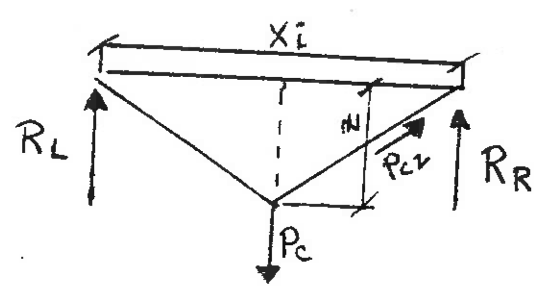
$$Py^2 = \frac{16\; Pcy^3}{1200\, X_i}\left(d_p + d_c\right)$$

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

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

DERIVATION OF REDUCTION FACTOR - F
(Based on Dead Load Configuration)

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



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

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

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.

ADDENDUM #1 TO STRAIN POLE ANALYSIS FOR PIN 1040.10 WHICH IS BEING USED AS A GUIDELINE FOR THIS TYPE OF ANALYSIS

Method For Determining
Load-At-Yield To Be Shown On Plans
(Characteristices Of Pole Not Known)

Refer to Page 7 of the Example:

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

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

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

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 N.Y.S. Specification Addendum No. 3 for each height pole.

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-at-yield.

Example: (Pg. 7)

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

$$P_{cy} = \sqrt{\frac{75.122.857.6^2}{.19 + .03}} = 3210$$

Refer to Page 5 of the Example:

Group Loading (AASHTO)

Group I = DL, H = 2245# (from Page 2)

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

Group III = DL + ICE + 1/2 WIND, $H = 2245 + 1845 + \frac{3210}{2} = 5693\#$

Determination of minimum load capacity at yield point (L):

For Group I : $L = \frac{2245}{.66} = 3402$ lbs.

Group II : $L = \frac{5455}{1.4x.66} = 5904$ lbs

Group III : $L = \frac{5693}{1.4x.66} = 6161$ lbs.

From the above, select the largest load. This load will be placed on the plans and labeled "Min. Load Capacity At Yield".

HBH:GD

3/10/76