APPENDIX 2

LOAD CALCULATIONS FOR TEST ON TOWER SEGMENT (Fig A2.1)

A2.1 NORMAL LOADING CONDITION (Fig A2.2 (a))

A.2.1.1 Calculation of vertical load on the segment

(i) Component due to transverse loads on the tower at TWLB = \( \frac{\Sigma Th}{a} \)

\[ \Sigma Th = \text{algebraic sum of the moments of the transverse loads on the tower about the section under consideration.} \]

\[ a = \text{base width of the section under consideration.} \]

\[ \Sigma Th = 1 \times 0.880 \times 38.07 + 2 \times 2.290 \times 33.22 + 2 \times 2.394 \times 28.02 + 2 \times 3.844 \times 22.82 + 1 \times 4.500 \times 4.614 \]

\[ = 516.012 \text{ tm} \]

\[ \frac{\Sigma Th}{a} = \frac{516.012}{6.9} = 74.784 \text{ t} \]

Load on one leg = \( \frac{74.784}{2} = 37.392 \text{ t} \)

(ii) Component due to vertical live loads acting on the tower = \( \Sigma V \)

\[ = 0.948 + 6 \times 2.260 \]

\[ = 14.508 \text{ t} \]

Load on one leg = \( \frac{14.508}{4} = 3.627 \text{ t} \)

(iii) Component due to dead weight of the tower = (Total weight of the tower - Weight of the bottom most panel)
FIG. A.21 NOTATIONS FOR LOAD CALCULATIONS FOR THE SEGMENT TEST
(a) NORMAL LOADING CONDITION

(b) TOP CONDUCTOR RIGHT BROKEN WIRE CONDITION

(c) MIDDLE CONDUCTOR RIGHT BROKEN WIRE CONDITION

(d) BOTTOM CONDUCTOR RIGHT BROKEN WIRE CONDITION

FIG. A.2.2 LOADING DIAGRAM FOR DIFFERENT LOADING CONDITIONS

All loads in Kg  Height in m
### Table A2.1

**SELF WEIGHT OF THE BOTTOM MOST PANEL**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Member</th>
<th>Length in m</th>
<th>Weight in Kg/m</th>
<th>Quantity</th>
<th>Total weight in Kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Leg</td>
<td>4.6</td>
<td>17.7</td>
<td>4</td>
<td>325.68</td>
</tr>
<tr>
<td>2</td>
<td>Diagonal bracing</td>
<td>6.0</td>
<td>5.8</td>
<td>8</td>
<td>278.40</td>
</tr>
<tr>
<td>3</td>
<td>Horizontal bracing</td>
<td>3.45</td>
<td>5.8</td>
<td>8</td>
<td>160.08</td>
</tr>
<tr>
<td>4</td>
<td>Plan bracing</td>
<td>5.5</td>
<td>5.8</td>
<td>8</td>
<td>255.20</td>
</tr>
<tr>
<td>5</td>
<td>Secondary bracings</td>
<td>8.8</td>
<td>4.5</td>
<td>8</td>
<td>316.80</td>
</tr>
<tr>
<td>6</td>
<td>Gusset plates</td>
<td>-</td>
<td>25.0</td>
<td>8</td>
<td>200.00</td>
</tr>
<tr>
<td>7</td>
<td>Bolts, nuts and washers</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>60.00</td>
</tr>
</tbody>
</table>

**Self weight of the bottom most panel**: 1596.16 ≈ 1.6 t

**Dead weight of the complete tower**: = 7.760 t

**Dead weight at the top of TWLB**: = 7.76 - 1.6 t = 6.16 t

**Load on one leg**: = \( \frac{6.16}{4} \) = 1.54 t

**Total vertical load on one leg**: = (i) + (ii) + (iii)

\[ 37.392 + 3.627 + 1.540 \]

\[ = 42.559 \text{ t} \]
A2.1.2. Calculation of transverse load on the segment

Total transverse load acting on the tower at TWLB

\[ \sum T = 1 \times 0.880 + 2 \times 2.290 + 2 \times 2.394 + 2 \times 3.844 + 1 \times 4.614 + 1 \times 2.600 \]

\[ = 25.15 \ t \]

Transverse load on one leg

\[ \frac{25.15}{4} = 6.29 \ t \]

A2.1.3 Calculation of longitudinal load on the segment

There are no longitudinal loads on the tower.

A2.2 TOP CONDUCTOR RIGHT BROKENWIRE CONDITION (Fig. A2.2(b))

A.2.2.1 Calculation of vertical load on the segment

(i) Component due to transverse loads

\[ \sum Th_a = \frac{372.885}{6.9} = 54.041 \ t \]

Load on one leg

\[ \frac{54.041}{2} = 27.021 \ t \]

(ii) Component due to vertical live loads acting on the tower

\[ = 0.711 + 5 \times 1.695 + 1.257 \]

\[ = 10.443 \ t \]

Load on one leg

\[ \frac{10.443}{4} = 2.611 \ t \]

(iii) Component due to dead weight of the tower

Load on one leg

\[ = 1.54 \ t \]
(iv) Component due to longitudinal load acting on the tower at TWLB

\[ L_h = 3.186 \times 33.22 - 105.839 \]
\[ \frac{L_h}{a} = \frac{105.839}{6.9} = 15.339 \text{ t} \]

Load on one leg = \( \frac{15.339}{2} = 7.670 \text{ t} \)

(v) Component due to eccentricity of vertical live loads

\[ Q_e = \frac{0.438 \times 4.3}{6.9} = 0.273 \text{ t} \]

Load on one leg = \( \frac{0.273}{2} = 0.137 \text{ t} \)

Total vertical load on one leg = (i)+(ii)+(iii)+(iv)+(v)

\[ = 27.021 + 2.611 + 1.540 + 7.670 + 0.137 \]
\[ = 38.979 \text{ t} \]

A2.2.2. Calculation of transverse load on the segment

(i) Component due to transverse loads acting on the tower at TWLB

\[ \sum T = 1 \times 0.660 + 1 \times 1.717 + 1.292 + 2 \times 1.796 + 2 \times 2.883 + 3.4605 + 1.95 \]
\[ = 18.438 \text{ t} \]

Load on one leg = \( \frac{18.438}{4} = 4.61 \text{ t} \)

(ii) Component due to twisting moment at the cross arm level

\[ \frac{L_e}{2b} = \frac{3.186 \times 4.3}{2 \times 6.9} = 0.993 \text{ t} \]
Total transverse load on one leg = (i) + (ii) 
= 4.610t + 0.993t 
= 5.603t (for TCRT BWC) 
= 4.610t - 0.993t 
= 3.617t (for TCLT BWC)

Hence TCRT BWC governs

A2.2.3 Calculation of longitudinal load on the segment

(i) Component due to longitudinal load acting on the tower
Total longitudinal load on the tower = 3.186 t
Load on one leg = \( \frac{3.186}{4} = 0.797 \) t

(ii) Component due to twisting moment at the cross arm level
Longitudinal load due to twisting moment on one leg = \( \frac{Le}{2b} \)
\[ \frac{Le}{2b} = \frac{3.186 \times 4.3}{2.69} = 0.993 \text{ t} \]

Total longitudinal load on one leg = (i) + (ii)
= 0.797t + 0.993t
= 1.790t (for TCRT BWC)
= 0.797t - 0.993 t
= 0.196t (for TCLT BWC)

Hence TCRT BWC governs.
A2.3 MIDDLE CONDUCTOR RIGHT BROKEN WIRE CONDITION

A2.3.1 Calculation of vertical load on the segment

(i) Component due to transverse loads on the tower at TWLB

\[ \Sigma \text{Th} = 1 \times 0.680 \times 38.07 + 2 \times 1.717 \times 33.22 \\
+ 1 \times 1.796 \times 28.02 + 1 \times 1.370 \times 28.02 \\
+ 2 \times 2.883 \times 22.82 + 1 \times 3.4605 \times 4.50 \]

\[ \Sigma \text{Th} = 375.067 \text{ tm} \]

\[ \frac{\Sigma \text{Th}}{a} = \frac{375.067}{6.9} = 54.358 \text{ t} \]

Load on one leg = \[ \frac{54.358}{2} = 27.179 \text{ t} \]

(ii) Component due to vertical live loads acting on the tower

\[ \Sigma \text{V} = 0.711 + 5 \times 1.695 + 1.257 \]

\[ \Sigma \text{V} = 10.443 \text{ t} \]

Load on one leg = \[ \frac{10.443}{4} = 2.611 \text{ t} \]

(iii) Component due to dead weight of the tower

Load on one leg = \[ 1.54 \text{ t} \]

(iv) Component due to longitudinal load acting on the tower at TWLB

\[ \frac{Lh}{a} = \frac{3.186 \times 28.02}{6.9} = 89.272 \text{ tm} \]

\[ \frac{Lh}{a} = \frac{89.272}{6.9} = 12.938 \text{ t} \]

Load on one leg = \[ \frac{12.938}{2} = 6.469 \text{ t} \]
(v) Component due to eccentricity of vertical loads

\[ Q = \frac{Q_a}{a} \]

\[ Q_a = (V_1 - V_2) \]

\[ = 1.695 \text{ t} - 1.257 \text{ t} \]

\[ = 0.438 \text{ t} \]

\[ Qe = 0.438 \times 4.6 \]

\[ = 6.9 \]

\[ a = 2 \]

\[ = 0.292 \text{ t} \]

Load on one leg

\[ = \frac{0.292}{2} \]

\[ = 0.146 \text{ t} \]

Total vertical load on one leg

\[ = (i) + (ii) + (iii) + (iv) + (v) \]

\[ = 27.179 + 2.611 + 1.540 + 6.469 + 0.146 \]

\[ = 37.945 \text{ t} \]

A2.3.2 Calculation of transverse load on the segment

(i) Component due to transverse loads acting on the tower at TWLB

\[ \Sigma T = 1 \times 0.660 + 2 \times 1.717 + 1 \times 1.796 \]

\[ + 1 \times 1.370 + 2 \times 2.883 + 1 \times 3.4605 + 1 \times 1.950 \]

\[ = 18.437 \text{ t} \]

Load on one leg

\[ = \frac{18.437}{4} \]

\[ = 4.61 \text{ t} \]
(ii) Component due to twisting moment at the cross arm level

\[ Le \]

\[ \frac{Le}{2b} = \frac{3.186 \times 4.6}{2 \times 6.9} \]

\[ = 1.062 \text{ t} \]

\[ \text{Total transverse load on one leg} = (i) + (ii) \]

\[ = 4.61t + 1.062t \]

\[ = 5.672t \text{ (for MCRT BWC)} \]

\[ = 4.61t - 1.062t \]

\[ = 3.548t \text{ (for MCLT BWC)} \]

Hence MCRT BWC governs.

A2.3.3 Calculation of longitudinal load on the segment

(i) Component due to longitudinal load acting on the tower

\[ L \]

\[ \text{Total longitudinal load on the tower} = 3.186 \text{ t} \]

\[ \text{Load on one leg} = \frac{3.186}{4} = 0.797 \text{ t} \]

(ii) Component due to twisting moment at the cross arm level

\[ L \]

\[ \text{Longitudinal load due to twisting moment on one leg} = \frac{Le}{2b} \]

\[ \frac{Le}{2b} = \frac{3.186 \times 4.6}{2 \times 6.9} = 1.062 \text{ t} \]

\[ \text{Total longitudinal load on one leg} = (i) + (ii) \]

\[ = 0.797t + 1.062t \]

\[ = 1.859t \text{ (for MCRT BWC)} \]

\[ = 0.797t - 1.062t \]

\[ = -0.265 \text{ t (for MCLT BWC)} \]

Hence MCRT BWC governs
A2.4 BOTTOM CONDUCTOR RIGHT BROKENWIRE CONDITION
(Fig. A2.2 (d))

A2.4.1 Calculation of vertical load on the segment

(i) Component due to transverse loads on the tower at TWLB

\[ \Sigma Th = 1 \times 0.660 \times 38.07 + 2 \times 1.717 \times 33.22 + 2 \times 1.796 \times 28.02 + 1 \times 2.883 \times 22.82 + 1 \times 2.457 \times 22.82 + 1 \times 3.4605 \times 4.50 \]

\[ = 377.283 \text{ tm} \]

\[ \frac{\Sigma Th}{a} = \frac{377.283}{6.9} = 54.679 \text{ t} \]

Load on one leg = \[ \frac{54.679}{2} = 27.340 \text{ t} \]

(ii) Component due to vertical live loads acting on the tower

\[ \Sigma V = 0.711 + 5 \times 1.695 + 1.257 \]

\[ = 10.443 \text{ t} \]

Load on one leg = \[ \frac{10.443}{4} = 2.661 \text{ t} \]

(iii) Component due to dead weight of the tower

Load on one leg = \[ 1.54 \text{ t} \]

(iv) Component due to longitudinal load acting on the tower at TWLB

\[ \frac{Lh}{a} = \frac{3.186 \times 22.82}{6.9} = 72.705 \text{ tm} \]

\[ \frac{Lh}{a} = \frac{72.705}{6.9} = 10.537 \text{ t} \]

Load on one leg = \[ \frac{10.537}{2} = 5.269 \text{ t} \]
Component due to eccentricity of vertical loads

\[ Q_e = \frac{Q_a (V_1 - V_2)}{8.9} \]

\[ Q = 1.695t - 1.257t = 0.438t \]

\[ Q_e_a = 0.438 \times 5.1 = 0.324t \]

Load on one leg \[ = \frac{0.324}{2} = 0.162t \]

Total vertical load \[ = (i) + (ii) + (iii) + (iv) + (v) \]
\[ = 27.340+2.611+1.540+5.269+0.162 \]
\[ = 36.922t \]

A2.4.2 Calculation of transverse load on the segment

(i) Component due to transverse loads acting on the tower at TWLB

\[ \Sigma T = 1 \times 0.660 + 2 \times 1.717 + 2 \times 1.796 + 1 \times 2.883 + 1 \times 2.457 + 1 \times 3.4605 + 1 \times 1.950 \]
\[ = 18.437t \]

Load on one leg \[ = \frac{18.437}{4} = 4.61t \]

(ii) Component due to twisting moment at the cross arm level

\[ \frac{Le}{2b} = \frac{3.186 \times 5.1}{2 \times 8.9} = 1.177t \]

Total transverse load on one leg \[ = (i) + (ii) \]
\[ = 4.61t + 1.177t \]
\[ = 5.787t \text{ (for BCRT BWC)} \]
\[ = 4.61t - 1.177t \]
\[ = 3.433t \text{ (for BCLT BWC)} \]

Hence BCRT BWC governs.
A 4.3 Calculation of longitudinal load on the segment

(i) Component due to longitudinal load acting on the tower

Total longitudinal load on the tower

Load on one leg

= $L$

= 3.186 t

= $\frac{3.186}{4}$ = 0.797 t

(ii) Component due to twisting moment at the cross arm level

Longitudinal load due to twisting moment on one leg

= $L_e$

= $\frac{2b}{2b}$

= $\frac{3.186 \times 5.1}{2 \times 6.9}$ = 1.177 t

Total longitudinal load on one leg = (i) + (ii)

= 0.797 t + 1.177 t

= 1.974 t (for BCRT BWC)

= 0.797 t - 1.177 t

= -0.380t (for BCLT BWC)

Hence BCRT BWC governs.
Table A2.2
RESOLUTION OF FORCES ON THE SEGMENT

<table>
<thead>
<tr>
<th>Loading condition</th>
<th>Vertical force acting at top of inclined leg (Kg)</th>
<th>Force Acting along axis of leg (Kg)</th>
<th>Force resolved along diagonal plane (Kg)</th>
<th>Transverse force (Kg)</th>
<th>Longitudinal force (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( F )</td>
<td>( F_L = F/\cos \theta )</td>
<td>( F_{LD} = F_L \sin \theta )</td>
<td>( T = F_{LD} \sin 45^\circ )</td>
<td>( L = F_{LD} \cos 45^\circ )</td>
</tr>
<tr>
<td>1</td>
<td>42559</td>
<td>43137</td>
<td>7049</td>
<td>4985</td>
<td>4985</td>
</tr>
<tr>
<td>2</td>
<td>38979</td>
<td>39510</td>
<td>6456</td>
<td>4565</td>
<td>4565</td>
</tr>
<tr>
<td>3</td>
<td>38979</td>
<td>39510</td>
<td>6456</td>
<td>4565</td>
<td>4565</td>
</tr>
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<td>4</td>
<td>37945</td>
<td>38462</td>
<td>6285</td>
<td>4444</td>
<td>4444</td>
</tr>
<tr>
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<td>38462</td>
<td>6285</td>
<td>4444</td>
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<td>6</td>
<td>36922</td>
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<tr>
<td>7</td>
<td>36922</td>
<td>37425</td>
<td>6115</td>
<td>4324</td>
<td>4324</td>
</tr>
</tbody>
</table>
## Table A2.3
CALCULATION OF LOADS ON THE SEGMENT

<table>
<thead>
<tr>
<th>Loading condition</th>
<th>Load along axis of leg (Kg)</th>
<th>Load along axis of leg resolved in transverse direction (Kg)</th>
<th>Load along axis of leg resolved in longitudinal direction (Kg)</th>
<th>Load along axis (transverse) (Kg)</th>
<th>Load along axis (longitudinal) (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43137</td>
<td>6290</td>
<td>0</td>
<td>- 4985</td>
<td>- 4985</td>
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<tr>
<td>2</td>
<td>39510</td>
<td>5603</td>
<td>1790</td>
<td>- 4565</td>
<td>1038</td>
</tr>
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<td>3</td>
<td>39510</td>
<td>3617</td>
<td>- 196</td>
<td>- 4565</td>
<td>- 948</td>
</tr>
<tr>
<td>4</td>
<td>38462</td>
<td>5672</td>
<td>1859</td>
<td>- 4444</td>
<td>1228</td>
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<td>5</td>
<td>38462</td>
<td>3548</td>
<td>- 265</td>
<td>- 4444</td>
<td>896</td>
</tr>
<tr>
<td>6</td>
<td>37425</td>
<td>5787</td>
<td>1974</td>
<td>- 4324</td>
<td>1463</td>
</tr>
<tr>
<td>7</td>
<td>37425</td>
<td>3433</td>
<td>- 380</td>
<td>- 4324</td>
<td>- 891</td>
</tr>
</tbody>
</table>
\[ \theta = \tan^{-1}\left(\frac{Q}{H}\right) \]

\[ F_{LZ} = F_L \cos \theta \]

\[ F_{LD} = F_L \sin \theta \]

\[ F_{LQ} = F_{LD} \sin 45^\circ \]

\[ F_{LD} = F_{LQ} \cos 45^\circ \]

\[ F_{H1} = F_{LQ} \]

\[ F_{H2} = F_{LQ} \]

\[ F + F_{LZ} = 0 \]

or

\[ F_{LZ} = -F \]

\[ D = x_2 - x_1 \]

\[ = (3.95 - 0.75) \sqrt{2} \]

\[ D = 4.525 \text{ m} \]

\[ H = 27.32 \text{ m} \]

\[ \theta = \tan^{-1}\left(\frac{D}{H}\right) \]

\[ \theta = 9.60^\circ \]

\[ F_L = \frac{F_{LQ}}{\cos \theta} \]

FIG. A2.3 RESOLUTION OF FORCES ON THE SEGMENT ALONG THE LOADING DIRECTIONS