

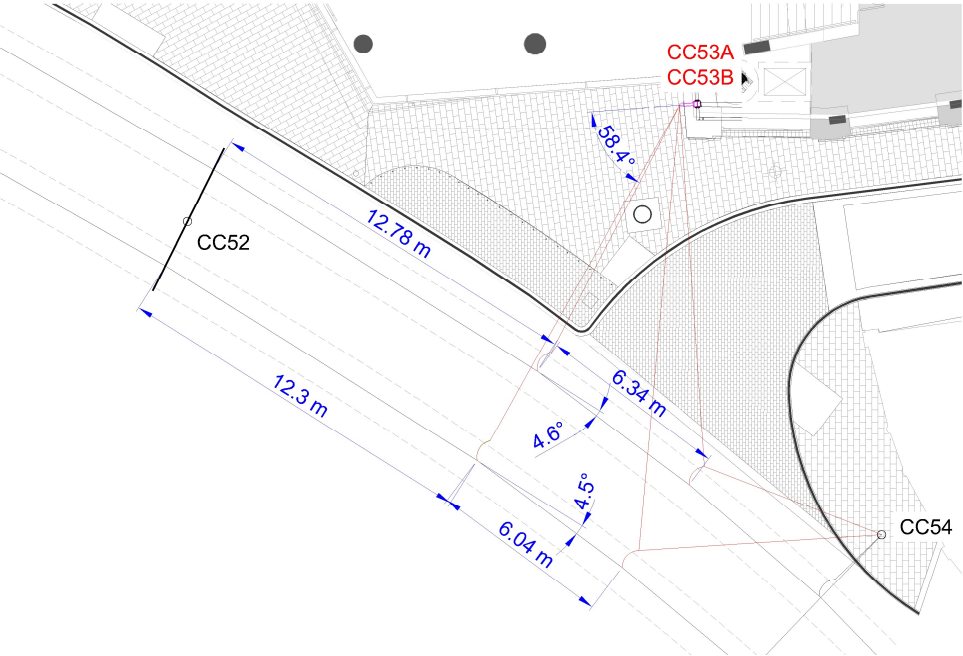
Calculation No.: POD-CAL-002121 rev 2

Calculation Title: Wall Fixing Loading calculation CC53A

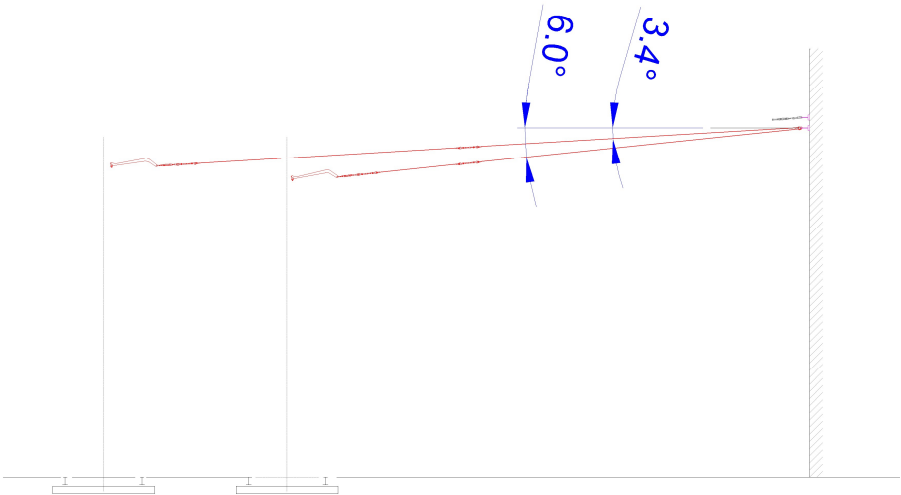
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Plan view of CC53A



Cross section view of CC53A



Main Data

Contact wire weight	$w_{CW} := 10.464 \text{ N m}^{-1}$
Contact wire diameter	$d_{CW} := 13.2 \text{ mm}$
Contact wire shape factor	$k_{CW} := 0.8$

Contact wire tension	$T_{cw} := 12 \text{ kN}$
No. of contact wires	$n_{cw} := 2$
Wire rope diameter	$d_{wr} := 6 \text{ mm}$
wire rope weight	$w_{wr} := 0.178 \text{ kg m}^{-1} \quad g_e = 1.746 \text{ N m}^{-1}$
Air density	$\rho_{air} := 1.226 \text{ kg m}^{-3}$
Operational wind speed	$V_{wo} := 25 \text{ m s}^{-1}$
Gust wind speed	$V_{wg} := 45 \text{ m s}^{-1}$
ice density	$\rho_{ice} := 900 \text{ kg m}^{-3}$
Radial ice thickness	$t_{ice} := 10 \text{ mm}$
Loading partial factor	$\gamma_f := 1.3$
Strong reg arm weight	$w_{sa} := 4 \text{ kg } g_e = 39.227 \text{ N}$
Inline insualtor weight	$w_{ins} := 0.5 \text{ kg } g_e = 4.903 \text{ N}$
Turnbuckle weight	$w_{tb} := 0.75 \text{ kg } g_e = 7.355 \text{ N}$

Location Data

Contact wire angle inbound	$\alpha_i := 4.5 \text{ deg}$
Contact wire angle outbound	$\alpha_o := 4.6 \text{ deg}$
Angle of pull off to building	$\theta_p := 58.4 \text{ deg}$
Inbound contact wire span 1	$s_{i1} := 12.30 \text{ m}$
Inbound contact wire span 2	$s_{i2} := 6.04 \text{ m}$
Outbound contact wire span 1	$s_{o1} := 12.78 \text{ m}$
Outbound contact wire span 2	$s_{o2} := 6.34 \text{ m}$
Inbound pull-off angle to horizontal	$\theta_i := 6 \text{ deg}$
Outbound pull-off angle to horizontal	$\theta_o := 3.4 \text{ deg}$

Load Case A - Static Load

Firstly work out the inbound radial load

$$R_{AI} := 2 \cdot T_{cw} \cdot \sin(0.5 \cdot \alpha_i) \cdot n_{cw} \cdot \gamma_f = 2.45 \text{ kN}$$

And outbound

$$R_{AO} := 2 \cdot T_{cw} \cdot \sin(0.5 \cdot \alpha_o) \cdot n_{cw} \cdot \gamma_f = 2.504 \text{ kN}$$

The pull offs aren't perpendicular to the wall so calculate the pull out and horizontal load on the fixings

pull out from Pull off 1 $L_{API} := R_{AI} \cdot \cos(\theta_p) = 1283.667 \text{ N}$

pull out from pull off 2 $L_{APO} := R_{AO} \cdot \cos(\theta_p) = 1312.178 \text{ N}$

Therefore pull out load on the fixing is

$$L_A := L_{API} + L_{APO} = 2595.845 \text{ N}$$

Horizontal load

$$L_{AHI} := R_{AI} \cdot \sin(\theta_p) = 2086.571 \text{ N}$$

$$L_{AHO} := R_{AO} \cdot \sin(\theta_p) = 2132.915 \text{ N}$$

Therefore

$$H_A := L_{AHI} + L_{AHO} = 4219.486 \text{ N}$$

It is assumed that the only vertical load will be from the pull off equipment itself and not contact wire load as the contact wire is unsupported. Also the weight of the equipment will be shared between both support locations.

Equipment in inbound bridle

1 x strong registration arm

2 x Inline insulators

1 x turnbuckles

12.94m Wire rope

Equipment in outbound bridle

1 x strong registration arm

2 x inline insulators

1 x turnbuckles

9.35m wire rope

$$w_i := (1 \cdot w_{sa} + 2 \cdot w_{ins} + 1 \cdot w_{tb} + 12.94 \text{ m} \cdot w_{wr}) \cdot \gamma_f = 102.669 \text{ N}$$

$$w_o := (1 \cdot w_{sa} + 2 \cdot w_{ins} + 1 \cdot w_{tb} + 9.35 \text{ m} \cdot w_{wr}) \cdot \gamma_f = 94.522 \text{ N}$$

Now calculate the vertical load due to the angle of the pull-offs to horizontal

$$v_o := R_{AO} \cdot \tan(\theta_o) = 148.778 \text{ N} \quad \text{Outbound vertical load due to radial load and pull-off angle}$$

$$v_i := R_{AI} \cdot \tan(\theta_i) = 257.486 \text{ N} \quad \text{Inbound vertical load due to radial load and pull-off angle}$$

Total vertical static load

$$V_A := w_i + w_o + v_o + v_i = 603.455 \text{ N}$$

Load Case B - Gust Wind Loading

For this case assume gust wind loading perpendicular to the contact wire

The wind loading will be shared between the supports either side of the bridle therefore the affected span will be

$$\text{for inbound} \quad s_{ia} := \frac{s_{i1} + s_{i2}}{2} = 9.17 \text{ m}$$

$$\text{for outbound} \quad s_{oa} := \frac{s_{o1} + s_{o2}}{2} = 9.56 \text{ m}$$

Calculate the additional loading on the contact wire from the wind

$$L_{wg_cw} := 0.5 \cdot \rho_{air} \cdot V_{wg}^2 \cdot k_{cw} \cdot d_{cw} = 13.108 \frac{\text{N}}{\text{m}}$$

Therefore additional load on the contact wires will be

$$\text{Inbound wire} \quad L_{wgi} := L_{wg_cw} \cdot s_{ia} \cdot \gamma_f = 156.265 \text{ N}$$

$$\text{Outbound wire} \quad L_{wgo} := L_{wg_cw} \cdot s_{oa} \cdot \gamma_f = 162.911 \text{ N}$$

Add this to the the radial loads worked out from the static case

$$R_{BI} := R_{AI} + L_{wgi} = 2606.078 \text{ N}$$

$$R_{BO} := R_{AO} + L_{wgo} = 2667.135 \text{ N}$$

As with Case A the pull-offs are still not perpendicular to the wall therefore the pull-out loads will be

pull out from Pull off 1 $L_{BPI} := R_{BI} \cdot \cos(\theta_p) = 1365.548 \text{ N}$

pull out from pull off 2 $L_{BPO} := R_{BO} \cdot \cos(\theta_p) = 1397.541 \text{ N}$

$$L_B := L_{BPI} + L_{BPO} = 2763.089 \text{ N}$$

And now for the horizontal load

$$L_{BHI} := R_{BI} \cdot \sin(\theta_p) = 2219.667 \text{ N}$$

$$L_{BHO} := R_{BO} \cdot \sin(\theta_p) = 2271.671 \text{ N}$$

Therefore

$$H_B := L_{BHI} + L_{BHO} = 4491.337 \text{ N}$$

The additional load from the wind will add some more vertical load due to the angle of the pull-offs to the wall, therefore

$$v_{Bo} := R_{BO} \cdot \tan(\theta_o) = 158.457 \text{ N} \quad \text{Outbound vertical load due to radial load and pull-off angle}$$

$$v_{Bi} := R_{BI} \cdot \tan(\theta_i) = 273.91 \text{ N} \quad \text{Inbound vertical load due to radial load and pull-off angle}$$

Add these to the original values for the weight of the equipment, which has not changed.

$$V_B := w_i + w_o + v_{Bi} + v_{Bo} = 629.558 \text{ N}$$

Load Case C - Ice Loading

This case considers ice loading on all components there is no inclusion for wind

Since there is no change to the radial load the pull out load and horizontal will be as per the static case

$$L_C := L_A = 2595.845 \text{ N}$$

$$H_C := H_A = 4219.486 \text{ N}$$

The vertical load will need to include 10mm radial ice on all componentry and contact wire, however we are not considering the contact wire being supported by the bridles as they provide registration only.

Firstly additional weight of ice on the wire rope per metre

$$w_{wr_ice} := \rho_{ice} \cdot \pi \cdot \left(\left(\frac{d_{wr} + 2 \cdot t_{ice}}{2} \right)^2 - \left(\frac{d_{wr}}{2} \right)^2 \right) g_e = 4.436 \frac{\text{N}}{\text{m}}$$

Additional ice load on Strong reg arm $w_{sa_ice} := 9.501 \text{ N}$

Additional ice load on Insulators $w_{ins_ice} := 5 \text{ N}$

Additional ice load on Turnbuckle $w_{tb_ice} := 5 \text{ N}$

Therefore additional ice loading on inbound pull-off

$$w_{i_ice} := \left(1 \cdot w_{sa_ice} + 2 \cdot w_{ins_ice} + 1 \cdot w_{tb_ice} + 12.94 \text{ m} \cdot w_{wr_ice} \right) \cdot \gamma_f = 106.481 \text{ N}$$

And additional ice loading on outbound pull-off

$$w_{o_ice} := \left(1 \cdot w_{sa_ice} + 2 \cdot w_{ins_ice} + 1 \cdot w_{tb_ice} + 9.35 \text{ m} \cdot w_{wr_ice} \right) \cdot \gamma_f = 85.776 \text{ N}$$

Therefore total vertical load is the load of the equipment, ice and vertical componet of radial load due to the pull-off angle.

$$V_C := w_i + w_{i_ice} + w_o + w_{o_ice} + v_o + v_i = 795.712 \text{ N}$$

Load Case D - Wind and Ice

This case looks at operational wind and ice loading on componetry but not on conductors

Firstly calualte the operational wind loading on the the contact wire per metre

$$L_{wo_cw} := 0.5 \cdot \rho_{air} \cdot V_{wo}^2 \cdot k_{cw} \cdot d_{cw} = 4.046 \frac{\text{N}}{\text{m}}$$

Therefore additional load on the contact wires will be

$$\text{Inbound wire} \quad L_{woi} := L_{wo_cw} \cdot s_{ia} \cdot \gamma_f = 48.23 \text{ N}$$

$$\text{Outbound wire} \quad L_{woo} := L_{wo_cw} \cdot s_{oa} \cdot \gamma_f = 50.281 \text{ N}$$

Therefore radial load is

$$R_{DI} := R_{AI} + L_{woi} = 2498.042 \text{ N}$$

$$R_{DO} := R_{AO} + L_{woo} = 2554.505 \text{ N}$$

The pull offs aren't perpendicular to the wall so calculate the pull out and horizontal load on the fixings

$$\text{pull out from Pull off 1} \quad L_{DPI} := R_{DI} \cdot \cos(\theta_p) = 1308.939 \text{ N}$$

$$\text{pull out from pull off 2} \quad L_{DPO} := R_{DO} \cdot \cos(\theta_p) = 1338.525 \text{ N}$$

$$L_D := L_{DPI} + L_{DPO} = 2647.464 \text{ N}$$

And now for the horizontal load

$$L_{DHI} := R_{DI} \cdot \sin(\theta_p) = 2127.65 \text{ N}$$

$$L_{DHO} := R_{DO} \cdot \sin(\theta_p) = 2175.741 \text{ N}$$

$$H_D := L_{DHI} + L_{DHO} = 4303.391 \text{ N}$$

Vertical load will now include ice on compentry (which was calculated in D) and radial load including the operaional wind load

$$v_{Do} := R_{DO} \cdot \tan(\theta_o) = 151.766 \text{ N} \quad \text{Outbound vertical load due to radial load and pull-off angle}$$

$$v_{Di} := R_{DI} \cdot \tan(\theta_i) = 262.555 \text{ N} \quad \text{Inbound vertical load due to radial load and pull-off angle}$$

$V_D := w_i + w_{i_ice} + w_o + w_{o_ice} + v_{Do} + v_{Di} = 803.768 \text{ N}$

Summary

Below is a summary of the calculated loads for each load case. The orange highlighted loads are the maximum values.

	Pull out load	Horizontal load	Vertical load
Load Case A - Static	$L_A = 2595.845 \text{ N}$	$H_A = 4219.486 \text{ N}$	$V_A = 603.455 \text{ N}$
Load Case B - Gust Wind	$L_B = 2763.089 \text{ N}$	$H_B = 4491.337 \text{ N}$	$V_B = 629.558 \text{ N}$
Load Case C - Ice	$L_C = 2595.845 \text{ N}$	$H_C = 4219.486 \text{ N}$	$V_C = 795.712 \text{ N}$
Load Case D - Operational wind + ice	$L_D = 2647.464 \text{ N}$	$H_D = 4303.391 \text{ N}$	$V_D = 803.768 \text{ N}$