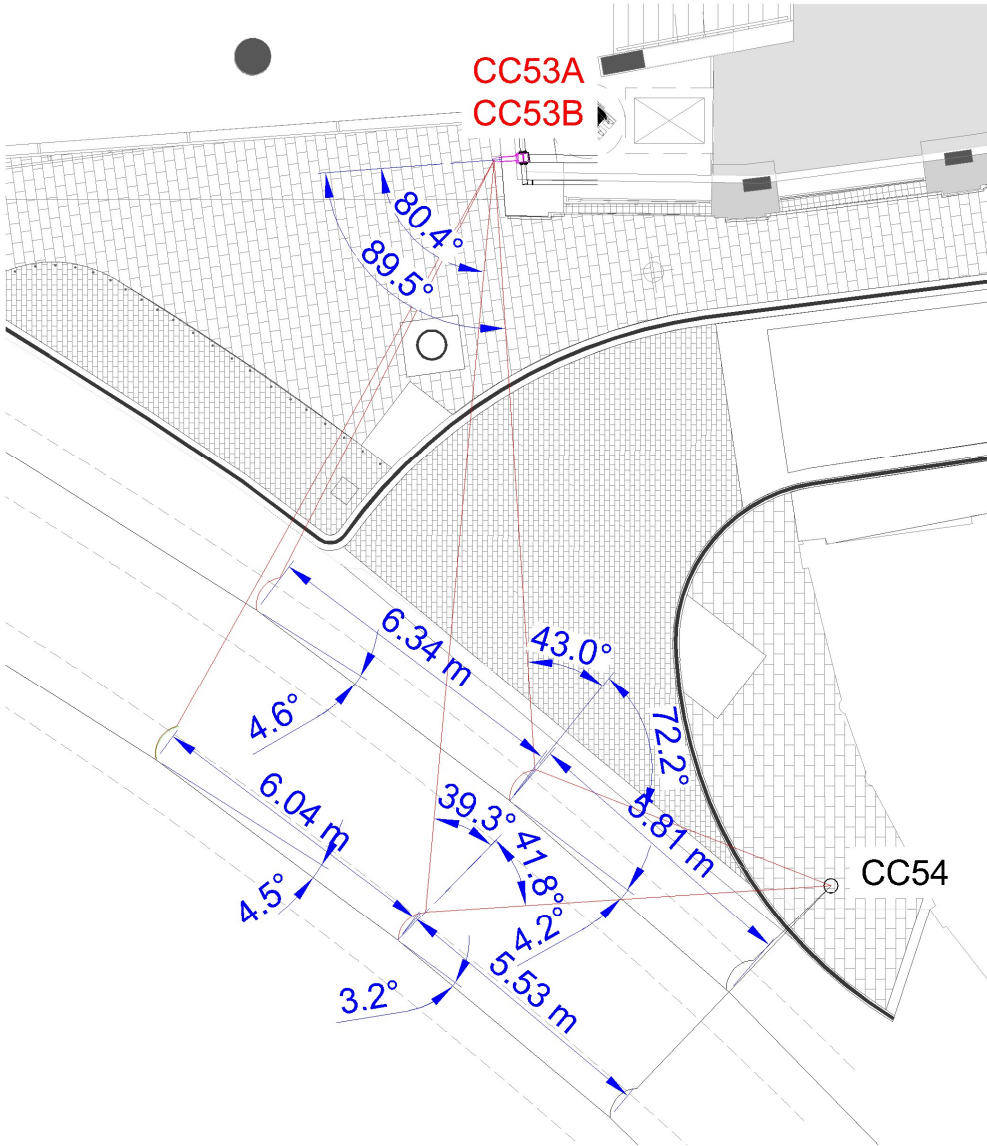


Bridle Arrangement



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	$w_{wr} := 0.178 \text{ kg m}^{-1}$ $g_e = 1.746 \text{ N m}^{-1}$
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	$\alpha_i := 3.2 \text{ deg}$
Contact wire angle outbound	$\alpha_o := 4.2 \text{ deg}$
Angle of inbound bridle leg 1 to registration	$\theta_{i1} := 41.8 \text{ deg}$
Angle of inbound bridle leg 2 to registration	$\theta_{i2} := 39.3 \text{ deg}$
Angle of outbound bridle leg 1 to registration	$\theta_{o1} := 72.2 \text{ deg}$
Angle of outbound bridle leg 2 to registration	$\theta_{o2} := 43 \text{ deg}$
Angle of inbound bridle leg connection to building	$\theta_{ib} := 80.4 \text{ deg}$
Angle of outbound bridle leg connection to building	$\theta_{ob} := 89.5 \text{ deg}$
Inbound contact wire span 1	$s_{i1} := 5.53 \text{ m}$
Inbound contact wire span 2	$s_{i2} := 6.04 \text{ m}$
Outbound contact wire span 1	$s_{o1} := 5.81 \text{ m}$
Outbound contact wire span 2	$s_{o2} := 6.34 \text{ m}$
Inbound bridle leg vertical connection angle	$\theta_{iv} := 3.8 \text{ deg}$
Outbound bridle leg vertical connection angle	$\theta_{ov} := 6 \text{ deg}$

Load Case A - Static Load

Calculate the radial load induced by the tension in the contact wire.

Inbound $R_{AI} := 2 \cdot T_{cw} \cdot \sin(0.5 \cdot \alpha_i) \cdot n_{cw} \cdot \gamma_f = 1.742 \text{ kN}$

Outbound $R_{AO} := 2 \cdot T_{cw} \cdot \sin(0.5 \cdot \alpha_o) \cdot n_{cw} \cdot \gamma_f = 2.287 \text{ kN}$

Calculate the loading in the bridle legs connected to the building. Firstly, calculate the horizontal componet which will be the same for both bridle legs due to equilibrium.

$$T_{A2_1x} := \frac{R_{AI}}{\frac{1}{\tan(\theta_{i1})} + \frac{1}{\tan(\theta_{i2})}} = 744.513 \text{ N}$$

And the inbound tension in the bridle leg is

$$T_{AI_2} := \frac{T_{A2_1x}}{\sin(\theta_{i2})} = 1175.459 \text{ N}$$

Repeat for the outbound leg

$$T_{AO_2x} := \frac{R_{AO}}{\frac{1}{\tan(\theta_{o1})} + \frac{1}{\tan(\theta_{o2})}} = 1640.959 \text{ N}$$

And the outbound tension in the bridle leg is

$$T_{AO_2} := \frac{T_{AO_2x}}{\sin(\theta_{o2})} = 2406.104 \text{ N}$$

Now to calculate the pull-out loading on the wall fixing

Pull out from bridle leg 1 $L_{API} := T_{AI_2} \cdot \cos(\theta_{ib}) = 196.03 \text{ N}$

Pull out from bridle leg 2 $L_{APO} := T_{AO_2} \cdot \cos(\theta_{ob}) = 20.997 \text{ N}$

Therefore total pull out load is

$$L_A := L_{API} + L_{APO} = 217.027 \text{ N}$$

Now to calculate the horizontal load

Horizontal load from bridle leg 1 $L_{AHI} := T_{AI_2} \cdot \sin(\theta_{ib}) = 1158.998 \text{ N}$

Horizontal load from bridle leg 2 $L_{AHO} := T_{AO_2} \cdot \sin(\theta_{ob}) = 2406.012 \text{ N}$

Therefore total horizontal load is

$$H_A := L_{AHI} + L_{AHO} = 3565.01 \text{ N}$$

It is assumed that the only vertical load will be from the bridle 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	Equipment in outbound bridle
1 x strong registration arm	1 x strong registration arm
4 x Inline insulators	4 x inline insulators
2 x turnbuckles	2 x turnbuckles
27.77m Wire rope	24.34m wire rope

$$w_i := (1 \cdot w_{sa} + 4 \cdot w_{ins} + 2 \cdot w_{tb} + 27.77 \text{ m} \cdot w_{wr}) \cdot \gamma_f = 158.632 \text{ N}$$

$$w_o := (1 \cdot w_{sa} + 4 \cdot w_{ins} + 2 \cdot w_{tb} + 24.34 \text{ m} \cdot w_{wr}) \cdot \gamma_f = 150.849 \text{ N}$$

There will also be some vertical load induced from the tension in the bridle leg. The tension in the bridle legs has been previously calculated.

$$V_{AI2} := T_{AI_2} \cdot \sin(\theta_{iv}) = 77.902 \text{ N}$$

$$V_{AO2} := T_{AO_2} \cdot \sin(\theta_{ov}) = 251.506 \text{ N}$$

Total vertical load is

$$V_A := \frac{w_i + w_o}{2} + V_{AI2} + V_{AO2} = 484.149 \text{ N}$$

Load Case B - Gust Wind Loading

For this case assume gust wind acting 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

$$\text{for inbound} \quad s_{ia} := \frac{s_{i1} + s_{i2}}{2} = 5.785 \text{ m}$$

$$\text{for outbound} \quad s_{oa} := \frac{s_{o1} + s_{o2}}{2} = 6.075 \text{ m}$$

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

$$\text{Inbound wire} \quad L_{wgi} := L_{wg_cw} \cdot s_{ia} \cdot \gamma_f = 98.582 \text{ N}$$

$$\text{Outbound wire} \quad L_{wgo} := L_{wg_cw} \cdot s_{oa} \cdot \gamma_f = 103.524 \text{ N}$$

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

$$\text{For Inbound} \quad R_{BI} := R_{AI} + L_{wgi} = 1840.892 \text{ N}$$

$$\text{For Outbound} \quad R_{BO} := R_{AO} + L_{wgo} = 2390.091 \text{ N}$$

As with load case A work out the loadings in the bridle legs

$$\text{For inbound} \quad T_{BI_2x} := \frac{R_{BI}}{\frac{1}{\tan(\theta_{i1})} + \frac{1}{\tan(\theta_{i2})}} = 786.639 \text{ N}$$

$$T_{BI_2} := \frac{T_{BI_2x}}{\sin(\theta_{i2})} = 1241.968 \text{ N}$$

$$\text{For outbound} \quad T_{BO_2x} := \frac{R_{BO}}{\frac{1}{\tan(\theta_{o1})} + \frac{1}{\tan(\theta_{o2})}} = 1715.253 \text{ N}$$

$$T_{BO_2} := \frac{T_{BO_2x}}{\sin(\theta_{o2})} = 2515.04 \text{ N}$$

Pull out load on the wall fixing

$$\text{pull out from inbound bridle leg} \quad L_{BPI} := T_{BI_2} \cdot \cos(\theta_{ib}) = 207.121 \text{ N}$$

$$\text{pull out from outbound bridle leg} \quad L_{BPO} := T_{BO_2} \cdot \cos(\theta_{ob}) = 21.948 \text{ N}$$

$$\text{Therefore total pull out load is} \quad L_B := L_{BPI} + L_{BPO} = 229.069 \text{ N}$$

Now to calculate the horizontal load

$$\text{Horizontal load from bridle leg 1} \quad L_{BHI} := T_{BI_2} \cdot \sin(\theta_{ib}) = 1224.575 \text{ N}$$

$$\text{Horizontal load from bridle leg 1} \quad L_{BHO} := T_{BO_2} \cdot \sin(\theta_{ob}) = 2514.944 \text{ N}$$

Therefore total horizontal load is

$$H_B := L_{BHI} + L_{BHO} = 3739.519 \text{ N}$$

There will be additional vertical load over the static case due to the increase tension in the bridle leg from the wind acting on the contact wire

$$V_{BI2} := T_{BI_2} \cdot \sin(\theta_{iv}) = 82.31 \text{ N}$$

$$V_{BO2} := T_{BO_2} \cdot \sin(\theta_{ov}) = 262.893 \text{ N}$$

$$V_B := \frac{w_i + w_o}{2} + V_{BI2} + V_{BO2} = 499.944 \text{ N}$$

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

$$L_C := L_A = 217.027 \text{ N}$$

and

$$H_C := H_A = 3565.01 \text{ N}$$

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

Firtsly additional weight of ice on the wire rope per metre

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

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

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

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

Therefore additional ice loading on inbound bridle

$$w_{i_ice} := (1 \cdot w_{sa_ice} + 4 \cdot w_{ins_ice} + 2 \cdot w_{tb_ice} + 27.77 \text{ m} \cdot w_{wr_ice}) \cdot \gamma_f = 211.511 \text{ N}$$

And additional ice loading on outbound bridle

$$w_{o_ice} := (1 \cdot w_{sa_ice} + 4 \cdot w_{ins_ice} + 2 \cdot w_{tb_ice} + 24.34 \text{ m} \cdot w_{wr_ice}) \cdot \gamma_f = 191.729 \text{ N}$$

Therefore total vertical load is

$$V_C := \frac{w_i + w_{i_ice} + w_o + w_{o_ice}}{2} + V_{AI2} + V_{AO2} = 685.769 \text{ N}$$

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

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

Therefore additional load on the contact wires will be

$$\text{Inbound wire} \quad L_{woi} := L_{wo_cw} \cdot s_{ia} \cdot \gamma_f = 30.426 \text{ N}$$

$$\text{Outbound wire} \quad L_{woo} := L_{wo_cw} \cdot s_{oa} \cdot \gamma_f = 31.952 \text{ N}$$

Therefore radial load is

$$R_{DI} := R_{AI} + L_{woi} = 1772.737 \text{ N}$$

$$R_{DO} := R_{AO} + L_{woo} = 2318.519 \text{ N}$$

Now to work out the loadings in the inbound bridle leg, firstly horizontal component of inbound bridle leg 1

$$\text{Inbound} \quad T_{DI_2x} := \frac{R_{DI}}{\frac{1}{\tan(\theta_{i1})} + \frac{1}{\tan(\theta_{i2})}} = 757.515 \text{ N}$$

$$T_{DI_2} := \frac{T_{DI_2x}}{\sin(\theta_{i2})} = 1195.986 \text{ N}$$

$$\text{Outbound} \quad T_{DO_2x} := \frac{R_{DO}}{\frac{1}{\tan(\theta_{o1})} + \frac{1}{\tan(\theta_{o2})}} = 1663.889 \text{ N}$$

$$T_{DO_2} := \frac{T_{DO_2x}}{\sin(\theta_{o2})} = 2439.726 \text{ N}$$

Pull out from wall fixing

$$\text{pull out from bridle leg 1} \quad L_{DPI} := T_{DI_2} \cdot \cos(\theta_{ib}) = 199.453 \text{ N}$$

$$\text{pull out from bridle leg 2} \quad L_{DPO} := T_{DO_2} \cdot \cos(\theta_{ob}) = 21.29 \text{ N}$$

$$\text{Therefore total pull out load is} \quad L_D := L_{DPI} + L_{DPO} = 220.744 \text{ N}$$

Now to calculate the horizontal load

$$\text{Horizontal load from bridle leg 1} \quad L_{DHI} := T_{DI_2} \cdot \sin(\theta_{ib}) = 1179.238 \text{ N}$$

$$\text{Horizontal load from bridle leg 1} \quad L_{DHO} := T_{DO_2} \cdot \sin(\theta_{ob}) = 2439.633 \text{ N}$$

$$\text{Therefore total horizontal load is} \quad H_D := L_{DHI} + L_{DHO} = 3618.871 \text{ N}$$

Vertical load will include the componet from radial load plus the additional weigth of the ice.

Additional vertical load due to radial load.

Inbound $V_{DI2} := T_{DI_2} \cdot \sin(\theta_{iv}) = 79.263 \text{ N}$

Outbound $V_{DO2} := T_{DO_2} \cdot \sin(\theta_{ov}) = 255.021 \text{ N}$

Therefore total vertical load is

$$V_D := \frac{w_i + w_{i_ice} + w_o + w_{o_ice}}{2} + V_{DI2} + V_{DO2} = 690.644 \text{ N}$$

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	$L_A = 217.027 \text{ N}$	$H_A = 3565.01 \text{ N}$	$V_A = 484.149 \text{ N}$
Load Case B - Gust Wind	$L_B = 229.069 \text{ N}$	$H_B = 3739.519 \text{ N}$	$V_B = 499.944 \text{ N}$
Load Case C - Ice	$L_C = 217.027 \text{ N}$	$H_C = 3565.01 \text{ N}$	$V_C = 685.769 \text{ N}$
Load Case D - Operational wind + ice	$L_D = 220.744 \text{ N}$	$H_D = 3618.871 \text{ N}$	$V_D = 690.644 \text{ N}$