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Connection and ANchor (CAN) Elements in PLS-POLE and TOWER

Introduction

CAN Elements are used to check the capacity or strength of a connection or anchor point in a model. The actual element can be placed at any joint of a model and allows for "attachment" of up to four elements in the model (such as braces, cables, guys, crossarms, davit arms, poles, etc.) that are connected to that joint. These elements contribute forces and moments to the CAN element.

CAN elements have no graphical representation but nonetheless offer many benefits for understanding some of the components loading on elements not typically dealt with in PLS-POLE or TOWER models.

CAN elements can be used to model things like:

- Pole and Tower Foundations as well as Guy Anchors.
- Crossarm connection bolts.
- Can be used to limit conductor tension on cross arms where a tension limit is to be enforced under dead-end conditions.
- Can be used to model pole bands, guying plates, brackets, and other entities not modeled by a member that still need a capacity defined and checked.

The modelling of CAN elements is discussed at some length in the PLS POLE manual Section 3.7 and Section 4.14. For users of TOWER, the respective sections of that manual are Section 3.5 and Section 4.17.

It is not the intent of this Technical Note to reproduce that data, so if you need further information, please refer to those sections.

CAN element properties

The properties of CAN elements can be reasonably straightforward to capture, or more complex based on the type of element you are attempting to check.

All CAN elements that are entered into a CAN library (*.can) can have the following parameters:

Property Label An identifier for the CAN element.

Stock Number An optional stock number if you are using PLS-POLE / PLS-CADD to track material quantities.

Strength Factor Choice of the Strength Factor to use for the CAN element. You may choose between the Strength Factors (*for Steel, Wood, Guys, Foundations, Insulators or Hardware*) that are input in the vector or wire loads tables.

The remaining properties are quite general and broad, to allow for a large variety of elements to be simulated, but they all relate to the capacity of the CAN element.

There are 16 unique capacities that can be entered for each CAN element. The capacity is defined for:

- Resultant Capacity - based on the resultant of the Longitudinal, Transverse, and Vertical Forces.
- Shear Capacity:
    - Longitudinal Shear: plane perpendicular to the Long. axis (resultant of the Trans. & Vert. Loads).
    - Transverse Shear: plane perpendicular to the Trans. axis (resultant of the Long. & Vert. Loads).
    - Vertical Shear: plane perpendicular to the Vert. axis (resultant of the Trans. & Long. Loads).
- Force Capacity:
    - Longitudinal Positive
    - Longitudinal Negative
    - Transverse Positive
    - Transverse Negative
    - Vertical Positive
    - Vertical Negative
- Moment Capacity:
    - About the Longitudinal axis – positive
    - About the Longitudinal axis – negative
    - About the Transverse axis – positive
    - About the Transverse axis – positive
    - About the Vertical axis – positive
    - About the Vertical axis – positive

NOTE: you do not need to enter all these capacities, and only those that are entered shall be checked.

The CAN library capacities are based on the global X, Y, and Z axes. The capacities entered must respect this convention. The axes can be rotated about the Z (vertical) axis when checking capacities by entering an azimuth in the ***Geometry/ Connections and Anchors****…* table.

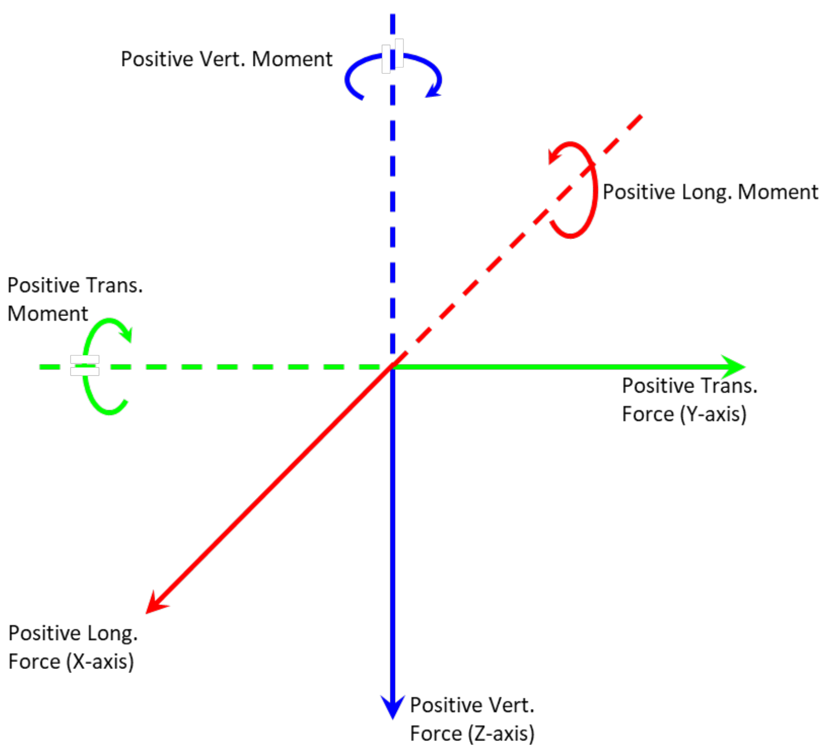


Figure 1 - CAN Coordinate System

There are 4 strength check types that can be used for CAN elements.

These are briefly discussed below:

1. **<u>MaxInteract:</u>**
   MaxInteract considers some interaction between load types (i.e., Resultant, Shear, Force and Moment), and reports on the maximum of these usages. PLS-POLE / TOWER determines the Usage of the CAN element for Resultant loads, Shear Loads, Forces and Moments, by considering the interaction of each capacity within these categories. The maximum usage is then reported.

2. **<u>Independent:</u>**
   Independent calculates the percentage usage of the CAN element for each load case as the ***largest*** of the ratios for each of the 16 capacities defined for each force or moment.

3. **<u>Interaction:</u>**
   Interaction calculates the percentage usage of the CAN element for each load case as the ***summation*** of the ratios for each of the 16 capacities defined for each force or moment.

4. **<u>Interaction-2xLong:</u>**
   Interaction-2xLong calculates the percentage usage of the CAN element for each load case as the ***summation*** of the ratios for each of the 16 capacities defined for each force or moment, except that the longitudinal positive and negative capacities used are double the input capacities for the CAN.
   This option was added as a Client request and was specifically intended to facilitate their checking of Double Arms when used. The intent of the check was to have a CAN element for a single cross arm, and then be able to determine the usage of either a single or double arm. Where the double arm has twice the Longitudinal capacity of the single arm, so the only user change required to see if a double arm is necessary was to change the Strength Check on the CAN element. ***It is not envisaged that this option will be widely used by other Clients.***

CAN element modelling

Placing a CAN element in a model can be a bit confusing, as there is no visible reference of the CAN element shown in the model.

Essentially speaking, the placement of a CAN element in a model is as follows:

1. Select the menu command – ***Geometry/ Connections and Anchors…***this will open the **CAN Connectivity** Dialog.
2. Insert a name for the CAN element.
3. Select the label of the Joint where the CAN element is to be attached.
4. Specify which CAN element you want to use from the CAN Library.
5. Provide a rotation of the CAN element by entering an optional Azimuth (or see 6.a below).
6. The user then selects up to a maximum of 4 labels of Members that are connected to that Joint. Firstly, by specifying the Type of Member (*Brace, Cable, Concrete Pole, Davit, FRP Pole, Guy, Laminated Wood Pole, Mast, Steel Pole, Tubular Davit, Tubular X-Arm, Vang Wood Pole or X-Arm*) and then by selecting the specific member of that type connected to the joint in question.

a. If the User has not specified an Azimuth/rotation angle, then the Azimuth will be taken from the 1st member defined.
b. If the User does not want to specify an Azimuth nor use the azimuth from the first Member connected, then the first member Connect column (Connect1) shall be left blank, and the Member's connected to the CAN should be populated from the second Connect column (Connect2) onwards

7. The User can then select the Type (*2-Parts, Clamp, Guy Strain, Post, Strain or Suspension*) and label of up to 2 Insulators attached to the CAN element.

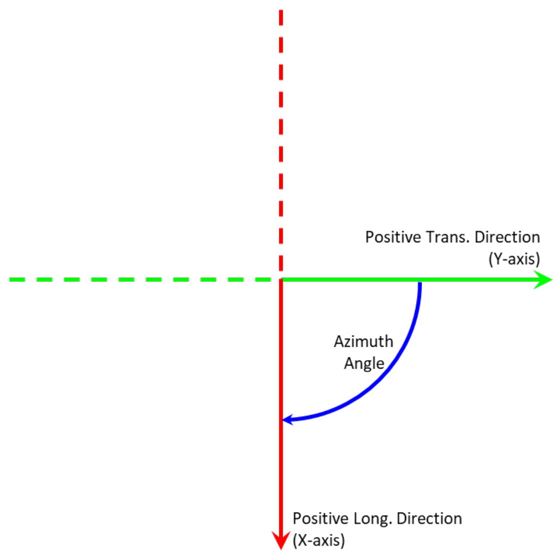


Figure 2 - Azimuth Angle of CAN

Examples

To better illustrate some of the possible/common use cases for CAN elements an example file has been embedded in this Technical Note, with several CAN examples to illustrate their use (*vc5.21_CAN.POL*).

This structure is a distribution wood pole. It is a dead-end single circuit with a dropped neutral configuration and is supported by 2 guy wires that use a shared anchor.

Click Here To Download The .bak File Example

This example file demonstrates the use of CAN elements for:

Guy Anchors

A Guy Anchor CAN element is relatively straight forward to model since we are only interested in the Resultant Guy Anchor capacity and not necessarily any other of the possible Capacity types that can be selected.

As mentioned, this example model has two guy wires.

To model the Anchor itself we can make use of a CAN element, which allows us to check the strength (and optionally track the material quantities if needed).

For an anchor such as this, where you only know the Holding Capacity, for example an 8” Helix Screw Anchor in Class 1 soil has a capacity of 115 kN, then the inputs to capture this element in your CAN Library is as follows. First select ***Components/ Connections and Anchors…***, and then enter the following data:

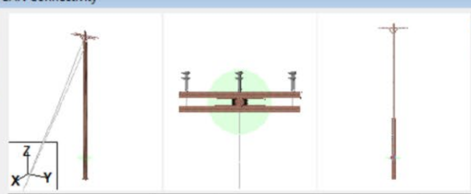
	CAN Property Label	Stock Number	Strength Factor	Strength Check	Resultant Capacity (kN)	Long. Shear Cap. (kN)	Tran. Shear Cap. (kN)	Vert. Shear Cap. (kN)	Long. Pos. Cap. (kN)	Long. Neg. Cap. (kN)	Tran. Pos. Cap. (kN)	Tran. Neg. Cap. (kN)	Vert. Pos. Cap. (kN)	Vert. Neg. Cap. (kN)	M-Long. Pos. Capacity (kN-m)	M-Long. Neg. Capacity (kN-m)	M-Tran. Pos. Capacity (kN-m)	M-Tran. Neg. Capacity (kN-m)	M-Vert. Pos. Capacity (kN-m)	M-Vert. Neg. Capacity (kN-m)
1	8" Helix Anchor - Class 1		Foundation	MaxInteract	115	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Note the following:

- The Strength Factor can be set to match Foundation, if this seems appropriate, or can be made to match one of the other selections.
- The Resultant Capacity is set to match the stated Holding Capacity of the screw anchor.
- In this case, the capacities for all but the Resultant force are left at zero and will be disregarded in any strength checks later.
- The Strength Check type is not needed, as there is only a single capacity type defined in this example, so it doesn’t matter which strength check type you select. And so all selected options will produce the same result.

Once the library is updated, to place this CAN element in a model you would select ***Geometry/ Connections and Anchors…***. And then enter the following data:

CAN Connectivity



Model Check Report

No errors or relevant warnings detected.

	CAN Label	Attach Label	CAN Property Set	Azimuth (deg)	Azimuth/Connect1 Member Type	Azimuth/Connect1 Member Label	Connect2 Member Type	Connect2 Member Label	Connect3 Member Type	Connect3 Member Label	Connect4 Member Type	Connect4 Member Label	Connect1 Insulator Type	Connect1 Insulator Label	Connect2 Insulator Type	Connect2 Insulator Label
1	Anch1	$Gnd1	8" Helix Anchor - C	0			Guy	G1	Guy	G2						

Note:

- Attachment labels for Guy wire anchor points are easily identified by the “$” sign in front of them, in this model it is “$Gnd1”.
- Since it is not required to specify an Azimuth for this type of element, both the **Azimuth** column and the **Azimuth/Connect1 Member Type** and **Azimuth/Connect1 Label** columns are left blank. The 2 guy wires that attach to this Joint are then listed for the **Connect2** and **Connect3** columns.

When a model analysis is Run, the load from both guy wires is summed together and checked against the stated capacity of the guy anchor (115 kN) which could be further reduced if a Strength Factor for Foundations is entered that is lower than 1 in the loading files (LCA or LIC), or in the PLS-CADD criteria file.

Limit conductor tension on cross-arms

Some utilities require a maximum tension be applied per conductor/phase under dead-end conditions. You can apply this type of check in addition to the standard member check from the analysis on the cross-arm elements.

For example, for a given dead-end/guying arrangement there might be a stated limit of maximum tension per conductor set to 7000 N.

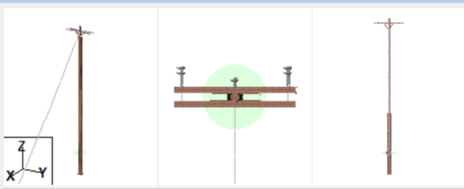
This type of CAN element can be created in in the ***Components/ Connections & Anchors…*** by entering the following data:

	CAN Property Label	Stock Number	Strength Factor	Strength Check	Resultant Capacity (kN)	Long. Shear Cap. (kN)	Tran. Shear Cap. (kN)	Vert. Shear Cap. (kN)	Long. Pos. Cap. (kN)	Long. Neg. Cap. (kN)	Tran. Pos. Cap. (kN)	Tran. Neg. Cap. (kN)	Vert. Pos. Cap. (kN)	Vert. Neg. Cap. (kN)	M-Long. Pos. Capacity (kN-m)	M-Long. Neg. Capacity (kN-m)	M-Tran. Pos. Capacity (kN-m)	M-Tran. Neg. Capacity (kN-m)	M-Vert. Pos. Capacity (kN-m)	M-Vert. Neg. Capacity (kN-m)
2	TensionLimiter_Dbl X-Arm		Hardware	Independent	7	0	0	0	7	7	0	0	0	0	0	0	0	0	0	0

In this case only values need be entered for the Longitudinal capacities (and perhaps the resultant).

Placing this CAN element into the model can be done by placing the CAN at the tip of the Vang element to which the strain insulators are attached. This is illustrated below. Three CAN elements are placed, one for each of the strain insulators:

CAN Connectivity



Model Check Report

No errors or relevant warnings detected.

	CAN Label	Attach Label	CAN Property Set	Azimuth (deg)	Azimuth/Connect1 Member Type	Azimuth/Connect1 Member Label	Connect2 Member Type	Connect2 Member Label	Connect3 Member Type	Connect3 Member Label	Connect4 Member Type	Connect4 Member Label	Connect1 Insulator Type	Connect1 Insulator Label	Connect2 Insulator Type	Connect2 Insulator Label
2	tensLim_1	I1AV	TensionLimiter_Dbl	0									Strain	I1		
3	tensLim_2	NAV	TensionLimiter_Dbl	0									Strain	N		
4	tensLim_3	I2AV	TensionLimiter_Dbl	0									Strain	I2		

Crossarm connection bolt

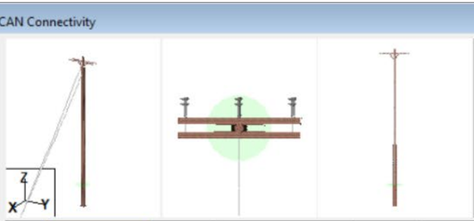
The last CAN element to be discussed is one to be used to check the shear loading on the Cross-arm connection bolt. In this case the member is attracting loads from several elements. The 2 x cross arms and the vang element applying the conductor loads. However, since these loads are all passed onto the Pole element, the CAN member only needs to be attached to the pole to determine the other loads being applied to the connection bolt.

The input parameters for this component are as follows:

	CAN Property Label	Stock Number	Strength Factor	Strength Check	Resultant Capacity (kN)	Long. Shear Cap. (kN)	Tran. Shear Cap. (kN)	Vert. Shear Cap. (kN)	Long. Pos. Cap. (kN)	Long. Neg. Cap. (kN)	Tran. Pos. Cap. (kN)	Tran. Neg. Cap. (kN)	Vert. Pos. Cap. (kN)	Vert. Neg. Cap. (kN)	M-Long. Pos. Capacity (kN-m)	M-Long. Neg. Capacity (kN-m)	M-Tran. Pos. Capacity (kN-m)	M-Tran. Neg. Capacity (kN-m)	M-Vert. Pos. Capacity (kN-m)	M-Vert. Neg. Capacity (kN-m)
3	5/8" Bolt		Steel	MaxInteract	0	49.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0

And the CAN element is placed in the model as follows:

CAN Connectivity



Model Check Report

No errors or relevant warnings detected.

	CAN Label	Attach Label	CAN Property Set	Azimuth (deg)	Azimuth/Connect1 Member Type	Azimuth/Connect1 Member Label	Connect2 Member Type	Connect2 Member Label	Connect3 Member Type	Connect3 Member Label	Connect4 Member Type	Connect4 Member Label	Connect1 Insulator Type	Connect1 Insulator Label	Connect2 Insulator Type	Connect2 Insulator Label
5	Bolt1	P:ARM	5/8" Bolt	0			Wood Pole	P								

Results and output:

Once an analysis is run there will be a section in the **Summary Report** with the results for the “*Connections and Anchors Check by Load Case*”:

Summary of Connections and Anchors Check by Load Case:

Load Case	CAN Label	Attach Label	Strength Factor	Strength Check	Usage %	
RULE 250B GRADE B NA+,I NA+	Anchl	$Gndl	1.00	MaxInteract	31.05	
RULE 250B GRADE B NA+,I NA+	tensLim_1	I1AV	1.00	Independent	97.63	
RULE 250B GRADE B NA+,I NA+	tensLim_2	I2AV	1.00	Independent	97.63	
RULE 250B GRADE B NA+,I NA+	tensLim_3	I3AV	1.00	Independent	97.63	
RULE 250B GRADE B NA+,I NA+	Boltl	P:ARM	1.00	MaxInteract	3.55	
RULE 250B GRADE B NA-,I NA-	Anchl	$Gndl	1.00	MaxInteract	31.05	
RULE 250B GRADE B NA-,I NA-	tensLim_1	I1AV	1.00	Independent	97.63	
RULE 250B GRADE B NA-,I NA-	tensLim_2	I2AV	1.00	Independent	97.63	
RULE 250B GRADE B NA-,I NA-	tensLim_3	I3AV	1.00	Independent	97.63	
RULE 250B GRADE B NA-,I NA-	Boltl	P:ARM	1.00	MaxInteract	3.55	
RULE 250B GRADE B Uplift NA+,I NA+	Anchl	$Gndl	1.00	MaxInteract	31.02	
RULE 250B GRADE B Uplift NA+,I NA+	tensLim_1	I1AV	1.00	Independent	97.54	
RULE 250B GRADE B Uplift NA+,I NA+	tensLim_2	I2AV	1.00	Independent	97.54	
RULE 250B GRADE B Uplift NA+,I NA+	tensLim_3	I3AV	1.00	Independent	97.54	
RULE 250B GRADE B Uplift NA+,I NA+	Boltl	P:ARM	1.00	MaxInteract	3.24	
RULE 250B GRADE B Uplift NA-,I NA-	Anchl	$Gndl	1.00	MaxInteract	31.02	
RULE 250B GRADE B Uplift NA-,I NA-	tensLim_1	I1AV	1.00	Independent	97.54	
RULE 250B GRADE B Uplift NA-,I NA-	tensLim_2	I2AV	1.00	Independent	97.54	
RULE 250B GRADE B Uplift NA-,I NA-	tensLim_3	I3AV	1.00	Independent	97.54	
RULE 250B GRADE B Uplift NA-,I NA-	Boltl	P:ARM	1.00	MaxInteract	3.24	
RULE 250C GRADE B NA+,I NA+	Anchl	$Gndl	1.00	MaxInteract	20.89	
RULE 250C GRADE B NA+,I NA+	tensLim_1	I1AV	0.80	Independent	82.02	
RULE 250C GRADE B NA+,I NA+	tensLim_2	I2AV	0.80	Independent	82.02	
RULE 250C GRADE B NA+,I NA+	tensLim_3	I3AV	0.80	Independent	82.02	
RULE 250C GRADE B NA+,I NA+	Boltl	P:ARM	1.00	MaxInteract	2.62	
RULE 250C GRADE B NA-,I NA-	Anchl	$Gndl	1.00	MaxInteract	20.89	
RULE 250C GRADE B NA-,I NA-	tensLim_1	I1AV	0.80	Independent	82.02	
RULE 250C GRADE B NA-,I NA-	tensLim_2	I2AV	0.80	Independent	82.02	
RULE 250C GRADE B NA-,I NA-	tensLim_3	I3AV	0.80	Independent	82.02	
RULE 250C GRADE B NA-,I NA-	Boltl	P:ARM	1.00	MaxInteract	2.62	
RULE 250D GRADE B NA+,I NA+	Anchl	$Gndl	1.00	MaxInteract	28.74	
RULE 250D GRADE B NA+,I NA+	tensLim_1	I1AV	0.80	Independent	112.26	NG
RULE 250D GRADE B NA+,I NA+	tensLim_2	I2AV	0.80	Independent	112.26	NG
RULE 250D GRADE B NA+,I NA+	tensLim_3	I3AV	0.80	Independent	112.26	NG
RULE 250D GRADE B NA+,I NA+	Boltl	P:ARM	1.00	MaxInteract	2.35	

For further information, and to inspect the specific loads for each load case, refer to the **Analysis Results Report**, where there are 2 tables, one for the loads/forces and the other for moments. These tables are produced for each load case that is applied to the model:

Connections and Anchors Check (Forces) for Load Case "RULE 250B GRADE B NA+,I NA+":

CAN Label	Attach Label	Eff. Attach Label	Azimuth (deg)	Strength Factor	Strength Check	Resultant (kN)	Resultant Capacity (kN)	Long. Shear (kN)	Long. Shear Cap. (kN)	Tran. Shear (kN)	Tran. Shear Cap. (kN)	Vert. Shear (kN)	Vert. Shear Cap. (kN)	Long. Force (kN)	Long. Pos. Cap. (kN)	Long. Neg. Cap. (kN)	Tran. Force (kN)	Tran. Pos. Cap. (kN)	Tran. Neg. Cap. (kN)	Vert. Force (kN)	Vert. Pos. Cap. (kN)	Vert. Neg. Cap. (kN)	Max. Usage %
Anchl	$Gndl	$Gndl	0	1.00	MaxInteract	35.702	115.000	24.696	0.000	35.683	0.000	25.808	0.000	-25.782	0.000	0.000	1.147	0.000	0.000	-24.670	0.000	0.000	31.05
tensLim_1	I1AV	I1AV	0	1.00	Independent	6.834	7.000	0.544	0.000	6.822	0.000	6.824	0.000	-6.812	7.000	7.000	0.397	0.000	0.000	0.372	0.000	0.000	97.63
tensLim_2	I2AV	I2AV	0	1.00	Independent	6.834	7.000	0.544	0.000	6.822	0.000	6.824	0.000	-6.812	7.000	7.000	0.397	0.000	0.000	0.372	0.000	0.000	97.63
tensLim_3	I3AV	I3AV	0	1.00	Independent	6.834	7.000	0.544	0.000	6.822	0.000	6.824	0.000	-6.812	7.000	7.000	0.397	0.000	0.000	0.372	0.000	0.000	97.63
Boltl	P:ARM	P:ARM	0	1.00	MaxInteract	20.659	0.000	1.755	49.500	20.603	0.000	20.641	0.000	20.585	0.000	0.000	-1.522	0.000	0.000	0.873	0.000	0.000	3.55

Connections and Anchors Check (Moments) for Load Case "RULE 250B GRADE B NA+,I NA+":

CAN Label	Attach Label	Eff. Attach Label	Azimuth (deg)	Strength Factor	Strength Check	M-Long. Moment (kN-m)	M-Long. Pos. Capacity (kN-m)	M-Long. Neg. Capacity (kN-m)	M-Tran. Moment (kN-m)	M-Tran. Pos. Capacity (kN-m)	M-Tran. Neg. Capacity (kN-m)	M-Vert. Moment (kN-m)	M-Vert. Pos. Capacity (kN-m)	M-Vert. Neg. Capacity (kN-m)	Max. Usage %
Anchl	$Gndl	$Gndl	0	1.00	MaxInteract	0.000	0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	31.05
tensLim_1	I1AV	I1AV	0	1.00	Independent	0.000	0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	97.63
tensLim_2	I2AV	I2AV	0	1.00	Independent	0.000	0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	97.63
tensLim_3	I3AV	I3AV	0	1.00	Independent	0.000	0.000	0.000	-0.000	0.000	0.000	0.000	0.000	0.000	97.63
Boltl	P:ARM	P:ARM	0	1.00	MaxInteract	-0.003	0.000	0.000	0.537	0.000	0.000	-0.271	0.000	0.000	3.55

This allows you to see the details of the loading on these CAN elements, and the basis for the Maximum Usage % calculations.