5400 King James Way, Suite 300
Madison, WI 53719, U.S.A.
Phone: 608.238.2171 **Fax:** 608.238.9241
Email: info@powerlinesystems.com
URL: https://www.powerlinesystems.com/

Modeling Cross Arms in PLS-POLE

Introduction

On a basic level cross arms serve the purposes of creating separation between conductors and the supporting structure and transferring the load to the supporting structure. Whether the load is designed for vertical loads on tangent structures or horizontal loads from dead ends, cross arm modeling and analysis can be as simple or as complex as the user wants to make it. PLS-POLE gives users the options to model cross arms with a high degree of accuracy as material properties, connection codes, and loading geometry can all be specified and analyzed through non-linear analysis methods.

This technical note will cover the basics of working with cross arms including specifying material properties and how basic dimensional property calculations are performed. More advanced methods of modeling, such as double cross arm H-frame structures, or wishbone structures will also be covered. Example backup files are also provided in the link at the top of page 6 to provide users with the option to follow along with the advanced modeling examples.

Cross Arm Basics

Cross Arm Properties:

Cross arms are modeled with a uniform rectangular cross-section over a specified length. Given that there are many different materials that may be used to manufacture a cross arm, it is up to the user to verify that the material properties are correctly input. Understanding cross arm property inputs is important in understanding the behavior of a cross arm. Details on these inputs and the applicable calculations are provided below. Power Line Systems has also worked with manufacturers to create cross arm component libraries that are available for download at the location linked below. These values, however, should always be verified by the user.

https://www.powline.com/files/pls_pole.html

Cross Arm Property Label and Stock Number:

The cross arm property and stock number are user defined labels that are unique to each cross arm. A label is required for each property, whereas stock numbers are optional. These are used for identification during modeling, and tracking material quantities. Manufacturers will often provide specific cross arm labels and stock numbers in their component libraries, but in the absence of this or if creating a non-standard cross arm for modeling purposes, it will be up to the user to create a unique label.

Cross Section Area, A:

Arm Depth multiplied by the arm Width. Bolt holes input in the Geometry dialogs will reduce the cross sectional area of the arm.

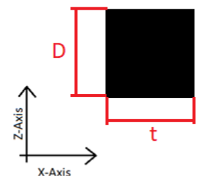
X Inertia, IX:

Moment of inertia about horizontal axis, i.e. resisting bending from vertical loads

Z Inertia, IZ:

Moment of inertia about vertical axis, i.e. resisting bending from loads perpendicular to the vertical plane through the arm (longitudinal loads)

Weight, W:
Arm dead weight based on the volume of the arm, and the weight density (wd) of the arm material.

X-Arm Property Formulas	
Property	Square
	
A	$D * t$
IX	$\frac{t * D^3}{12}$
IZ	$\frac{D * t^3}{12}$
W	$A * L * wd$
SX	$\frac{t * D^2}{6}$
SZ	$\frac{D * t^2}{6}$

Depth, D:
Arm depth. Used for wind load calculation and deduction of cross section area and section modulus when vertical bolt hole is defined.

Width, t:
Optional arm width. Used for deduction of cross section area and section modulus when horizontal bolt hole is defined. Default value = *Cross section area / Depth*

Length, L:
Overall length of the arm. Arm length defines the origin and end points of the arm. If there will be points outside of this length that the arm will need to connect to a longer arm will be required. An arm will not automatically adjust to match the required length.

Mod. of Elasticity, E:
Modulus of elasticity of arm material

Drag coefficient, CD:
Drag coefficient (for wind load calculation)

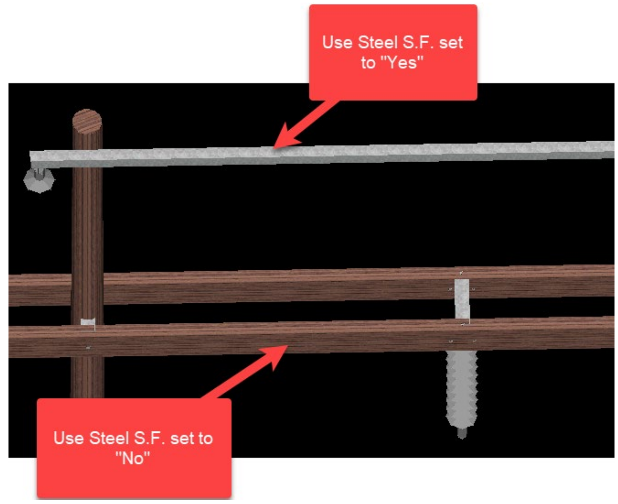
Geometry:
Geometry, which will be covered in greater depth below, is used to specify intermediate joints between the origin and end of the arm. This dialog is also used to specify vertical and horizontal bolt holes to reduce the cross sectional area and section modulus.

Strength Check Type:

Calculated: The most common strength check method, the calculated check requires the inputs of Design Normal Stress, X Section Modulus (SX), and Z Section Modulus (SZ). POLE will use the axial force, and moments about X and Z to determine the usage of the arm.

Calculated-Angle: POLE allows users to design cross arms constructed of angle steel. This process is entirely possible within the POLE , but is covered in detail in a separate Tech Note and Video.

Nominal - Nominal Circular - Nominal Triangular: Nominal checks are available in POLE, but are less commonly used as the calculated method is more accurate. Information about these analysis methods can be found in section 3.2.1.2 of the POLE manual.



Use Steel S.F.:

Selecting "No" will use the strength factor from the Strength Factor Non-Tubular Arms column. Selecting "Yes" will use the value in the Strength Factor Steel Poles, Tubular-Arms, Towers column. Selecting "Yes" will also change the appearance of the cross arm in the model when rendering to use the appropriate material.

Cross Arm Geometry and Connection:

Correctly setting up cross arm geometry and attaching the cross arm to a structure is a relatively easy task, but a small mistake can end up causing confusing issues with analysis if not done correctly. There are two basic steps to attaching a cross arm to a pole: defining the attachments, and attaching the arm to a structure.

While in the cross arm components library, clicking the Geometry field opens an additional dialog. This dialog allows users to specify intermediate joints between the origin and end points of the arm. There is no reason to create joints at the very beginning and end of the arm as POLE will create these automatically even though they do not appear in this geometry dialog. These end joints will appear with labels ":O" and ":E" in the geometry dialog when connecting the arm to a structure. There are four columns where information can be input:

Joint Label:

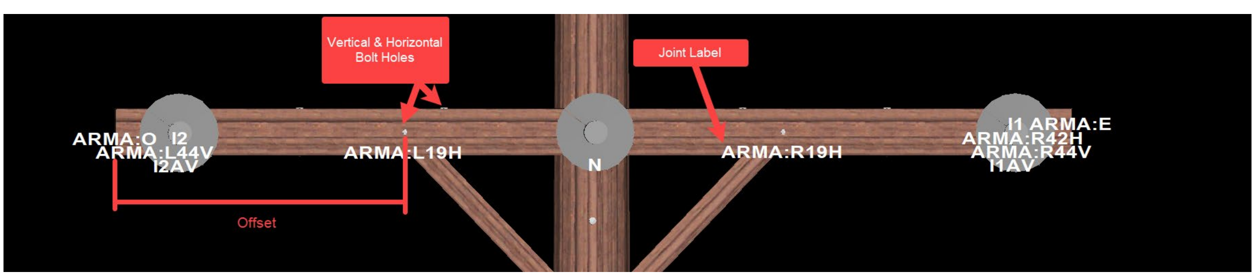
This label is a short, but unique label that the user defines to differentiate between different attachment points. While in the connection dialog, this label will appear after the cross arm label (x-armlabel:jointlabel).

Offset:

Joints are defined as a distance from the origin of the arm, the origin being on the left side of the arm. An example of this is a 10' arm. An Offset of 3' will be on the left half of the arm, and 5' will be at the arm midpoint.

Horiz. & Vert. Hole Diameter:

Holes drilled in the arm will reduce the section modulus in the X and Z directions. To account for this, users can specify the dimension of the hole that will be drilled for bolts to be added. Horizontal holes are drilled through the face of the arm, and reduce the SX value. Vertical holes are drilled top to bottom on the arm and reduce the SZ value.



This dialog can be thought of as specifying the standard arm attachments. When defining attachments in this dialog, the attachments and holes will be present in all instances where this arm property is used. If there are instances where a unique attachment is required, the user can add this attachment in the **Geometry/Cross Arms...** dialog. Keep in mind that joints cannot be collocated. Adding a joint using the geometry dialog to the same location as a joint created in the components dialog will results in warnings and errors during a structure analysis.

Connecting a cross arm to a structure is done either using the graphical method, or going through the connection dialog found at **Geometry/Cross Arms...** If the graphical approach is used, the arm will be added as Pinned X, to the center of the pole. This is likely not the desired end result so adjustments will need to be made in the connection dialog.

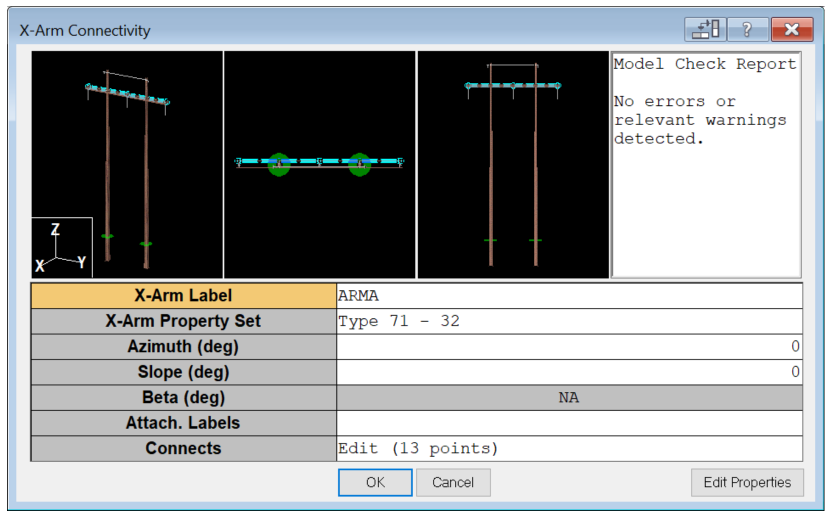
To add an arm to a structure, open the **Geometry/Cross Arms...** dialog. There are seven columns, of which one will typically be greyed out. The use of these columns are as follows:

X-Arm Label:
This field allows users to enter a unique label for each arm.

X-Arm Property Set:

Users select the appropriate cross arm from the drop down list. This list is populated by cross arm labels created in **Components/Cross Arm...**

Azimuth:
If left at the default 0, the arm will align with the end joint pointing along the positive transverse axis. Changing the azimuth of the cross arm will rotate the arm clockwise, so that the end points to the azimuth specified. This compass can be shown or hidden to assist with rotation using **View/Display Options/Show Structure Compass**.



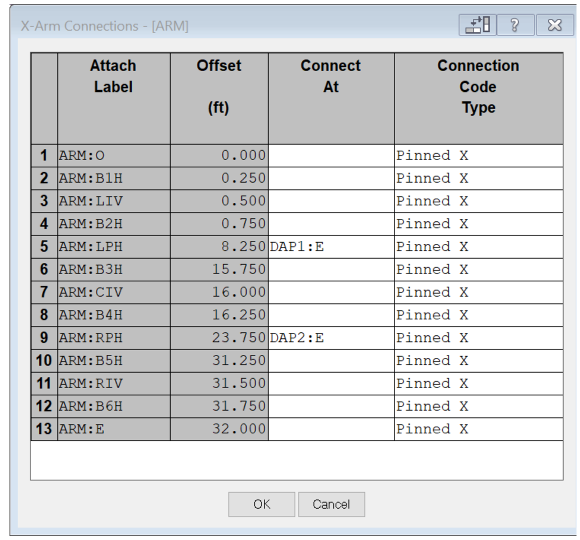
Slope:
If left at the default 0, the arm will be level across its length. Changing this value will rotate the arm counter-clockwise. This can be useful for wishbone-type structures (as shown below).

Beta:
The beta value only applies when angle cross arms are used. This value is discussed in greater detail in the Angle Cross Arm technical video.

Attach Labels:
Attachment labels are very similar to the joints specified in the geometry dialog of the Cross Arm components library. A user can specify the offset from the arm origin, and either a vertical or horizontal bolt hole. Unlike changing the component library, changes to these attachment labels will not affect other structures using the same cross arm. These attachments are best used when a unique attachment to an arm will be used. Standard attachment location is better specified in the component library.

Connects:

Cross arm connections are highly important for two reasons. The first is that accidentally specifying the wrong connection can cause non-convergence during analysis. The second reason is that different connection codes will give different analysis results. Engineering judgement and connection hardware play a large role when determining which connection code option to select.


X-Arm Connections - [ARM]

	Attach Label	Offset (ft)	Connect At	Connection Code Type
1	ARM:O	0.000		Pinned X
2	ARM:B1H	0.250		Pinned X
3	ARM:LIV	0.500		Pinned X
4	ARM:B2H	0.750		Pinned X
5	ARM:LPH	8.250	DAP1:E	Pinned X
6	ARM:B3H	15.750		Pinned X
7	ARM:CIV	16.000		Pinned X
8	ARM:B4H	16.250		Pinned X
9	ARM:RPH	23.750	DAP2:E	Pinned X
10	ARM:B5H	31.250		Pinned X
11	ARM:RIV	31.500		Pinned X
12	ARM:B6H	31.750		Pinned X
13	ARM:E	32.000		Pinned X

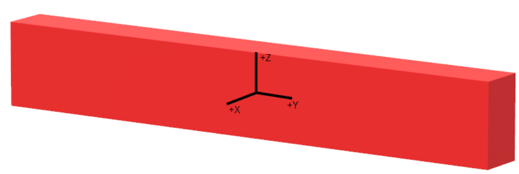
OK Cancel

The first two columns of the X-Arm Connections dialog were specified in previous attachment dialogs. These cannot be adjusted in this menu. The Connects At and Connection Code Type columns are where arm connection will be specified. The Connect At column is used to specify where the arm will connect to another member. This will typically be a pole attachment, or another arm attachment, but can be other structural attachments. Clicking a field will provide a drop-down list of available attachments. If more than one connection is specified, as in an H-frame or wishbone, the distance between the connection points must match the distance between the arm attachment points. Differences in attachment distances will create warnings.

The Connection Code Type column is used to specify the fixity with which an arm is attached to another member. There are 10 options to choose from, but the basic connection options are either fixed or pinned in various directions. Each of these options are further described below:

Fixed/Fixed Face:
When fixed is selected, the cross arm will be totally fixed to the attachment point specified. No rotation in any direction will be allowed and moments from the arm will be transferred into the structure. Selecting Fixed and attaching to a pole attachment point will place the arm at the center of the pole. The arm can also be offset from the center of the pole by using a cross arm protruding from the pole, which will be discussed below. Using Fixed Face will offset the arm from the center of the pole to the face of the pole without needing to create an additional cross arm.

Pinned X, Y, Z, XY, etc:
Pinning an arm will allow rotation of the arm around the axis specified. An overview of the available pin directions is available in section 4.3 of the PLS-POLE manual. Arms that are pinned in any direction will be connected at the center of the structure. As with a fixed connection, the arm can be offset from the center of the pole by pinning the arm to the end of a cross arm that is protruding from the face of the structure.



Arm pin directions are based on the structure coordinate system, not the arm orientation. While the structure coordinate system and the arm coordinate system will be equal when the arm aligns with the transverse axis, rotating the arm around the pole will require that the pinned direction be changed accordingly. Pinning an arm in the x-direction, for example, will work for arms on the transverse axis. Leaving the arm as Pinned X, but rotating the arm 90 degrees will result in the arm being able to roll. Changing to Pinned Y would be more appropriate if a pinned direction is to be specified.

Pinned Face:
Like Fixed Face, Pinned Face will offset the cross arm to the face of the structure. Additionally, the structure will be pinned in the direction that allows the arm to rotate about the connection point. This will replicate a single

bolt going through the face of the arm into the pole. Using Pinned Face simplifies the modeling process as the possibility of changing the pinned direction or incorrectly pinning a cross arm is reduced.

Advanced Cross Arm Modeling

PLS-POLE Modeling Examples
You Must Save This PDF To Your Computer To Gain Access
Viewing It In Your Web Browser Won't Work

Modeling cross arms can be as simple or complex as a user wants to make it. On the simple end, a cross arm can be modeled with conservative values, and connected to a pole joint with a fixed connection code. On the more complex end are specific material properties and pinned connections to multiple attachment points. The best case scenario is the inclusion of cross arms into framing elements, making more complex models quick and easy to create. A few more advanced modeling scenarios are detailed below. Each of these scenarios are modeled in such a way that they can be used to create a framing element.

Double Cross Arm on H-Frame:

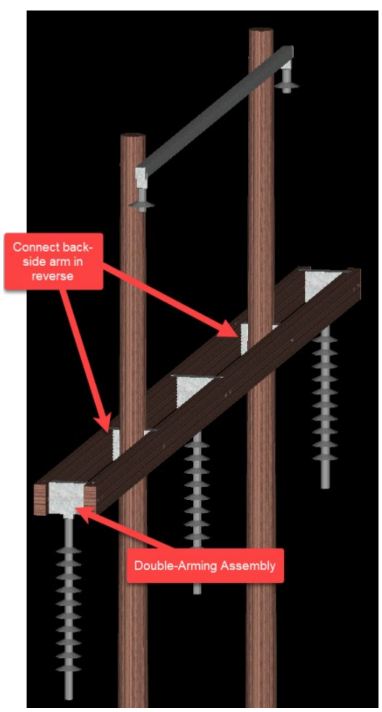
This model is considered advanced for two reasons. The first is that spacers modeled out of cross arms are needed to attach to the pole, and support the suspension insulators. The second is that cross arms need to be added in a specific order. There are cross arms attached to cross arms, which must be systematically done.

Top cross arm:

The top cross arm is straight-forward. Attachment points on the arm, added either in the components or attachments dialogs must align with the center-to-center distance between the poles. The only additional step is to use one of the connection codes to attach the cross arm to the attachment points on the two poles. Pinned face is chosen in the example, but Pinned X on the pole or attached to an offset cross arm element would also be acceptable.

Double cross arm:

In order to make a double cross arm assembly that can adapt to different pole sizes a cross arm element will be used to attach the arms to the poles, and to replicate a double arming bracket (DA) assembly that will support the suspension insulators. The example uses a length of 1.25', but this will depend on typical pole diameters for your projects. The DA element should be approximately the average of potential pole diameters. This will result in the cross arms being offset from the pole for smaller class poles, and running through the pole in larger classes, but results in a close approximation. If a more accurate model is desired, different lengths of DA cross arm elements would need to be modeled to match the cross arm spacing to the pole diameter.

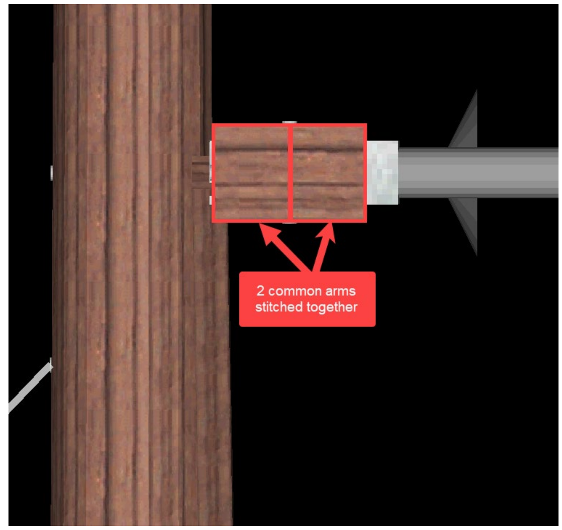


When building this model, the order of adding the cross arm elements matters. There must be an attachment available for cross arms to attach to. The DA cross arm element must be attached to the poles first, with the cross arms themselves added second, and finally the DA elements attached to the cross arms. The connection code to use is up to engineering judgement. The DA elements can either be fixed on both sides or one of the two sides can be pinned to allow rotation. At least one of the attachments for the DA elements must be fixed or stability issues may cause issues during analysis.

Stitched X-Arms:

In a situation where more arm strength is desired, but a larger arm is not available stitching the arms together may be a viable solution. As with many modeling decisions, engineering judgement is required when deciding how to connect the two arms. This will also depend on the hardware used to connect the arms. A decision must be made on whether movement will be allowed at the interface between the two cross arms being stitched.

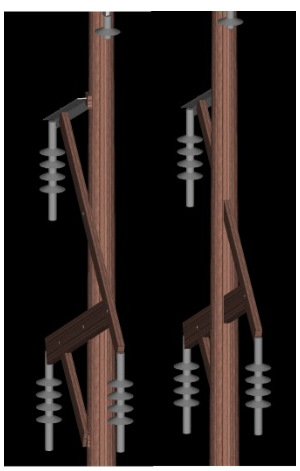
If there will be movement allowed, then there will not be a fixed connection. In this case, the two arms are connected by a short cross arm element that replicates the bolts holding the cross arms together. Again, making one connection fixed is required for model stability. Setting the other connection to pinned will allow the arms to flex independently of each other.



The example for this type of structure assumes that the two arms will not flex independently of each other. One way to model this is to use short cross arm elements, but to fix both ends. Another way, shown in the model, is to create a cross arm component with the built up section properties of both cross arms. Using the equations shown above a user can create their own cross arm property to attach insulators to.

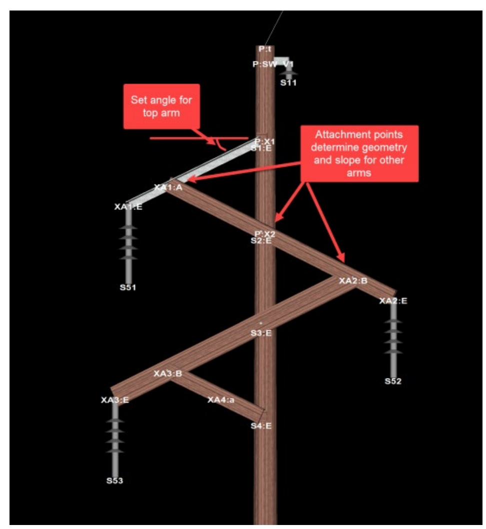
The example for this structure type has one additional caveat that needs to be considered when modeling. The situations where an insulator would connect to a cross arm at the same location that a cross arm connects to a pole are rare, but can happen. Due to how the software connects cross arms, an insulator cannot attach to the same joint as what is used for connecting to the pole. In this case, the best modeling technique is to use a vang element connected to the pole, and long enough to slightly protrude from the arm. This load transfer mechanism will allow the insulator to be located correctly, and without doubling up on the connection to the arm.

Wishbone Structure:



Arms on face of pole — Arms in center of pole

The main difficulty with modeling a wishbone structure is aligning joints on the pole with arm connection locations. Typically with cross arms the critical dimension is just between two points. Modeling a wishbone, however requires the alignment of three points that lie on a sloping line. Typically a structure drawing will have the horizontal and vertical dimensions called out, but trigonometry will be required to make sure the arm properly connects to the structure and other arms.



Unlike other structures, cross arms on a wishbone structure cannot be connected using the pinned or fixed face connections very easily. Since poles are tapered, moving the arms to the face will change the distance between attachment points. To address this the example structure uses short cross arm elements of constant length protruding from the pole. This will allow the arms to approximately attach to the face of the structure. The other option is to leave the arms at their default pinned location in the center of the structure.