

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/

Reinforcing Wood Poles within PLS-POLE

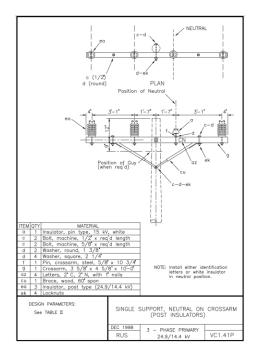
Introduction

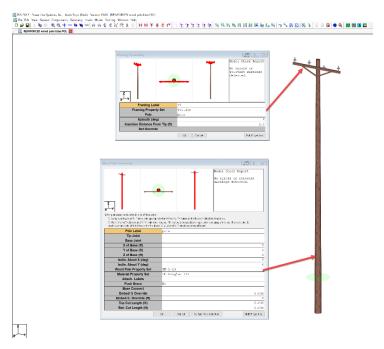
Wood poles an essential commodity that helps support the overhead lines industry around the world. Many of these wood pole structures are increasingly being required to do more today than was originally intended. The addition of communication wires and degradation of wood poles over time may can add more load to a structure than intended by the original design. Wood poles should be replaced and is why inspection and maintenance of the electrical grid infrastructure is of such importance. In instances, where outages, maintenance or cost issues don't allow for a pole replacement there are pole restoration products designed to restore poles weakened by decay or other damage so that they meet or exceed structural strength requirements defined by applicable codes.

There are many products available that consist of a steel channel and other structural shapes that reinforce a wood pole and support the wood pole both above and below the ground line. This additional reinforcement is intended to increase the moment capacity at and near the ground line of the structure. This technical note focuses on the design and life cycle of a wood pole distribution structure and portrays how updates made to the infrastructure of the electric grid and degradation of a wood pole can be evaluated in PLS-POLE. Then when a structural solution is needed how this can be modeled in PLS-POLE.

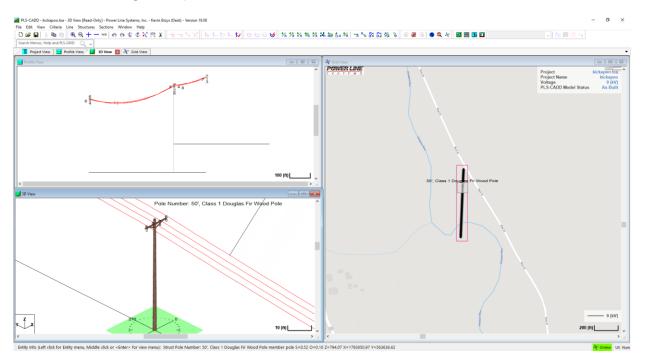
PLS-POLE Design & Modeling

The original design of this example will center on a Class 1 Douglas Fir wood pole with a RUS frame named vc1.41p from the RUS Framing Library available in PLS-POLE at <u>https://www.powline.com/files/pls_pole/rus/RUSModels.html</u>. Below is the structure drawing of the structure as well as the structure modeled in PLS-POLE.





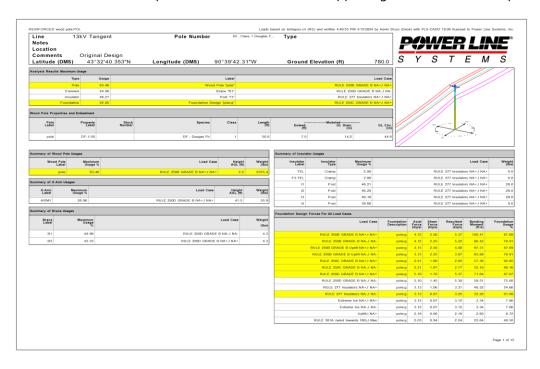
This structure consists of a Douglas Fir wood pole that has a Modulus of Rupture (MOR) of 8 ksi and a Modulus of Elasticity (MOE) of 1920 ksi. The 50' Class 1 wood pole used for the structure has an ultimate ground line moment of about 184,500 ft*lbs assuming a 10% plus 2' embedment.



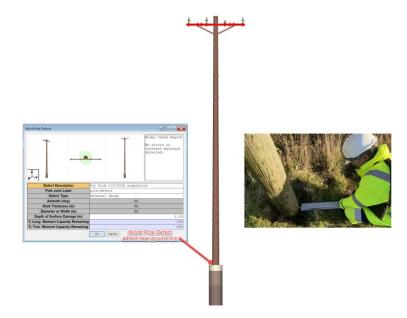
This example begins when this structure goes from the design phase to construction and is spotted along a rural road in Richland County in the Wisconsin Driftless region. This pole is designed to support 3 phases of 2/0 "Quail" ACSR and 1/0 "Raven" ACSR neutral wire. All wires were constructed with a design tension of 1000 lbs at 60° F. The ahead and back spans are 159' and 413'respectively with some vertical projection between the adjacent structures. The ruling span for this section is 350 feet. This scenario is modeled in **PLS-CADD/Lite** below with the **PLS-POLE/Wood** structure spotted about 300' North of the Kickapoo River. The structure is spotted in PLS-CADD/Lite using a criteria file set up with the NESC Heavy requirements and PLS-POLE models show there is adequate clearance for the conductors at the maximum operating temperatures and the initial design of this structure has a maximum wood pole usage of 65% when analyzed against NESC Heavy loading requirements.

Notes Location Comments Latitude (DI		ginal D 3°32'4	esign 0.353"N	Longitude (DMS)	90°39'42.3	1"W	Ground	Elevation (ft) 7	80.0 S	Y		/ E R T	E M	N/ 1 S
nalysis Results N	taximum Usag	•												///	/
	Туре	Usage		La						ad Case					
E1.	Pole	64.94 44.95		Wood Pole "p Brace "					E 250B GRADE B N				//		
	sulator	46.21		Post					LE 277 Insulators Na						
Foun	dation	98.02		Foundation Design "pole	kg*			RULE 250	B GRADE B Uplift N	N+,I NA+		///			
Vood Pole Propert	ties and Embe	dment													
Pole	Prope	rty bel	Stock Number	Species	Class	Length (ft)	Embed. (ft)	Modelec G	L Diam. (in)	GL Cire. (in)		<u>ت</u>		3	
pole	DF-1	50		DF - Dougas Fir	1	50.0	7.0		14.2	44.6			· · · · · ·		
ummary of Wood	Pole Usages						Summary of Insula	tor Usages							
Wood Pole Label	Max	imum ige %		Load Cas	Height AGL (ft)	Weight (1bs)	Insulator	Insulator Type	Maximum Usage %					Load Case	• •
pole		64.94		RULE 250B GRADE B NA+,I NA	• 6.6	2355.4	TEL	Clamp	0.00			RULE	250B GRADE	B NA+,I NA+	•
ummary of X-Arm	Usages						F3-TEL	Clamp	0.00					B NA+,I NA+	
X-Arm Label	Maximum			Load Case	Height AGL (ft)	Weight (Ibs)	11	Post	46.21					ors NA+,I NA+	
	Usage %						13	Post	46.18					ors NA+,I NA+	
ARM1	26.85			RULE 250D GRADE B NA+,I NA+	41.5	55.9	N	Post	38.68			RULE	277 Insulat	ors NA+,I NA+	•
ummary of Brace	Usages						Foundation Design	Forces For All	Load Cases						
Brace Label	Maximu Usa	im se %			Load Case	Weight (Ibs)			Load Case	Foundation	Axial Force (kips)	Shear Force (kips)	Resultant Force (kips)	Bending Moment (ft-k)	Founda
B1	44.	95		RULE 250D GRADE	B NA JI NA	4.3		RULE 250B	GRADE B NA+J NA+	pole:g	4.24	1.90	4.65	77.57	6
82	43.	41		RULE 250D GRADE	B NA+,I NA+	4.3		RULE 250E	GRADE B NA-J NA	pole:g	4.24	1.66	4.55	66.72	(
									E B Uplift NA+,I NA+	pole:g		1.90	3.41	75,41	5
							R		DE B Uplitt NA-J NA	pole:g		1.66	3.28	64.82	t
									GRADE B NA+,I NA+	pole:g		1.54	2.67	49.16	3
									GRADE B NA+J NA+	pole:g		1.44	4,33	53.52	
									GRADE B NA-J NA	poleig		1.03	4.28	44.77	
									Insulators NA+,I NA+	pole:g		0.78	2.92	31.34	8
								RULE 27	Insulators NA-,I NA	pole:g	2.82	0.64	2.89	24.91	(
									treme Ice NA+,I NA+	pole:g		0.06	2.81	2.58	
									xtreme Ice NA-,I NA	pole:g		0.06	2.81	2.58	
							1		Uplift,I NA+	pole:g	2.15	0.05	2.15	2.13	
									nd towards 180),I Max	pole:g	2.03	0.94	2.24	22.64	

As the life of this pole progresses it may be determined that it can be a joint use asset and is selected as a structure to add some communication wires. Using our existing PLS-CADD/Lite model this scenario can be investigated. Two additional communication attachments are modeled to the pole and two XLP HICKORY Covered Line Wire wires were strung into the model at 750 lbs at 60 deg F. The additional loads from the new wire incorporated into the structural analysis as shown below. Because of the excess capacity of the wood pole at the initial design these updates appear acceptable, and the wood pole usage went from 65% to 84%. Two additional communication wires can be added and while this increases the overall usage of the pole it still falls within acceptable usages when looking at required loading requirements. These new communication wires are added, and this pole continues its useful life supporting wires over the Kickapoo River.



Wooden utility poles have finite lifetimes and can develop defects that reduce the strength of a pole eventually resulting in a pole reaching a point where it may not have the strength to meet the original design requirements. This occurs because natural elements gradually wear down a pole due to rot, natural imperfections, damage, extreme weather events, or other factors. Over time the material strength of the wood pole decreases. In **PLS-POLE** this can be accounted for with the wood pole defect feature which can be found at the menu command **Geometry/Miscellaneous/Wood Pole Defects...**. The area defined by the Wood Pole Defects will reduce the cross-sectional area of the wood pole. PLS-POLE will calculate a new Moment of Inertia and Section Modulus based on the defects defined for the cross-sectional area and their location within the cross-sectional area of the pole. We have a YouTube video that describes the wood pole defects feature at https://www.youtube.com/watch?v=IfasvcZGCUE&t=12s.



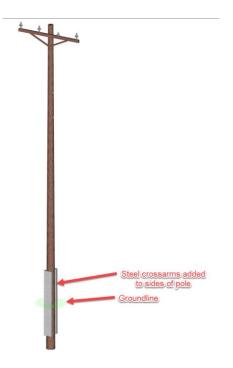
For our example pole, there was a ground line inspection that was undertaken and found some external decay at/near the ground line. Based on the pole inspection reports a 1" deep external decay wood pole defect was modeled around the circumference of the wood pole at the ground line of the wood pole within PLS-POLE. The subsequent structural analysis shows that the design loads from distribution service and new communication wires now has a structure usage of 131%. A pole replacement or a structural solution is needed to extend the service life of this structure.

Location	13kV Tan		Pole Number	50 , Class	s 1 Douglas F	Туре			E	Ŷ		42	ī.ii	<u>NE</u>
Comments Latitude (D		I Design 2'40.353"N	Longitude (DMS)	0°39'42.31	"W	Ground E	levation (ft) 78	S	Y	s	Т	ΕM	S
Analysis Results M	aximum Usage												///	//
		Usage		Label					d Case					//
	Pole Element	44.98	11000	Pole "pole" Brace "B1"			RUL RU	E 2508 GRADE B NA+ LE 250D GRADE B NA				18	//	
	Insulator	46.21		Post "11"				JLE 277 Insulators NA+				X		
Fo	oundation	92.85	Foundation Des	ign "pole:g"			RUL	E 250C GRADE B NA	UNA+	/	///			
Nood Pole Properti	es and Embedment									///	//			
Pole Label	Property Label	Stock Number	Species	Class	Length (ft)	Embed. (ft)	Modeled- GL	Diam. G	L Cire.					
pole	DF-1-50		DF - Dougas Fir	1	50.0	7.0		14.2	44.6			· · · · ·		
summary of Wood	Pole Usages					Summary of Insulator U	isages							
Wood Pol	le Maximum el Usage %		Load Case	Height AGL (11)	Weight (Ibs)	Insulator	Insulator Type	Maximum Usage %					Load Case	We
pol	o 131.17		RULE 2508 GRADE B NA+,I NA-	0.1	2355.4	TEL	Clamp	2.08					rs NA+,I NA+	
Summary of X-Arm	Usages					F3-TEL	Clamp	2.08					rs NA+,I NA+	
X-Arm Label	Maximum Usage %		Load Case	Height AGL 199	Weight (Iba)	11	Post	46.21					rs NA+,I NA+	2
						13	Post	46.18					rs NA+,I NA+	2
ARM1	26.96		RULE 250D GRADE B NA+,I NA+	41.5	55.9	N	Post	38.68			RUL	277 Insulate	rs NA+,I NA+	
Summary of Brace	Usages					Foundation Design For	ces For All Load	Cases						
Brace Label	Maximum Usage %			Load Case	Weight (Ibs)			Load Case	Foundation Description	Axial Force (kips)	Shear Force (kips)	Resultant Force (kips)	Bending Moment (ft-k)	Founda Us
81	44.98		RULE 250D GRADE	B NA-J NA-	4.3		RULE 2508 (GRADE B NA+,I NA+	pole:g	4.72	2.56	5.37	100.41	87
82	43.33		RULE 250D GRADE	B NA+,I NA+	4.3			GRADE B NA-,I NA-	pole;g	4.72	2.25	5.22	86.42	70
								E B Uplift NA+,I NA+	pole:g	3.15	2.56	4.06	97.31	87
								SRADE B NA+,I NA+	pole:g		1.80	2.85	57.36	92
							RULE 250C	GRADE B NA-,I NA-	pole:g		1.67	2.77	52.16	00
								GRADE B NA+,I NA+	pole:g	5.10	1.70	5.37	71.64	87
							RULE 250D	SHOUL D HAT THAT		5.10				
							RULE 250D	GRADE B NA-, I NA-	pole:g	5.10	1.45	5.30	59.51	
							RULE 250D RULE 277	GRADE B NA-, I NA- Insulators NA+, I NA+	pole:g	5.10 3.13	1.45	5.30 3.31	40.52	54
							RULE 250D RULE 277 RULE 277	GRADE B NA-, I NA- Insulators NA+, I NA+ Insulators NA-, I NA-	pole:g pole:g pole:g	5.10 3.13 3.13	1.45 1.06 0.87	5.30 3.31 3.25	40.52 32.20	54 91
							RULE 250D RULE 277 RULE 277 Ex	GRADE B NA-,I NA- insulators NA+,I NA+ Insulators NA-,I NA- treme Ice NA+,I NA+	pole:g pole:g pole:g pole:g	5.10 3.13 3.13 3.12	1.45 1.06 0.87 0.07	5.30 3.31 3.25 3.12	40.52 32.20 3.34	54 91 7
							RULE 250D RULE 277 RULE 277 Ex	GRADE B NA-, I NA- Insulators NA+, I NA+ Insulators NA-, I NA-	pole:g pole:g pole:g	5.10 3.13 3.13 3.12 3.12	1.45 1.06 0.87	5.30 3.31 3.25	40.52 32.20	75 54 91 7 7 6

Reinforcing a wood pole structure within PLS-POLE

Pole reinforcement can be added to an existing wood pole to help increase the ground line moment capacity of a pole by adding steel reinforcing members to a wood pole. This solution has a portion of the reinforcing driven below ground to support the wood pole below the groundline. The reinforcing is then banded or bolted to the pole above ground. Contact your manufacturer for details and product information.

This can be modeled within PLS-POLE by attaching a series of crossarms to the bottom of a wood pole. This structural member adds additional capacity to the pole and helps transfer the load into the embedded portion below the ground.



For our example pole, a 10-foot-long steel channel was braced against the longitudinal faces of the wood pole and driven into the ground and banded to the pole. The wood pole usage with the addition of the steel reinforcing now has a usage of 83% subjected to the same load cases as the original design.

Line Notes Location Comments Latitude (DN	13kV Tang Original IS) 43*32		Pole Number Longitude (DMS)	50', (90"39'42.31		Doug¶type Ground E	levation (ft)) 78	F	Y	w s	ER T		s s
argets Results Har	Imum Usage									202	- 22		111	77
	Type Us	*9*		Laber					Case			1		/
		2.83	. We	a Pole facer				2 2568 GRADE 8 MA				1X	//	
		1.87		Brace 781* Peak 711*				LE 250D GRADE & NA			1	X		
			faungation 1							1		//		
as Pale Property	and Engelstand										//			
.582		Mumber	8gariaa	Class	Langh	Entry.	Wodalad		- 92	1	- 2	-	3	
p = 20	DF-1.80		DF - Designe Fe	. 1		**		14.2	***	/		· · ·		
									Ľ	_	_			
wood Pre	Masteriam		Lead 0	A DL TO	warget class	Bummary of Insulator	Unages Insulator Type	Maatmum Usage %		_	_		LOAD Came	
Labor	(reage %		BULE 2528 GRADE B NAU / N		(104)	761	Cump	2.00				£ 277 inside		1.1
			THE PERSON AND A REAL PROPERTY AND A			FRITEL	Clamp	2.08				£ 277 heads		-
many of 2.4m U	ungen .					10	Peal	40.21			Wijk	£ 277 Inaula	ma hite i hite	
1.1.1	Wastinum Usage %		Load Com	A 22.195	*** (A.S.	0	Pest	48.30				£ 277 :===ale		
ARMI	28.01		RULE 2550 GRADE & NA-J NA-	81.8	11.0		Pest	46.10					into faitur a talen	
Part	22.42		MULE 2828 GRADE & NA+ I NA+	2.2	400.0		Pest	10.60		_	- MUA	£ 277 Insule	Inter NAVA 3944	
Piq	21.84		RULE 2338 GRADE & NAV) NAV	2.2	495.0	Paundation Design Pa	rive for All Loss (Campo						
mmary of Brass in	ages :							Loss Case	Countyline .	A ATAK Parse (hip-t)	Shear Faros (Arps)	Resultant Pares (hips)	Rendering Sectors	reards
Brace	Mastroom			LOOS Case	Warght	-	BULE 2120		and a	1.44	8.87	4.44	44.65	
					1.			CORNER IN NAL 7 MA	paie g	8.84	2.38	6.57	85.85	
81	44.37		RULE 2110 GAU		4.5			DE B LEUR NA- I NA-		3.66	2.67	4.77	84.79	
82	#3.30		RULE 250D GRA	DE B NANJ NAN	6.0			LDE IR LIGHT HALF HAL	parte a	3.88	8.14	4.40	83.41	**
								GRADE & NAU NAU BRADE & NAU NA	parte g	3.91	2.00	3.81	57.22	
								GRADE & NA+ / NA+			1.14	0.10	24.25	
						-		ORADE & NA. J NA.			1.84		88.78	**
						1	RULE 117	Insulation MALL MILL	paley	3.83	9.10	4.08	40.28	0.0
						1. Contract (1. Contract)	But 6 27	T Includence Not-1 April	point a	8.88	0.01	4.94	82.01	**
								trame too NA-J NA-	1110		0.07	3.82	9.82	. *
							t	streme to NAU NA		3.82	9.01	3.82	3.32	,
								AND THE REAL	a site a	2.66	0.345	2.44	2.84	
						-		of towards (BU) Max	pole a	2.81	1.14	1.04	22.54	

Below is the modeling process within PLS-POLE to add steel reinforcing members:

• Within PLS-POLE use the menu command **Components/Cross Arm...** and create X-arm member with structural properties to represent the steel reinforcing members. Use the geometry field to define joints along the x-arm where it is attached to the pole.

Cross Arm Property Label	Steel Reinforcing	
Stock Number	stl	
Cross Section Area (in^2)		1
X Inertia (in^4)		6
Z Inertia (in^4)		6
Weight (lbs)		
Depth (in)		
Width (in)		
Length (ft)		
Modulus of Elasticity (ksi)		29
Drag Coef.		
Geometry	Edit (2 points)	
Strength Check Type	Calculated	
Use Steel S.F.	Yes	
Vertical Capacity (lbs)	NA	
Trans. Capacity (lbs)	NA	
Long. Capacity (lbs)	NA	
Design Normal Stress (psi)		60
X Section Modulus (in ³)		2
Z Section Modulus (in^3)		1
Texture		
Long Leg (in)	NA	
Short Leg (in)	NA	
Thick. (in)	NA	
BetaW (in)	NA	
Radius of Gyration X (in)	NA	
Radius of Gyration Y (in)	NA	
Radius of Gyration Z (in)	NA	

0

0

• Create joints along the wood pole where the steel reinforcing will be attached or banded to the existing wood pole. Using a global Z can be helpful. This can be done with the menu command **Geometry/Wood Poles...** and using the Attach. Labels field.

7	• 1	Model Check Report No errors or relevant warnings detected.	D wood pole.POL)	4 74 74 74 74 76 76	24 80 5 a 24 a 1	°N 85 85 86 9	a a a
 poles may be located in one of two ways: 1) By tip and base joint. This is only appropriately the process of the pr	angles. This should be used for single poles		Joint	bels and Holes for - (pole) Distance From	Global Z	Hole	terest Hole
Pole Label	pole		Label	Origin/Top Joint (ft)	of Attach (ft)	Diameter (in)	Azimuth (deg)
Tip Joint				(14)	(11)	(iii)	(deg)
Base Joint			2 pole:F4-PH1			5 0	
X of Base (ft)		(3 pole:F4-PH2			3 0	
Y of Base (ft)		(3 porerr4-PHZ			1 0	
Z of Base (ft)		(5				
Inclin. About X (deg)		(6				
Inclin. About Y (deg)		(7			-	
Wood Pole Property Set	DF-1-50		8			-	
Material Property Set	DF-Douglas Fir		9				
Attach. Labels	Edit (3 points)		10			-	
Push Brace	No		11			-	
Base Connect			12			-	
Embed % Override		0.000	13			-	
Embed % Override		(
Embed C. Override (ft)							
		0.00					

• Create a small davit arm. This is needed to attach the steel reinforcing x-arm member to the wood pole and keep vertical cross arms orientated correctly. The geometry field for the davit arm will define the length of this member. Below this is modeled as 3".

				dian as a	No. 10. 00. 00. 00. 00. 00.		
				L T T T	CTTTTY % %	a 🗸 🕫 Va Va 🖌 🌆 🎝 ю Ba M	1 TA "N 63 63 99
Davit Property Label	REINF CONN		 				
Stock Number	KEINF_CONN		 				
Cross Section Area (in^2)			 5				
X Inertia (in^4)			60				
Z Inertia (in^4)			 60				
Weight (lbs)			0.1				
Depth (in)			 1				
Width (in)			1	Arm Geom	etry and Bolt Holes - [REINF	_CONN]	4
Drag Coef.			 1		Joint Label	END	
Modulus of Elasticity (ksi)			 290000		Horz. Offset (ft)		
Geometry	Edit (1 point))	250000		Vert. Offset (ft)		
Strength Check Type	Nominal	,		Но	rz. Hole Diameter (in)		
Use Steel S.F.	No		 		rt. Hole Diameter (in)		
Vertical Capacity (lbs)			 99999		. ,		
Tension Capacity (Ibs)			999999			OK Cancel	
Compres. Capacity (lbs)			 999999				
Long. Capacity (lbs)			 99999				
Design Normal Stress (psi)		NA					
X Section Modulus (in^3)		NA					
Z Section Modulus (in^3)		NA					
Texture							

• Attach davit arms to pole. Use the Azimuth or orientate the davit arms to the correct side of the pole. Four connections are used below to simulate the four locations the reinforcing member is banded to the pole.

avit Arm Connectivity			£8 7 - 2
	Model Check	c Report or relevant warnings detected.	
Davit Label	Attach Label	Davit Property Set	Azimuth (deg)
1 STRAP1	pole:F4-PH1	REINF CONN	270
2 STRAP4	pole:F4-PH2	REINF_CONN	270
3 STRAP1A	pole:F4-PH1	REINF_CONN	90
4 STRAP4A			

• Attach steel reinforcing x-arms to davit arms. Update the connection code type at the connection points.

0

0

Attach Label	Offset (ft)	Connect At	Connection Code Type
PH1:0	0.000		Pinned X
PH1:botbolt	1.000	STRAP1A:END	Fixed Face
PH1:topbolt	5.000	STRAP4A:END	Fixed Face
PH1:E	10.000		Pinned X

Creating a Framing is a nice way to manage these solutions. The menu command
Components/Framing/Manager... allows for management of the framesets and Geometry/Framing/Add can
all portions of a PLS-POLE model attached to a pole as a frame. This will consist of a block of all material attached
to the pole but not the pole itself. This frame can then easily be added to future structures.