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Reinforcing Wood Poles within PLS-POLE

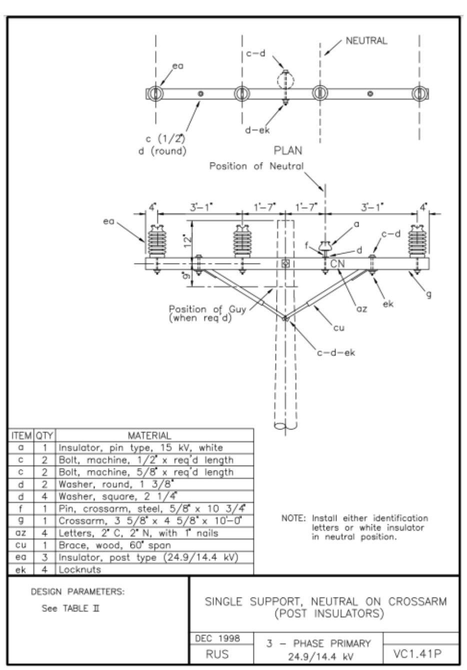
Introduction

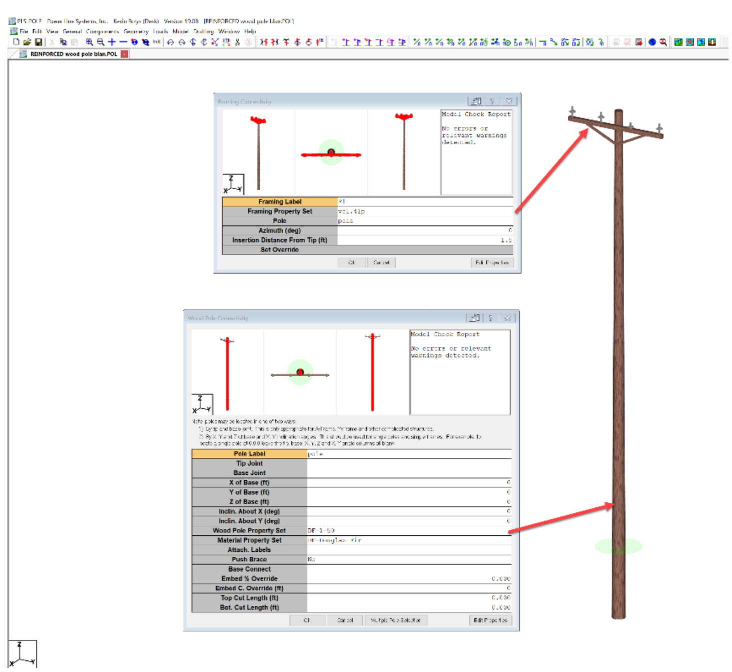
Wood poles an essential commodity that helps support the overhead lines industry around the world. Many of these wood pole structures are increasingly being required to do more today than was originally intended. The addition of communication wires and degradation of wood poles over time may can add 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.

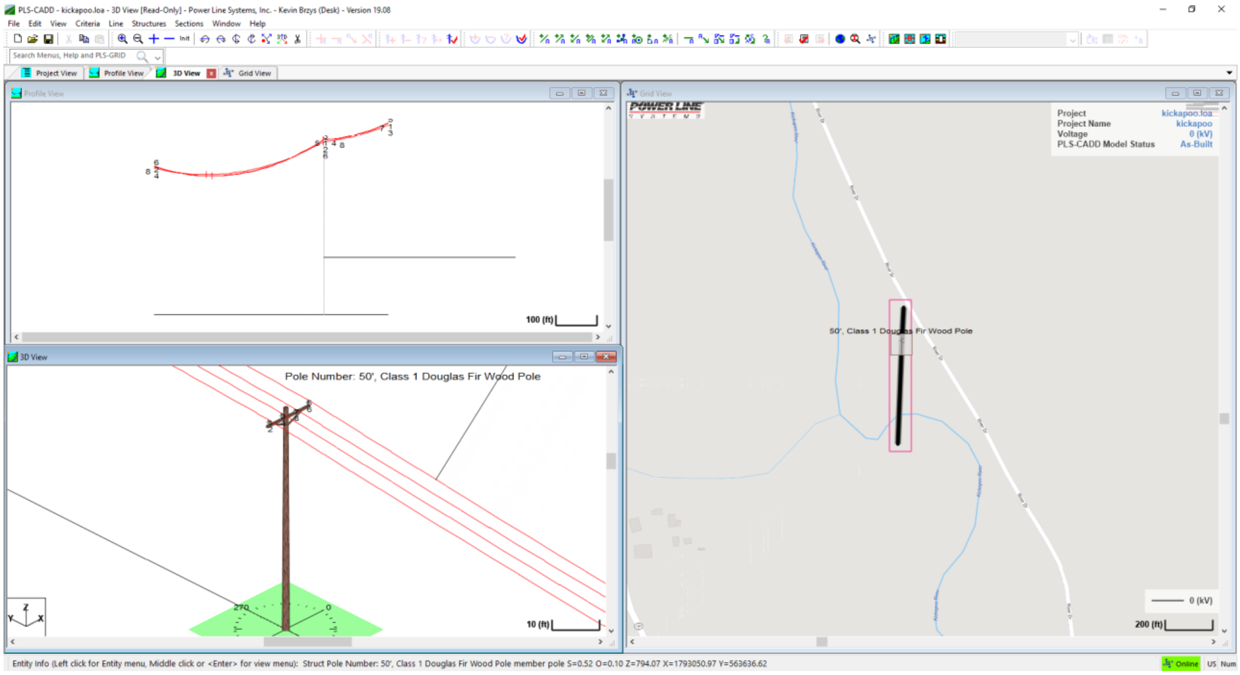
PLS-POLE Design & Modeling

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 https://www.powline.com/files/pls_pole/rus/RUSModels.html. Below is the structure drawing of the structure as well as the structure modeled in PLS-POLE.

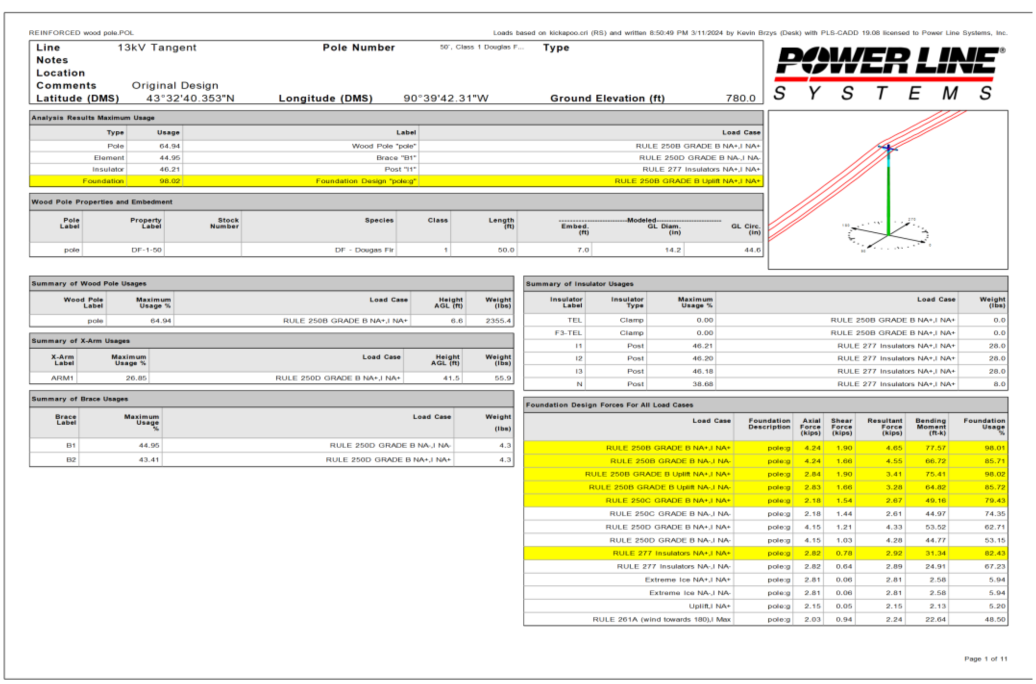




This structure consists of a Douglas Fir wood pole that has a Modulus of Rupture (MOR) of 8 ksi and a Modulus of Elasticity (MOE) of 1920 ksi. The 50′ Class 1 wood pole used for the structure has an ultimate ground line moment of about 184,500 ft*lbs assuming a 10% plus 2′ embedment.



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.



REINFORCED wood pole.POL

Loads based on kickapoo.cri (RS) and written 8:50:49 PM 3/11/2024 by Kevin Brzys (Desk) with PLS-CADD 19.08 licensed to Power Line Systems, Inc.

Line 13kV Tangent | Pole Number 50', Class 1 Douglas F... | Type
Notes
Location
Comments Original Design
Latitude (DMS) 43°32'40.353"N | Longitude (DMS) 90°39'42.31"W | Ground Elevation (ft) 780.0

POWER LINE SYSTEMS

Analysis Results Maximum Usage

Type	Usage	Label	Load Case
Pole	64.94	Wood Pole "pole"	RULE 250B GRADE B NA+,I NA+
Element	44.95	Brace "B1"	RULE 250D GRADE B NA-,I NA-
Insulator	46.21	Post "I1"	RULE 277 Insulators NA+,I NA+
Foundation	98.02	Foundation Design "pole:g"	RULE 250B GRADE B Uplift NA+,I NA+

Wood Pole Properties and Embedment

Pole Label	Property Label	Stock Number	Species	Class	Length (ft)	Modeled Embed. (ft)	Modeled GL Diam. (in)	GL Circ. (in)
pole	DF-1-50		DF - Dougas Fir	1	50.0	7.0	14.2	44.6

Summary of Wood Pole Usages

Wood Pole Label	Maximum Usage %	Load Case	Height AGL (ft)	Weight (lbs)
pole	64.94	RULE 250B GRADE B NA+,I NA+	6.6	2355.4

Summary of X-Arm Usages

X-Arm Label	Maximum Usage %	Load Case	Height AGL (ft)	Weight (lbs)
ARM1	26.85	RULE 250D GRADE B NA+,I NA+	41.5	55.9

Summary of Brace Usages

Brace Label	Maximum Usage %	Load Case	Weight (lbs)
B1	44.95	RULE 250D GRADE B NA-,I NA-	4.3
B2	43.41	RULE 250D GRADE B NA+,I NA+	4.3

Summary of Insulator Usages

Insulator Label	Insulator Type	Maximum Usage %	Load Case	Weight (lbs)
TEL	Clamp	0.00	RULE 250B GRADE B NA+,I NA+	0.0
F3-TEL	Clamp	0.00	RULE 250B GRADE B NA+,I NA+	0.0
I1	Post	46.21	RULE 277 Insulators NA+,I NA+	28.0
I2	Post	46.20	RULE 277 Insulators NA+,I NA+	28.0
I3	Post	46.18	RULE 277 Insulators NA+,I NA+	28.0
N	Post	38.68	RULE 277 Insulators NA+,I NA+	8.0

Foundation Design Forces For All Load Cases

Load Case	Foundation Description	Axial Force (kips)	Shear Force (kips)	Resultant Force (kips)	Bending Moment (ft-k)	Foundation Usage %
RULE 250B GRADE B NA+,I NA+	pole:g	4.24	1.90	4.65	77.57	98.01
RULE 250B GRADE B NA-,I NA-	pole:g	4.24	1.66	4.55	66.72	85.71
RULE 250B GRADE B Uplift NA+,I NA+	pole:g	2.84	1.90	3.41	75.41	98.02
RULE 250B GRADE B Uplift NA-,I NA-	pole:g	2.83	1.66	3.28	64.82	85.72
RULE 250C GRADE B NA+,I NA+	pole:g	2.18	1.54	2.67	49.16	79.43
RULE 250C GRADE B NA-,I NA-	pole:g	2.18	1.44	2.61	44.97	74.35
RULE 250D GRADE B NA+,I NA+	pole:g	4.15	1.21	4.33	53.52	62.71
RULE 250D GRADE B NA-,I NA-	pole:g	4.15	1.03	4.28	44.77	53.15
RULE 277 Insulators NA+,I NA+	pole:g	2.82	0.78	2.92	31.34	82.43
RULE 277 Insulators NA-,I NA-	pole:g	2.82	0.64	2.89	24.91	67.23
Extreme Ice NA+,I NA+	pole:g	2.81	0.06	2.81	2.58	5.94
Extreme Ice NA-,I NA-	pole:g	2.81	0.06	2.81	2.58	5.94
Uplift,I NA+	pole:g	2.15	0.05	2.15	2.13	5.20
RULE 261A (wind towards 180),I Max	pole:g	2.03	0.94	2.24	22.64	48.50

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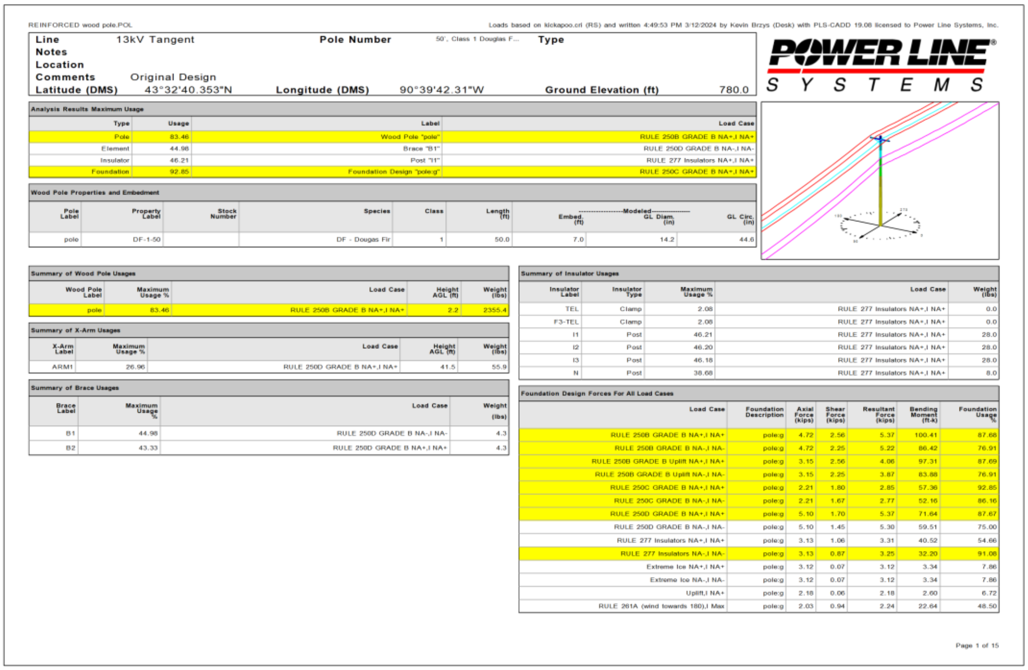
As the life of this pole progresses it may be determined that it can be a joint use asset and is selected as a structure to add some communication wires. Using our existing PLS-CADD/Lite model this scenario can be investigated. Two additional communication attachments are modeled to the pole and two 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.



REINFORCED wood pole.POL

Loads based on kickapoo.cri (RS) and written 4:49:53 PM 3/12/2024 by Kevin Brzys (Desk) with PLS-CADD 19.08 licensed to Power Line Systems, Inc.

Line 13kV Tangent **Pole Number** 50', Class 1 Douglas F... **Type**
Notes
Location
Comments Original Design
Latitude (DMS) 43°32'40.353"N **Longitude (DMS)** 90°39'42.31"W **Ground Elevation (ft)** 780.0

POWER LINE SYSTEMS

Analysis Results Maximum Usage

Type	Usage	Label	Load Case
Pole	83.46	Wood Pole "pole"	RULE 250B GRADE B NA+,I NA+
Element	44.98	Brace "B1"	RULE 250D GRADE B NA-,I NA-
Insulator	46.21	Post "I1"	RULE 277 Insulators NA+,I NA+
Foundation	92.85	Foundation Design "pole:g"	RULE 250C GRADE B NA+,I NA+

Wood Pole Properties and Embedment

Pole Label	Property Label	Stock Number	Species	Class	Length (ft)	Modeled Embed. (ft)	Modeled GL Diam. (in)	GL Circ. (in)
pole	DF-1-50		DF - Dougas Fir	1	50.0	7.0	14.2	44.6

Summary of Wood Pole Usages

Wood Pole Label	Maximum Usage %	Load Case	Height AGL (ft)	Weight (lbs)
pole	83.46	RULE 250B GRADE B NA+,I NA+	2.2	2355.4

Summary of X-Arm Usages

X-Arm Label	Maximum Usage %	Load Case	Height AGL (ft)	Weight (lbs)
ARM1	26.96	RULE 250D GRADE B NA+,I NA+	41.5	55.9

Summary of Brace Usages

Brace Label	Maximum Usage %	Load Case	Weight (lbs)
B1	44.98	RULE 250D GRADE B NA-,I NA-	4.3
B2	43.33	RULE 250D GRADE B NA+,I NA+	4.3

Summary of Insulator Usages

Insulator Label	Insulator Type	Maximum Usage %	Load Case	Weight (lbs)
TEL	Clamp	2.08	RULE 277 Insulators NA+,I NA+	0.0
F3-TEL	Clamp	2.08	RULE 277 Insulators NA+,I NA+	0.0
I1	Post	46.21	RULE 277 Insulators NA+,I NA+	28.0
I2	Post	46.20	RULE 277 Insulators NA+,I NA+	28.0
I3	Post	46.18	RULE 277 Insulators NA+,I NA+	28.0
N	Post	38.68	RULE 277 Insulators NA+,I NA+	8.0

Foundation Design Forces For All Load Cases

Load Case	Foundation Description	Axial Force (kips)	Shear Force (kips)	Resultant Force (kips)	Bending Moment (ft-k)	Foundation Usage %
RULE 250B GRADE B NA+,I NA+	pole:g	4.72	2.56	5.37	100.41	87.68
RULE 250B GRADE B NA-,I NA-	pole:g	4.72	2.25	5.22	86.42	76.91
RULE 250B GRADE B Uplift NA+,I NA+	pole:g	3.15	2.56	4.06	97.31	87.69
RULE 250B GRADE B Uplift NA-,I NA-	pole:g	3.15	2.25	3.87	83.88	76.91
RULE 250C GRADE B NA+,I NA+	pole:g	2.21	1.80	2.85	57.36	92.85
RULE 250C GRADE B NA-,I NA-	pole:g	2.21	1.67	2.77	52.16	86.16
RULE 250D GRADE B NA+,I NA+	pole:g	5.10	1.70	5.37	71.64	87.67
RULE 250D GRADE B NA-,I NA-	pole:g	5.10	1.45	5.30	59.51	75.00
RULE 277 Insulators NA+,I NA+	pole:g	3.13	1.06	3.31	40.52	54.66
RULE 277 Insulators NA-,I NA-	pole:g	3.13	0.87	3.25	32.20	91.08
Extreme Ice NA+,I NA+	pole:g	3.12	0.07	3.12	3.34	7.86
Extreme Ice NA-,I NA-	pole:g	3.12	0.07	3.12	3.34	7.86
Uplift,I NA+	pole:g	2.18	0.06	2.18	2.60	6.72
RULE 261A (wind towards 180),I Max	pole:g	2.03	0.94	2.24	22.64	48.50

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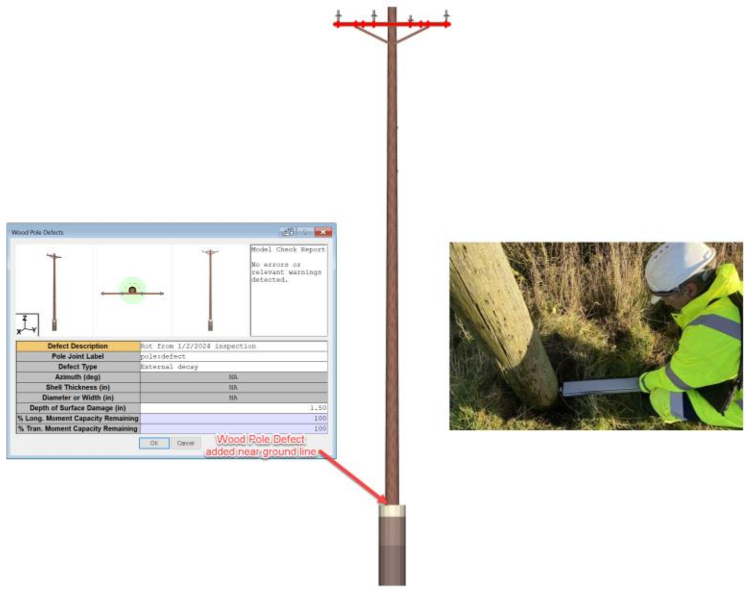
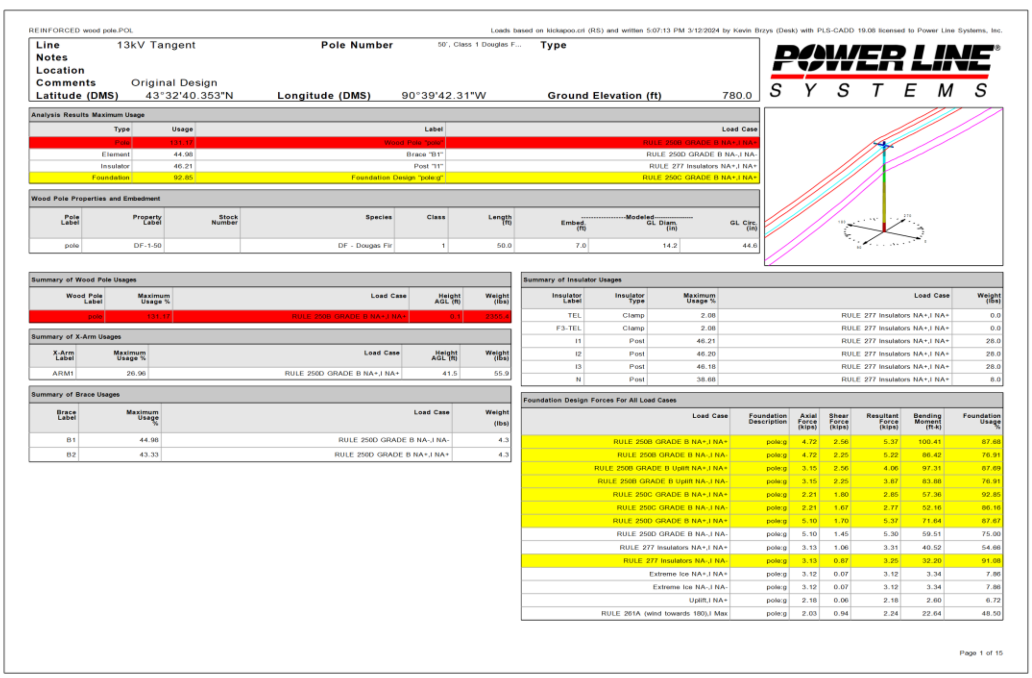
Wooden utility poles have finite lifetimes and can develop defects that reduce the strength of a pole eventually resulting in a pole reaching a point where it may not have the strength to meet the original design requirements. This occurs because natural elements gradually wear down a pole due to rot, 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.



REINFORCED wood pole.POL

Loads based on kickapoo.cri (RS) and written 5:07:13 PM 3/12/2024 by Kevin Brzys (Desk) with PLS-CADD 19.08 licensed to Power Line Systems, Inc.

Line	13kV Tangent	**Pole Number**	50', Class 1 Douglas F...	**Type**	
Notes					
Location					
Comments	Original Design				
Latitude (DMS)	43°32'40.353"N	**Longitude (DMS)**	90°39'42.31"W	**Ground Elevation (ft)**	780.0

POWER LINE SYSTEMS

Analysis Results Maximum Usage

Type	Usage	Label	Load Case
Pole	131.17	Wood Pole "pole"	RULE 250B GRADE B NA+,I NA+
Element	44.98	Brace "B1"	RULE 250D GRADE B NA-,I NA-
Insulator	46.21	Post "I1"	RULE 277 Insulators NA+,I NA+
Foundation	92.85	Foundation Design "pole:g"	RULE 250C GRADE B NA+,I NA+

Wood Pole Properties and Embedment

Pole Label	Property Label	Stock Number	Species	Class	Length (ft)	Modeled Embed. (ft)	Modeled GL Diam. (in)	GL Circ. (in)
pole	DF-1-50		DF - Dougas Fir	1	50.0	7.0	14.2	44.6

Summary of Wood Pole Usages

Wood Pole Label	Maximum Usage %	Load Case	Height AGL (ft)	Weight (lbs)
pole	131.17	RULE 250B GRADE B NA+,I NA+	0.1	2355.4

Summary of X-Arm Usages

X-Arm Label	Maximum Usage %	Load Case	Height AGL (ft)	Weight (lbs)
ARM1	26.96	RULE 250D GRADE B NA+,I NA+	41.5	55.9

Summary of Brace Usages

Brace Label	Maximum Usage %	Load Case	Weight (lbs)
B1	44.98	RULE 250D GRADE B NA-,I NA-	4.3
B2	43.33	RULE 250D GRADE B NA+,I NA+	4.3

Summary of Insulator Usages

Insulator Label	Insulator Type	Maximum Usage %	Load Case	Weight (lbs)
TEL	Clamp	2.08	RULE 277 Insulators NA+,I NA+	0.0
F3-TEL	Clamp	2.08	RULE 277 Insulators NA+,I NA+	0.0
I1	Post	46.21	RULE 277 Insulators NA+,I NA+	28.0
I2	Post	46.20	RULE 277 Insulators NA+,I NA+	28.0
I3	Post	46.18	RULE 277 Insulators NA+,I NA+	28.0
N	Post	38.68	RULE 277 Insulators NA+,I NA+	8.0

Foundation Design Forces For All Load Cases

Load Case	Foundation Description	Axial Force (kips)	Shear Force (kips)	Resultant Force (kips)	Bending Moment (ft-k)	Foundation Usage %
RULE 250B GRADE B NA+,I NA+	pole:g	4.72	2.56	5.37	100.41	87.68
RULE 250B GRADE B NA-,I NA-	pole:g	4.72	2.25	5.22	86.42	76.91
RULE 250B GRADE B Uplift NA+,I NA+	pole:g	3.15	2.56	4.06	97.31	87.69
RULE 250B GRADE B Uplift NA-,I NA-	pole:g	3.15	2.25	3.87	83.88	76.91
RULE 250C GRADE B NA+,I NA+	pole:g	2.21	1.80	2.85	57.36	92.85
RULE 250C GRADE B NA-,I NA-	pole:g	2.21	1.67	2.77	52.16	86.16
RULE 250D GRADE B NA+,I NA+	pole:g	5.10	1.70	5.37	71.64	87.67
RULE 250D GRADE B NA-,I NA-	pole:g	5.10	1.45	5.30	59.51	75.00
RULE 277 Insulators NA+,I NA+	pole:g	3.13	1.06	3.31	40.52	54.66
RULE 277 Insulators NA-,I NA-	pole:g	3.13	0.87	3.25	32.20	91.08
Extreme Ice NA+,I NA+	pole:g	3.12	0.07	3.12	3.34	7.86
Extreme Ice NA-,I NA-	pole:g	3.12	0.07	3.12	3.34	7.86
Uplift,I NA+	pole:g	2.18	0.06	2.18	2.60	6.72
RULE 261A (wind towards 180),I Max	pole:g	2.03	0.94	2.24	22.64	48.50

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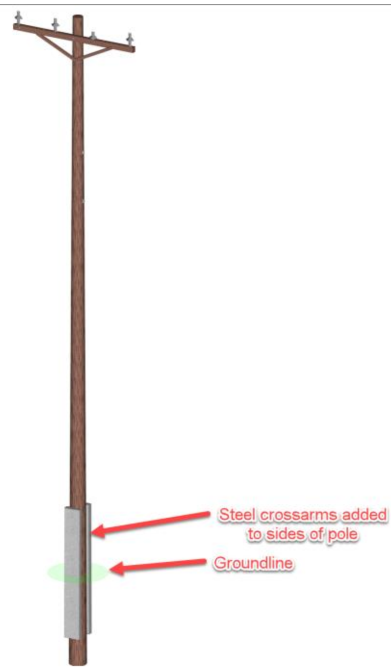
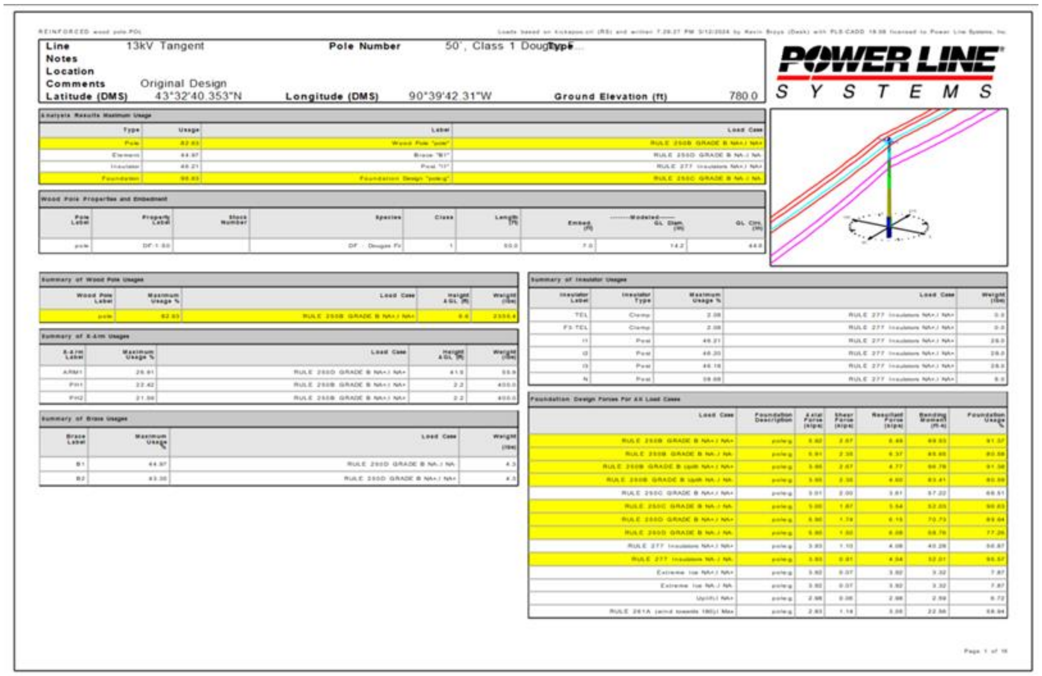
Reinforcing a wood pole structure within PLS-POLE

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.

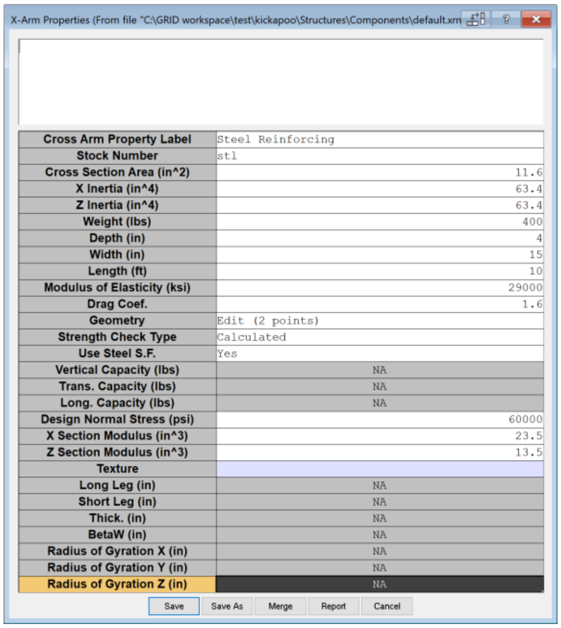


For our example pole, a 10-foot-long steel channel was braced against the longitudinal faces of the wood pole and driven into the ground and banded to the pole. The wood pole usage with the addition of the steel reinforcing now has a usage of 83% subjected to the same load cases as the original design.

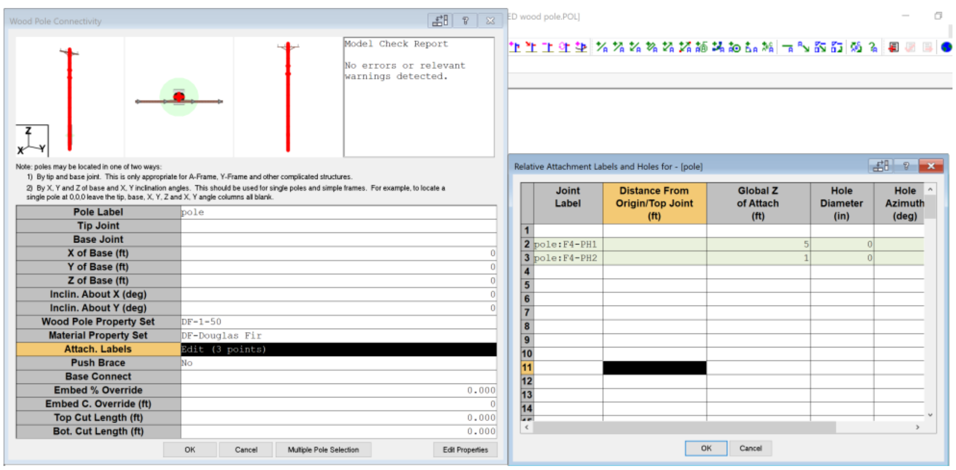


Below is the modeling process within PLS-POLE to add steel reinforcing members:

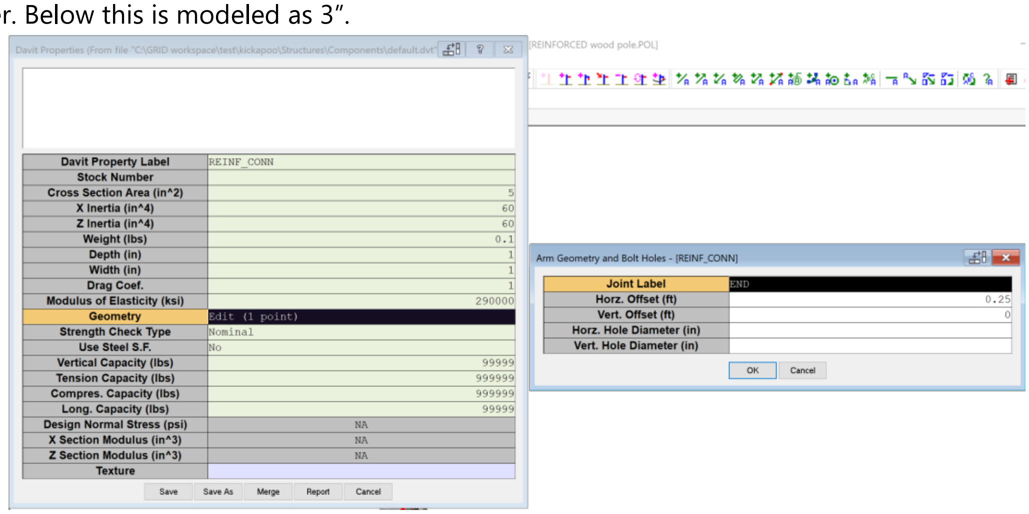
- Within PLS-POLE use the menu command **Components/Cross Arm...** and create X-arm member with structural properties to represent the steel reinforcing members. Use the geometry field to define joints along the x-arm where it is attached to the pole.



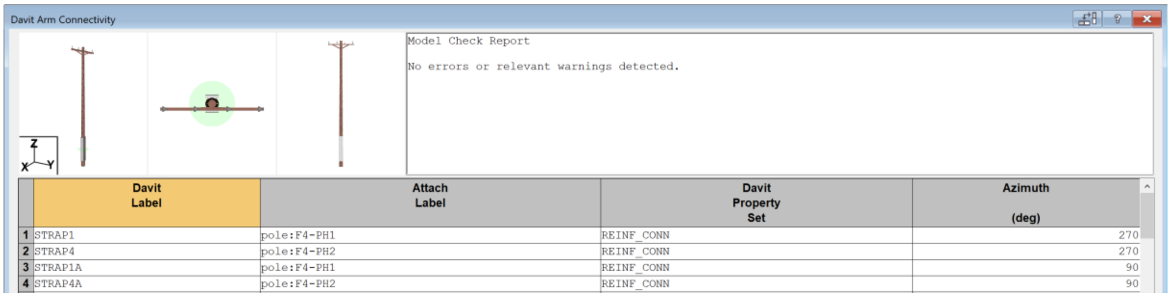
- Create joints along the wood pole where the steel reinforcing will be attached or banded to the existing wood pole. Using a global Z can be helpful. This can be done with the menu command **Geometry/Wood Poles…** and using the Attach. Labels field.



- 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".



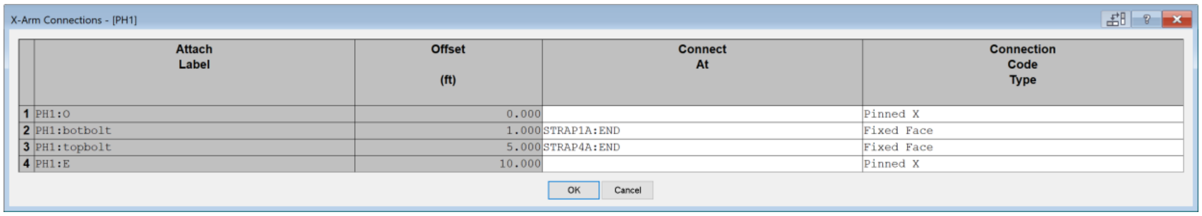
- Attach davit arms to pole. Use the Azimuth or orientate the davit arms to the correct side of the pole. Four connections are used below to simulate the four locations the reinforcing member is banded to the pole.

- 
Davit Arm Connectivity

Model Check Report

No errors 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	pole:F4-PH2	REINF_CONN	90

- Attach steel reinforcing x-arms to davit arms. Update the connection code type at the connection points.
  - 
X-Arm Connections - [PH1]

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

OK Cancel

- 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.