GO 95
Overhead Electric Line Construction

<u>Current</u>

Allowable Strength Design (ASD)

(aka Working Stress Design (WSD) and Allowable Stress Design)

<u>Proposed</u>

Load & Resistance* Factor Design (LRFD)

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*"Resistance" = "Strength"

What is this?

Loading And Safety Factors For All Grades Of Construction.

Loading: The following conditions of loading shall be taken in computing the necessary strength of all parts of poles, structures and conductors.

(a) Heavy Loading: Heavy loading will be considered as applying to all parts of the State of California where the elevation exceeds 3000 feet above sea level, except where United States weather reports, over a term of years, show that different conditions exist. (See Appendix A for map indicating the approximate location of the district subject to heavy loading.) This loading shall be taken as the resultant stress due to wind, ice and dead weight under the following conditions:

1. **Wind:** A horizontal wind pressure of 6 pounds per square foot of projected area on cylindrical surfaces, or 10 pounds per square foot on flat surfaces. Where latticed structures are used, the actual exposed area of one lateral face shall be increased by 50% to allow for pressure on the opposite face, provided this computation does not indicate a greater pressure than would occur on a solid structure of the same outside dimensions, under which conditions the latter shall be taken.
2. **Ice:** A radial thickness of one–half inches of ice, weighing 57 pounds per cubic foot, on all conductors shall be assumed in computing vertical and wind loadings.
3. **Temperature:** This shall be considered at the time of maximum loading to be 0 deg. F. The normal temperature for computing erection conditions is 60 deg. F. Maximum temperature (in computing sag under this condition) shall be assumed as 130 deg. F.

(b) Light Loading: This condition shall be considered as existing in all parts of the state, where heavy loading does not apply. This loading shall be taken as the resultant of wind pressure and dead weight of the various parts of the span construction under the following conditions:

1. **Wind:** A horizontal wind pressure of 8 pounds per square foot of projected area on cylindrical surfaces, or 13 pounds per square foot on flat surfaces. Where latticed structures are used, the same increase in exposed area shall be used as in heavy loading.
2. **Ice:** No ice loading is to be considered.
3. **Temperature:** This shall be considered at the time of maximum loading to be 25 deg. F. The normal temperature for computing erection conditions is 60 deg. F. Maximum temperature (in computing sag under this condition) shall be assumed as 130 deg. F.

(c) Safety Factors: The following safety factors shall be used in computing the strength requirements of all parts of the structures and in calculating the limiting sag for conductors. These safety factors are expressed as the ration of the ultimate strength of the material divided by the stress which will exist in it under the most severe conditions to which it will be subjected under the given loading conditions.

Table 3

	Minimum safety factor for the various grades of construction		
	Grade "A"	Grade "B"	Grade "C"
Wires, cables and conductor fastenings	2	2	2
Pins	2	2	2
Pole line hardware	2	2	2
Line insulators (mechanical)	3	2	2
Guy insulators (mechanical)			
Interlocking	2	2	2
Noninterlocking	3	3	3
Guys	3	2	2
Wooden poles	4	3	2 ½
Wooden crossarms	4	3	2 ½
Structural steel poles, towers and crossarms	2 ½	2	2
Foundations against uplift	1 ½	1 ½	1 ½
Foundations against depression	3	2	2
Reinforced concrete pole and crossarms	4	3	3

Poles, crossarms and other wooden members in all grades of construction shall be replaced or reinforced when their safety factor is reduced below two-thirds of the above. Butt treatment of poles with creosote by the "Open Tank: process is not recognized as an effective means in preserving the life of poles. Nothing in these rules shall be construed as requiring the use of poles so treated; nevertheless, attention is called to this advantageous means of prolonging the life of poles.

(d) Ultimate Strengths of Materials: The following values of ultimate strengths of materials are given, these strengths to be used in connection with the safety factors indicated above except for materials not listed or where thorough tests have indicated that other ultimate strengths will apply.

1. **Wooden Poles and Crossarms:** The ultimate fiber strength of poles and crossarms shall be assumed as follows:

Port Ocford cedar	6900 pounds per square inch
Douglas fir	5400 pounds per square inch
Western red or white cedar	5100 pounds per square inch
Redwood	3900 pounds per square inch

2. **Structural Steel:** Structural steel shall be in accordance with the manufactures' standard specifications. Where these specifications are not available, the following ultimate strengths may be used:

Tension	55,000 pounds per square inch
Compression	55,000 pounds per square inch

Minus 180 $\frac{L}{r}$

Shear	46,000 pounds per square inch

3. **Reinforced Concrete** (as in poles, etc.): The ultimate strength of materials used shall not exceed values commonly accepted as good practice.

   The absence of other data, the following ultimate strengths may be used for materials of concrete structures:

   Steel: Tension or compression, 55,000 pounds be square inch.

   Concrete Mixture: 1-2-4 Portland Cement - Compression:

   900 pounds per square inch in 7 days after mixing
   2400 pounds per square inch in 30 days after mixing
   3400 pounds per square inch in 90 days after mixing
   4400 pounds per square inch in 6 months after mixing

4. **Wire:** The ultimate strengths to be sued for copper wires shall agree with values given in Appendix B. For wires of other materials the makers' specifications may be used, provided that authoritative tests have been made to justify the makers' rating.
5. **Foundations:** In calculating the strength of foundations against unlift the weight of concrete shall be taken as 140 pounds per cubic foot and the weight of earth (calculated at 30 degrees from the vertical) shall be taken as 90 pounds per cubic foot. The strength of foundations against depression shall be calculated from the best available data on the soil in question.

It's a copy of Section V of General Order (GO) 64.

The CPUC issued GO 64, rules for overhead electric line construction, in 1922. It was the predecessor to GO 64-A issued on December 17, 1928, the successor to which is GO 95 first adopted on December 23, 1941.

Today, the methodology, and loading and strength criteria delineated in GO 95, while more expansive, are essentially the same as those in the 100+ year old GO 64. While still functional, there are good reasons to modernize.

General Order 64

Section V

General Strength Requirements For All Classes Of Supply Lines

52 Loading And Safety Factors For All Grades Of Construction.

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2. **Ice:** No ice loading is to be considered.

3. **Temperature:** This shall be considered at the time of maximum loading to be 25 deg. F. The normal temperature for computing erection conditions is 60 deg. F. Maximum temperature (in computing sag under this condition) shall be assumed as 130 deg. F.

(c) Safety Factors: The following safety factors shall be used in computing the strength requirements of all parts of the structures and in calculating the limiting sag for conductors. These safety factors are expressed as the ration of the ultimate strength of the material divided by the stress which will exist in it under the most severe conditions to which it will be subjected under the given loading conditions.

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Reasons for Modernizing Section IV of GO 95 and the Proposed Approach

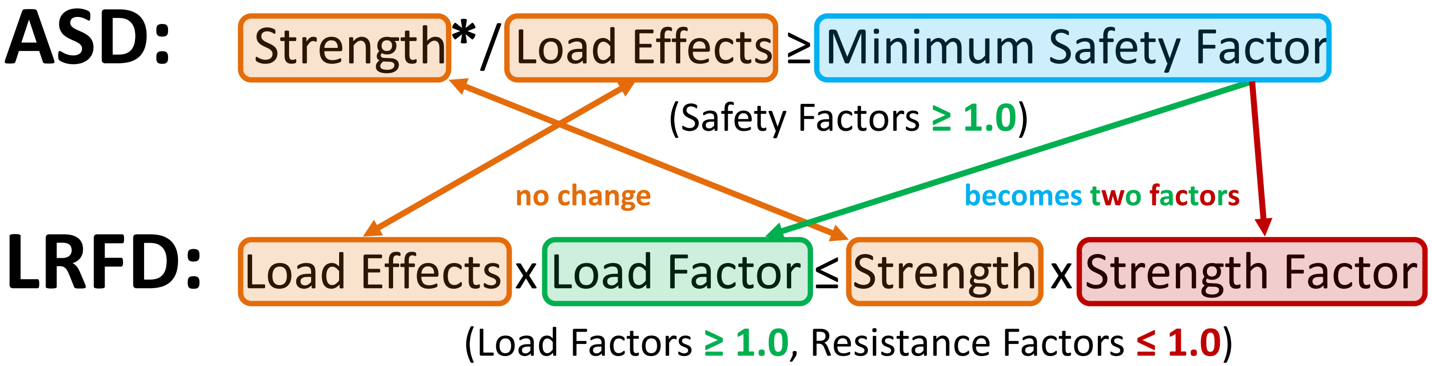
Summary:

The proposed changes aim to replace the outdated **Allowable Strength Design (ASD)** method with the more modern and widely adopted **Load and Resistance Factor Design (LRFD)** approach, which is already standard across most of the U.S. and North America and is the approach most taught in current engineering curricula.

Key Rationale for/Benefits of Modernization:

1. **Improve Structural Reliability and Consistency**
    1. ASD, as currently embodied in GO 95, results in inconsistent reliability across different materials and components.
    2. LRFD provides a framework to account for variability in loads and material strengths, promoting more uniform safety and performance.
2. **Align with National Standards** The proposed LRFD-based rules align with the structural methodology embedded in the **National Electrical Safety Code (NESC)**.
    1. This creates consistency across jurisdictions and reflects current engineering best practices.
3. **Provide a Framework for Incorporating Reliability-Based Design (RBD) Criteria into GO 95**
    1. LRFD sets the groundwork for eventually transitioning to RBD, which allows for a more rigorous, data-driven approach to reliability.
4. **Maintain Continuity with Existing Requirements**
    1. The proposed load and resistance factors are calibrated to match current safety factors used under ASD, ensuring that initial results are consistent with past practices.
5. **Encourage Better Data Usage and Design Transparency**
    1. LRFD enables clearer, more traceable design decisions by:
        1. Separating how loads and strengths are factored.
        2. Incorporating quality and quantity of data for materials and loading conditions.
        3. Facilitating the use of improved information as it becomes available.
6. **Foster Risk Awareness and Practical Understanding of Failure**
    1. LRFD emphasizes that all structures/line components carry a small but manageable probability of failure.
    2. This approach supports realistic expectations and more resilient designs, rather than attributing all failures to design flaws or rare events.
7. **Support Cost-Effective Safety Improvements**
    1. While maintaining safety, LRFD provides a framework to enable utilities to optimize material use and design more cost-effectively.
    2. It encourages improved understanding of how structures respond to actual loads in the field.
8. **Ease of Transition**
    1. Although LRFD introduces a more robust framework, its practical application requires little to no additional effort compared to ASD.

Summary of Current and Proposed Approaches



PREMISE FOR LRFD PROPOSAL: Implementation of LRFD with the proposed values of load and strength factors will yield the same design results as the minimum safety factors currently included in GO 95.

*The terms “Strength” and “Resistance” can be used interchangeably in this context.

Current Safety Factors

Table 4: Minimum Safety Factors

Line Element	Grades of Construction		
	Grade "A"	Grade "B	Grade "C"
Conductors, splices and conductor fastenings (other than tie wires)	2	2	2
Pins	2	2	2
Pole line hardware	2	2	2
Line Insulators (mechanical)	3	2	2
Guy insulators (mechanical)			
Interlocking	2	2	2
Noninterlocking glass fiber	3	2 (a)	2 (b)
Guys	2	2	2
Messengers and span wires	2	2	2
Foundations against uplift	1.5	1.5	1.5
Foundations against depression	3	2	2
Poles Towers and Structures			
Wood	4	3	2
Metal (including elements of foundations)	1.5 (c)	1.25 (c)	1.25 (c)
Reinforced concrete	4	3	3
Prestressed or post-tensioned concrete	1.8	1.5	1.5
Other engineered materials	1.5	1.25	1.25
Crossarms			
Wood	2	2	2
Metal	1.5(c)	1.25(c)	1.25(c)
Prestressed Concrete	1.8	1.5	1.5
Other engineered materials	1.5	1.25	1.25

Proposed Load and Strength Factors

Table 4-1: Minimum Load Factors

Load Condition	Load Factors		
	"Grade A"	"Grade B"	"Grade C"
Vertical Loads	1.5	1.25	1.25
Wind Loads	1.5	1.25	1.25
Wire Tension Loads	1.5	1.25	1.25

Table 4-2: Maximum Strength Factors

Line Element	Strength Factors		
	"Grade A"	"Grade B"	"Grade C"
Conductors, splices and conductor fastenings (other than tie wires)	.75	.62	.62
Pins	.75	.62	.62
Pole line hardware	.75	.62	.62
Line Insulators (mechanical)	.5	.62	.62
Guy insulators (mechanical)			
Interlocking	.75	.62	.62
Noninterlocking glass fiber	.5	.62 (a)	.62(b)
Guys	.75	.62	.62
Messengers and span wires	.75	.62	.62
Foundations against uplift	1.0	.83	.83
Foundations against depression	.5	.62	.62
Poles, Towers and Structures			
Wood	.375	.415	.625
Metal (including elements of foundations)	1.0(c)	1.0(c)	1.0(c)
Reinforced concrete	.37	.41	.41
Prestressed or post-tensioned concrete	.83	.83	.83
Other engineered materials	1.0	1.0	1.0
Crossarms			
Wood	.75	.62	.62
Metal	1.0(c)	1.0(c)	1.0(c)
Prestressed Concrete	.83	.83	.83
Other engineered materials	1.0	1.0	1.0

GO 95 Allowable Strength Design (ASD)

Strength / Load Effects ≥ Minimum Safety Factor

Same "Unchanged" Terms

Load & Resistance Factor Design (LRFD)

Load Effects x Load Factor ≤ Strength x Strength Factor

or

Strength / Load Effects ≥ Load Factor / Strength Factor

Thus, for the current proposal

effective "Minimum Safety Factor" = Load Factor / Strength Factor

Selection of Load and Strength Factors

1) Load factors are the same for all loads within the same Grade of Construction.

Table 4-1: Minimum Load Factors

Why three sets of Load Factors when the values in all sets are the same?

Load Condition	Load Factors		
	"Grade A"	"Grade B"	"Grade C"
Vertical Loads	1.5	1.25	1.25
Wind Loads	1.5	1.25	1.25
Wire Tension Loads	1.5	1.25	1.25

2) For each Minimum Safety Factor in Table 4 the Strength Factor for the LRFD proposal (Table 4-2) was determined as follows to provide for consistent design results:

Strength Factor = Load Factor / Minimum Safety Factor

Examples to Demonstrate Equivalence

Load Factor/Strength Factor = Minimum Safety Factor

1) Guys (Grade A) 1.5/.75 = 2
2) Wood Poles (Grade A) 1.5/.375 = 4
3) Wood Poles (Grade B) 1.25/.415 = 3

Table 4: Minimum Safety Factors

Line Element	Grades of Construction		
	Grade "A"	Grade "B	Grade "C"
Conductors, splices and conductor fastenings (other than tie wires)	2	2	2
Pins	2	2	2
Pole line hardware	2	2	2
Line Insulators (mechanical)	3	2	2
Guy insulators (mechanical)			
Interlocking	2	2	2
Noninterlocking glass fiber	3	2 (a)	2 (b)
Guys	2	2	2
Messengers and span wires	2	2	2
Foundations against uplift	1.5	1.5	1.5
Foundations against depression	3	2	2
Poles Towers and Structures			
Wood	4	3	2
Metal (including elements of foundations)	1.5 (c)	1.25 (c)	1.25 (c)
Reinforced concrete	4	3	3
Prestressed or post-tensioned concrete	1.8	1.5	1.5

Table 4-1: Minimum Load Factors

Load Condition	Load Factors	
	"Grade A"	"Grade B"
Vertical Loads	1.5	1.25
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Table 4-2: Maximum Strength Factors

Line Element	Strength Factors	
	"Grade A"	"Grade B"
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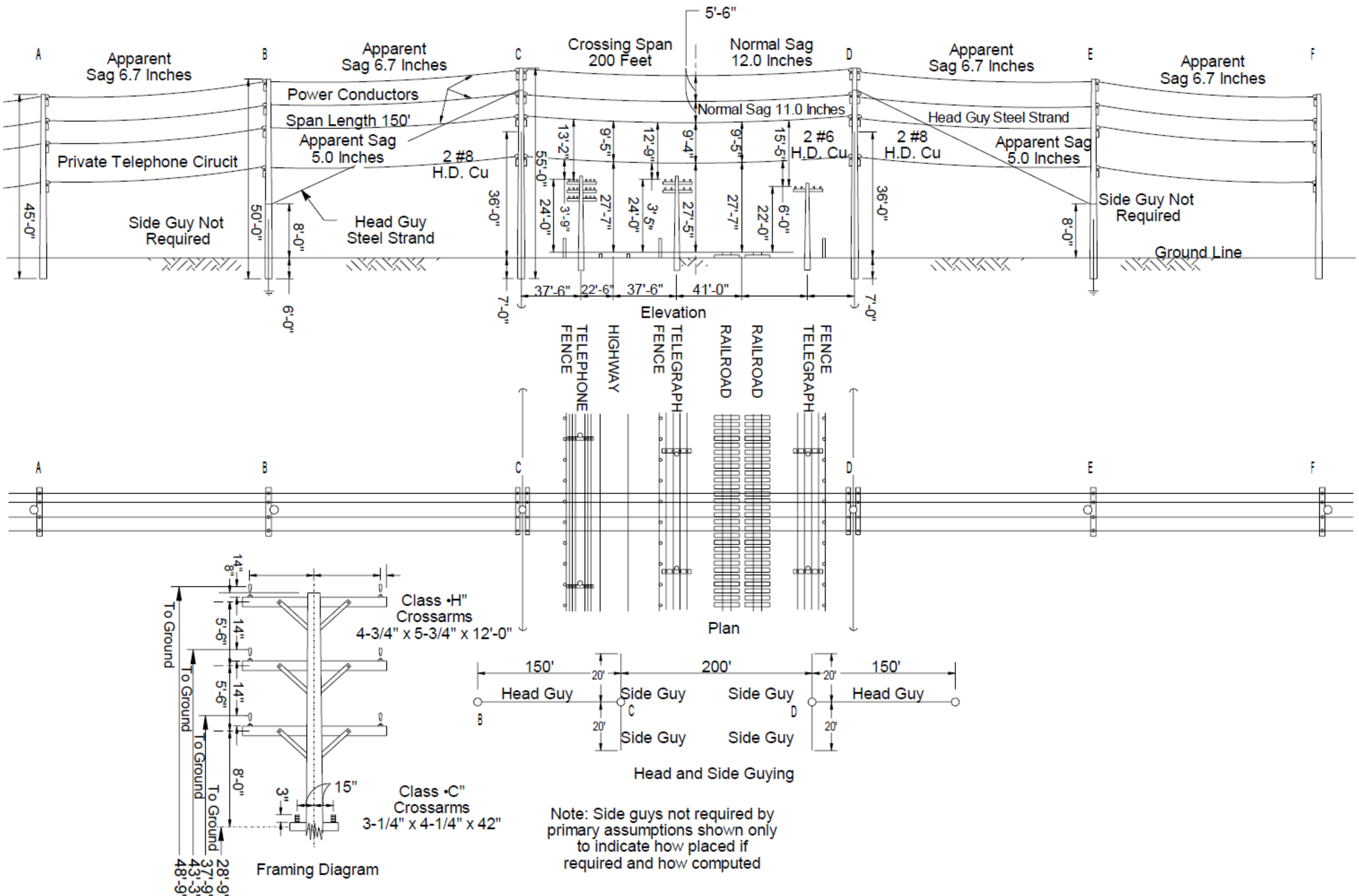
Pole line hardware	.75	.62
Line Insulators (mechanical)	.5	.62
Guy insulators (mechanical)		
Interlocking	.75	.62
Noninterlocking glass fiber	.5	.62 (a)
Guys	.75	.62
Messengers and span wires	.75	.62
Foundations against uplift	1.0	.83
Foundations against depression	.5	.62
Poles, Towers and Structures		
Wood	.375	.415
Metal (including elements of foundations)	1.0(c)	1.0(c)
Reinforced concrete	.37	.41

Crossing of Class •H" Supply Line Over Major Railroad and Major Communication Lines



10. Poles

The crossing poles are western red cedar and their dimensions are as follows:

Length	55 feet
Height above ground	48 feet
Circumference at top	28 inches
Diameter at top	8.9 inches
Circumference at ground line	49.0 inches
Diameter at ground line	15.6 inches

Distance from ground line to conductors supported is given as follows:

Top supply conductors	48′ 9″
Middle supply conductors	43′ 3″
Lower supply conductors	37′ 9″
Private telephone conductors	28′ 4″

Ground level at base of pole is considered to be at the same elevation as top of rail.

No Change Necessary

Dimensions of adjacent poles B and E are:

Length	50 feet
Height above ground	43.5 feet
Circumference of top	28 .0 inches
Diameter of top	8.9 inches
Circumference at ground line	47.0 inches
Diameter at ground line	15.0 inches

11. Transverse Load on Crossing Poles C and D

The moment at the ground due to an 8 pound wind pressure on conductors is:

$$Mc = Ln\ P_h\left(\frac{S_1 + S_2}{2}\right) \text{ pound–feet}$$

Where:

L	=	Height of conductors above ground in feet
n	=	Number of wires
S_1 and S_2	=	Length of crossing and adjacent spans, respectively
P_h	=	Horizontal load per lineal foot due to an 8 pound wind pressure on projected area of wire
P_h	=	0.276 pounds per lineal foot for 00 AWG bare, stranded copper
	=	0.108 pounds per lineal foot for 6 AWG bare, solid copper
	=	0.085 pounds per lineal foot for 8 AWG bare, solid copper
M_{c0}	=	Moment due to pressure on top supply conductors
M_{c1}	=	Moment due to pressure on middle supply conductors
M_{c2}	=	Moment due to pressure on lower supply conductors
M_{c3}	=	Moment due to pressure on telephone conductors

$$M_{c0} = 48.75 \times 2 \times 0.276 \times \left(\frac{150 + 200}{2}\right) = 4710 \text{ lb-feet}$$

$$M_{c1} = 43.25 \times 2 \times 0.276 \times \left(\frac{150 + 200}{2}\right) = 4180 \text{ lb-feet}$$

$$M_{c2} = 37.75 \times 2 \times 0.276 \times \left(\frac{150 + 200}{2}\right) = 3650 \text{ lb-feet}$$

$$M_{c3} = 28.33 \times 2 \times 0.108 \times \left(\frac{200}{2}\right) = 610 \text{ lb-feet}$$

$$M_{c3} = 28.33 \times 2 \times 0.085 \times \left(\frac{150}{2}\right) = 360 \text{ lb-feet}$$

Total Moment due to Wind pressure on conductors = 13,510 lb-feet

The moment at the ground due to an 8 pound wind pressure on the pole is:

$$Mp = PH^2\left(\frac{D_1 + 2D_2}{72}\right) \text{ pound-feet}$$

Where:

M_p	=	Moment due to wind pressure on pole
P	=	Pressure in lbs per sq. ft. on projected area of pole (8 lbs/sq. ft.)
H	=	Height of pole above ground in feet (48′)
D_1	=	Diameter of pole at ground in inches (15.6″)
D_2	=	Diameter of pole at top in inches (8.9″)

$$Mp = \frac{8\ 48^2 \times 15.6 + 2 \times 8.9}{72} = 8550 \text{ lb-ft.}$$

Total moment = 13,510 + 8,550 = 22,060 lb–ft.

Moment of resistance of pole = $M = \frac{FI}{c}$

Where:

F = Fiber stress in pounds per sq. in.

I = Moment of inertia of section $= \frac{\pi D_1^4}{64 \times 12}$

c = Distance from neutral axis to outer fiber $= \frac{D_1}{2}$

No Change Necessary

$$M = \frac{\pi F D_1^3}{384} = \frac{F D_1^3}{122}$$

$$F = \frac{122M}{D_1^3} = \frac{122 \times 22060}{15.6^3} = 710 \text{ lbs per square inch}$$

The allowable fiber stress for western red cedar poles to provide a factor of safety of 4 is 1,500 pounds per sq. in., hence the crossing poles are not required to be side guyed since they have a factor of safety of 8.5 for transverse load.

This paragraph will need minor modifications for LRFD.

12. Side Guying

If side guying were required fo
computing the same would be

Side guys are designed to take
acting merely as a strut.

The transverse force acting on
and D and the transverse wind
of conductor used in computin
distance between the guyed p
adjacent to these poles.

The total wind pressure is com

On Conductors

3 x 2 x 0.276 x 1

2 x 0.108 x $\frac{200}{2}$ =

2 x 0.085 x $\frac{150}{2}$ =

On Pole

$\frac{D_1 + D_2\ HP}{24}$ = 15.

Total Wind Pressu

Key Variables:

- Fiber stress = 710 psi
- Fiber strength (western red cedar) = 6,000 psi
- Minimum Safety Factor for Grade A Wood Pole = 4

SAME RESULTS

ASD Requirement:

Strength / Load Effects ≥ Minimum Safety Factor

6,000 psi/710 psi = 8.5 > 4 (Minimum Safety Factor)

Acceptable! (excess margin = 8.5/4 = 2.1)

LRFD Requirement:

Strength x Strength Factor ≥ Load Effects x Load Factor

6,000 psi x 0.375 ≥ 710 psi x 1.5

2,250 psi > 1,065 psi

Acceptable! (excess margin = 2250 psi/1065 psi = 2.1)