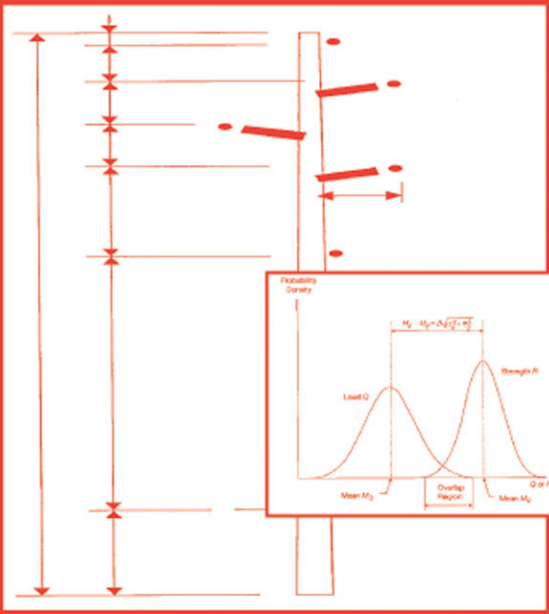
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Reliability-Based Design of Utility Pole Structures



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Chapter 1
INTRODUCTION

1.1 CURRENT PRACTICE

There is a need to provide a design methodology for distribution and transmission poles that yields consistent structural reliabilities across all material types: wood, steel, concrete, fiberglass, and other new materials. Whereas this document is currently focused on poles, future editions will have an expanded scope to cover reliability-based design (RBD) for all utility structures and components.

Prevailing U.S. practice and most state laws require that transmission and distribution lines be designed to meet the basic safety requirements of whichever edition of the *National Electrical Safety Code (NESC)* is adopted by each state. The current *NESC* rules (IEEE 2002) for the selection of design load and strength factors are largely based on successful experience but they do not have a strong theoretical foundation. Some designers find the rules too restrictive, whereas others adopt more conservative criteria. In fact, individual utilities often develop their own loading criteria to supplement the *NESC* rules.

A desire to achieve more consistent structural reliabilities across materials was the impetus for the development of the American Society of Civil Engineers (ASCE) *Manual 74*,"Guidelines for transmission line structural loading" (ASCE 1991) and the International Electrotechnical Commission (IEC), "Design criteria of overhead transmission lines," *IEC 60826* (IEC 2002). Although *ASCE Manual 74* offers consistent methods to calculate loads, there is still a need to provide consistent methods to calculate strength across pole materials.

The nominal strength (R_n) of a pole is calculated using a variety of approaches and guides, depending on the pole material type. This includes, for example, *ASCE Manual 72* for steel poles (ASCE 1990), *ANSI O5.1-2002* for wood poles (ANSI 2002), and the Precast/Prestressed Concrete Institute (PCI), "Specification guide for prestressed concrete poles" (PCI 1999). *ASCE Manual 104*, "Recommended practice for fiber-reinforced polymer products for overhead utility line structures,"

has recently been developed for fiber-reinforced polymer (FRP) poles (ASCE 2003).

In addition to these guides, pole manufacturers typically use in-house models for predicting the nominal strength of prestressed concrete poles and FRP poles. These strength guides, standards, and in-house methods have essentially evolved independently so there is little consistency in the definition of nominal strength across pole materials. For some pole materials and design methods, the nominal strength value is close to a mean strength, whereas for other pole materials the nominal strength represents a more conservative value, such as a 5% or 10% lower exclusion limit (LEL). As a result, a wide range of possibilities currently exists concerning what the nominal strength of a pole really represents. This results in inconsistent and unknown reliability levels for different pole materials.

To illustrate the problem, refer to Fig. 1-1. Any strength property of a pole, such as the lateral strength of a Class 1 wood pole in a cantilever test, is a random variable (testing 100 identical poles in the same manner will result in 100 different values of the strength). The many sources of uncertainty in observed pole strength include inherent material property variability, geometric variability, manufacturing effects, and variation in the testing method. The strength of a pole may thus be characterized by a probability density function (PDF) with a mean value (m) and a coefficient of variation (COV), as shown in Fig. 1-1. The COV (the standard deviation divided by the mean) varies with the pole material and pole type. The COV is higher, for example, for wood poles than for steel poles. The higher COV causes the PDF for wood poles to be wider and flatter than for steel poles. The procedure used to calculate the nominal or characteristic strength of the pole (whether per *ASCE Manual 72* [ASCE 1990] or *ANSI O5.1-2002* [ANSI 2002] yields a nominal strength R_n that falls somewhere on the horizontal axis of the PDF in Fig. 1-1.

Figure 1-1 shows three possible positions of the nominal strength: $R_n = R_1$, R_5, and R_{50}, representing a 1%, 5%, and 50% LEL, respectively. For example, a 5% LEL nominal strength (a 5th percentile) is a value not achieved by 5% of the poles. For a normal density function, the 5th percentile is 1.645 standard deviations below the mean:

$$R_5 = m - 1.645\,(m \times \text{COV}). \qquad \text{(Eq. 1-1)}$$

A 50% LEL or 50th percentile nominal strength is a value not reached by 50% of the poles. For a normal density function, R_{50} is also the mean strength. It follows that $R_{50} > R_5 > R_1$ and the distance between these values grows with increasing COVs. Clearly, unless strength design methods for different pole materials yield consistent nominal value definitions (e.g., all materials at the 5% LEL), it will be difficult to achieve consistent reliability among material types.