Effect of Inspection Holes on Flexural Properties of Douglas-Fir Utility Poles

Jeffrey J. Morrell
Arijit Sinha
Milo Clauson
Connie S. Love

Abstract

Routine inspection of wood utility poles to detect internal decay involves drilling holes at or about the ground line. While these holes are useful for detecting internal decay, their presence raises concern among engineers about their potential effects on pole flexural properties. The effect of inspection holes on flexural properties was studied on 92 Douglas-fir poles. Drilling up to six 20-mm-diameter inspection holes had no significant effect on flexural properties, indicating that inspection does not adversely affect pole condition.

Preservative-treated wood poles provide excellent performance for supporting overhead electrical lines (Graham 1983). Over time, however, some of these poles develop decay that can be either on the pole surface (external decay) or on the interior (internal decay). The National Electric Safety Code mandates that utilities perform periodic assessments of pole condition and either reinforce or replace poles when they have lost more than one-third of their original design value (Institute of Electrical and Electronics Engineers 1997). External decay is normally detected by excavating the soil around the pole, removing visibly degraded wood, and then measuring the residual circumference to determine if the cross-sectional area is sufficient to support the design load (Morrell 1996). Internal decay detection and assessment is more difficult and generally involves drilling a series of steep sloping holes beginning at or below the ground line and then moving upward. The holes are probed to detect internal voids and can be used to measure the thickness of the residual shell. The hole can then be used to apply remedial treatments to arrest any fungal attack.

While drilling these holes is beneficial because it allows the utility to detect and arrest internal decay, some engineers have expressed concerns about the potential negative impacts of these holes on pole flexural properties. This may be an especially important problem when utilities bore new holes each time they inspect a pole. Clearly, drilling too many holes in a given zone can have potentially negative effects on pole properties (Falk et al. 2003), but there is little guidance for utilities concerning the number of holes that can be drilled. In this article, we describe full-scale bending tests to assess the effects of inspection holes on flexural properties.

Materials and Methods

Ninety-two green, freshly peeled Douglas-fir (*Pseudotsuga menziesii* [Mirb] Franco) pole sections (6 m long) were obtained from western Oregon and Washington. The poles were sprinkled with water to maintain them in the green condition until tested. The circumference of each pole was measured at the butt, at the theoretical ground line for a 12-m-long pole, and at the tip. The poles were then randomly assigned to four treatment groups:

1. No holes.
2. Holes (15.6 mm in diameter) drilled 150 mm below the ground line, 150 mm above the ground line, and 450 mm above the ground line. The three holes were approximately 375 mm long and drilled inward at a 45° angle. Each hole was 120° around from the others.
3. Holes (21.9 mm in diameter) drilled 150 mm below the ground line, 150 mm above the ground line, and 450 mm

The authors are, respectively, Professor, Assistant Professor of Renewable Materials, Senior Faculty Research Assistant, and Senior Faculty Research Assistant, Dept. of Wood Sci. and Engineering, Oregon State Univ., Corvallis (jeff.morrell@oregonstate.edu [corresponding author], arijit.sinha@oregonstate.edu, milo.clauson@oregonstate.edu, connie.love@oregonstate.edu). This paper was received for publication in January 2011. Article no. 11-00016.

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above the ground line. The three holes were approximately 375 mm long and drilled inward at a 45° angle. Each hole was 120° around from the others.
4. Holes (21.9 mm in diameter) drilled in pairs beginning 150 mm below the ground line, 150 mm above the ground line, and 450 mm above the ground line. The six holes were approximately 375 mm long and drilled inward at a 45° angle. Pairs of holes at a given location from the ground line were drilled 120° apart; that is, one pair was offset by 60° from the adjacent pair.

The poles were tested in a modified four-point bending method that forced the maximum bending stress to be in the region containing the inspection holes while maintaining a nearly constant moment in the high-moment zone so that the bending moment at failure could be accurately calculated (Fig. 1). The test setup was a modification of that described by Crews et al. (2004) as reported by Elkins et al. (2007).

The poles were tested as simply supported beams with two point loads applied near the assumed ground line. The end bearing points allowed the pole to rotate as well as move longitudinally. Wood saddles were used at the bearing points as well as at the points of loading. The U-shaped saddles measured 275 mm in length and were made out of Douglas-fir, so the point of contact between the two materials was of similar hardness.

Pole length provided an acceptable span-to-depth ratio and was not shear critical. With those criteria, the poles were tested on four-point bending where the length for the test specimen was 6 m with a minimum 300-mm overhang on each end (Fig. 1).

A 200-kip capacity hydraulic actuator mounted on a steel portal frame attached to the laboratory strong floor was used to apply the load to the poles. The load was displacement controlled, and the rate of loading was 0.25 mm/s. This rate was derived using procedures described in ASTM Standard D1036 (ASTM International 2005). An external load cell attached to the rod end of the actuator measured the force as it was applied to the pole. Deflection and force data were compiled continuously at 10 Hz during the test using National Instruments LabVIEW 6.1 operated through a personal computer.

The poles were loaded to failure, defined as the point at which the pole could not continue to take increasing load. After testing, failure location was recorded, photographs were taken at the point of failure, and notes were made of any significant features that might have contributed to the failure. A full-section disk was removed adjacent to the failure zone, weighed, oven-dried (103°C), and weighed to determine moisture content at the time of testing. The disk was also used to determine ring count in the outer 50 mm as well as the entire cross section. Ring counts were taken in two directions, 90° from one another, and the values were averaged for a given pole. Ring count in the outer 50 mm is important because the American National Standards Institute Standard ANSI 05.1 requires that poles have a minimum of five rings in this zone (ANSI 2008).

Disk volume was estimated by taking two measurements for both diameter and thickness and averaging these values. Average disk volume and the ovendry weight were used to determine specific gravity.

The section modulus was determined at the point of failure from the butt and ground-line circumference data taken, assuming a constant taper and uniform circular cross section. The maximum load was used to calculate the moment at failure assuming a prismatic member. The section modulus used as input for the modulus of rupture (MOR) values was the section of the pole at the failure location. All section modulus calculations were based on the gross pole section and were then adjusted for MOR at the ground line (MOR-GL).

The MOR-GL data were analyzed using unpaired *t* tests to compare differences between the nonbored and bored poles at $\alpha = 0.05$. Normality of the data was checked using

Figure 1.—Photograph showing a pole in the test setup.

the Shapiro-Wilk test followed by a nonparametric analysis of variance.

Results and Discussion

Measurements at an assumed ground line (10% of length plus 0.6 m) indicated that the poles were in ANSI Pole Classes 5 or 6 (ANSI 2008). These would make them relatively small and should magnify any potential effects of drilling compared with larger poles that are more commonly used by North American utilities. Measurements of the number of annual rings at the butt and the number in the outer 50 mm of the radius indicated that all poles met the minimum ANSI requirement of no fewer than five rings in the outer 50 mm.

MOR-GL for poles with no inspection holes averaged 41.44 MPa, while average MORs for poles receiving any of the inspection hole treatments ranged from 39.48 to 40.43 MPa (Table 1). Coefficients of variation for the treatments ranged from 12 to 21 percent. These values were slightly lower but within the range for previous tests performed using this test assembly (Elkins et al. 2007).

Unpaired *t* tests comparing the means for poles with no inspection holes with those with holes indicated that the presence of three or six holes in the ground-line region had no significant effect on flexural properties, nor were there any differences in MOR-GL between the three inspection hole treatments (Table 2). The four treatment groups were then presorted on the basis of increasing modulus of elasticity (MOE) values. As expected, MOR values increased with increased MOE values within a treatment (Fig. 2). Because MOE and specific gravity are normally

Table 1.—Effect of diameter and number of inspection holes on flexural properties of Douglas-fir poles.[a]

Hole diameter (mm)	No. of holes	GL circumference (cm)	Total no. of annual rings	No. of rings, outer 50 mm	MOR-GL (MPa)	COV (%)
None	0	80.3 (5.3)	33.3 (8.7)	18.1 (5.7)	41.44 (6.91)	16.7
15.6	3	77.8 (5.0)	35.7 (11.7)	20.4 (8.2)	40.43 (7.16)	17.7
21.9	3	79.0 (3.8)	34.6 (8.9)	19.3 (10.5)	39.48 (8.32)	21.0
21.0	6	78.8 (2.8)	35.2 (10.5)	20.0 (7.3)	40.26 (4.84)	12.0

[a] Values represent means of 23 poles per treatment, while figures in parentheses represent 1 standard deviation. GL = ground line; MOR-GL = modulus of rupture at GL; COV = coefficient of variation.

*Table 2.—*t *tests comparing modulus of rupture at ground line for poles that were not bored or received three or six inspection holes that were 15.6 or 20.9 mm in diameter at ground line.*

	Control vs. three 15.6-mm holes		Control vs. three 20.9-mm holes		Control vs. six 20.9-mm holes	
Mean (MPa)	41.44	40.43	41.44	39.48	41.44	40.26
Variance (MPa)	6.91	7.16	6.91	8.32	6.91	4.84
No. of replications	23	23	23	23	23	23
Degrees of freedom	44		44		44	
t statistic	0.4869		0.8592		0.6743	
$P(T \leq t)$, 1-tailed	0.3144		0.1976		0.2521	
t critical, 1- tailed	1.6802		1.6829		1.6849	
$P(T \leq t)$, 2-tailed	0.6288		0.3952		0.5041	
t critical, 2-tailed	2.0154		2.0195		2.0227	

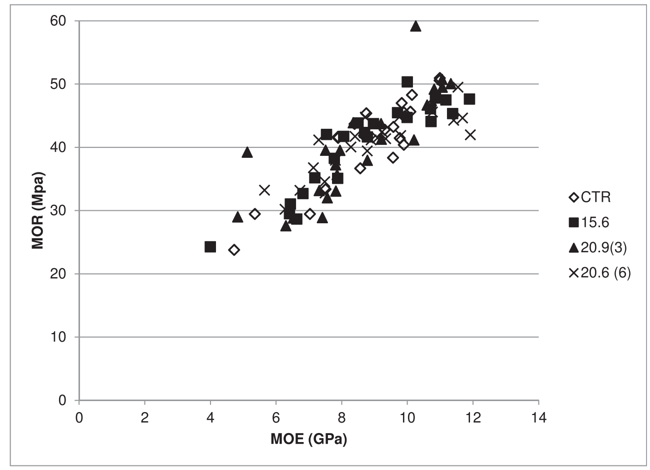

Figure 2.—Relationship between modulus of rupture (MOR) at ground line and modulus of elasticity (MOE) for poles with or without inspection holes around the ground line.

well correlated (US Department of Agriculture 2010), MOE was chosen as the explanatory variable, and the data were further checked against statistical skew in the distribution. The MOE data varied significantly from the pattern expected if the data were drawn from a population with normal distribution ($P < 0.001$; Shapiro-Wilk test for normality). This anomaly was largely an artifact of sample procurement. Poles were randomly selected from the existing production over a wide geographic area, and the authors had little control over the sources. We noted substantial differences in properties with source. The nonnormal distribution impeded the ability to generalize the results to a wider population. In an attempt to further analyze the results, a nonparametric analysis of variance showed that MOR significantly correlated with MOE, and the treatments did not influence the MOR values (Kruskal-Wallis rank sum test; $P = 0.5708$). As a result, neither three nor six holes drilled at the ground line significantly affected pole properties.

Most utilities inspect their poles on a 10- to 15-year cycle using the same inspection holes to determine if decay has progressed between inspections. These holes are also often used to apply internal remedial treatments (Mankowski et al. 2002). The flexural data indicate that these inspection holes did not adversely affect the pole. A few utilities require that additional inspection holes be drilled at each inspection cycle. While this is not generally recommended (Morrell 1996), the data suggest that drilling a second set of holes does not adversely affect flexural properties. Clearly, however, continued drilling will ultimately reduce the cross-sectional area to the point where properties are reduced, especially on smaller poles, such as those evaluated in these tests. A further consideration for additional drilling would be the presence of internal decay, which could magnify the effects of adding more holes.

Conclusion

Drilling inspection holes had no significant negative effect on flexural properties of Douglas-fir distribution poles and remains a valuable method for detecting internal decay so that it can be remediated to prolong pole service life.

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