FIELD TEST OF A NOVEL NONDESTRUCTIVE TESTING DEVICE ON WOOD DISTRIBUTION POLES

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Abstract. In July 2015, a field test was performed on 50 utility poles that had been removed from service. The poles were nondestructively tested with a novel device, the PoleXpert device. The poles were then destructively tested. Results indicated that the device's output correlated well with the actual bending strength of the utility poles. Therefore, it appears that the device has the potential to identify weak or structurally compromised poles. Seventeen of the poles were reinstalled in the ground and tested. The other 33 poles were tested horizontally in a pole-testing fixture. The device demonstrated positive correlation in both situations.

Keywords: Wood utility poles, PoleXpert PX device, nondestructive testing, acoustic waves, novel device.

INTRODUCTION

For more than 100 yr, wood utility poles remain the material of choice for the distribution of electric power (ASC 2015). Cost, availability, life-cycle analysis, environmental footprint, and other factors drive this use. Discarding wood that comes from utility poles is challenging for electric power companies because this wood has generally been treated with toxic chemical products (Freitas et al 2013). While in service, wood utility poles should be inspected periodically, such as on an 8-10 yr cycle. The purpose of this inspection is to determine which poles remain serviceable, which should be shored up

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if necessary, and which have reached or are nearing the end of their service life. The inspection process needs to be relatively fast, yet also provide accurate and reliable results. In the case of structural lumber and wood structures, there are a variety of nondestructive evaluation (NDE) techniques. These techniques seek to assess the existing or residual strength and/or stiffness in a member or structure. Although never perfectly correlated, they do have a strong history of capitalizing on the direct relationships among stiffness, strength, vibrational frequency, acoustic velocity, and other parameters. New nondestructive techniques and novel applications are being developed on a continual basis as ways and means of improving lumber and structure value, enhancing service life, improving safety, and/or other details. Implementation of commercial NDE devices for lumber grading hinge on both technological and commercial feasibility (Galligan et al 2016). From the very beginning of NDE for lumber grading, these factors have been the subject of study and debate (Galligan and Courteau 1965). The technology of machine lumber grading was based on the two commercial machine-based predictors of strength, modulus of elasticity (MOE) and density (Galligan et al 2016). Machine stress grading was founded on nondestructive testing of principles that had been known for more than 20 yr. An example demonstrating the fundamental relationships published by Senft et al (1962) suggested the usefulness of using MOE to predict modulus of rupture (MOR).

In North America, the Machine Stress Rated Lumber Producers Council represents the interests of machine-rated lumber producers in the manufacturing, marketing, promotion, utilization, and technical aspects of machine stress–rated (MSR) lumber and machine-evaluated lumber (MEL; MSR Lumber Producers Council 2015). The MSR and MEL are the two types of machine-graded lumber produced in North America under the auspices of the American Lumber Standard Committee (ALSC; Galligan and McDonald 2000). As a measure to allow mills to enhance southern pine lumber in various markets, the Southern Pine Inspection Bureau increased the number of allowable grades of MSR and MEL significantly (Galligan et al 2016). The decrease in visually graded design values coupled with the increase in the number of MSR and MEL grades are the major driving forces in the dramatic increase in stress grading technology used by mills in the south from 2012 to 2015 (Galligan et al 2016). The MSR and MEL grades produced must be acceptable to engineers, code authorities, and regulatory agencies. To achieve that acceptance, most companies rely mainly on their ability to meet the ALSC requirements for production and quality control and on representation by the grading agency or lumber association (Galligan et al 2016).

Many studies have used acoustic approaches to assess utility poles for detection of decay or weakened structure (Rabe et al 2004; Freitas et al 2013; Senalik et al 2013; Ross 2015), but limited research has been conducted using both acoustic and vibrational analyses. A novel device for assessing the performance and residual life of in-service utility poles has been developed by PoleXpert LLC (2015) (PX; PoleXpert LLC, Carson City, NV). The PX device uses a combination of acoustic and vibrational analyses along with pole size characteristics for an assessment. The PX device testing technology is based on the measurement and analysis of the natural acoustic frequencies of an installed utility pole (considered as a cantilever beam). In this process, the PX device is affixed to the pole at approximately 1.22 m above the ground line (Figs 1 and 2). Next, the standing in-situ pole is tapped (accelerated) with a 0.907-kg hard rubber mallet. The acoustic pulses produced by the tapped mallet are then captured, subsequently processed, and interpreted by the PX device. This computational process takes 3-5 s. The PX device is then relocated 120° from the initial orientation, and the process is repeated. Then, it is relocated 240° from the initial orientation, and the process is repeated for a third time to determine an average reading. In this manner, the device develops information about the entire circumference of the utility pole. By determining the

Figure 1. A PoleXpert specialist affixes the PX device, which is used to nondestructively evaluate an in-service wooden utility pole, at approximately 1.22 m above the ground line.

Figure 2. The PoleXpert device used to nondestructively evaluate in-service wood utility poles.

natural frequencies, the PX device calculates the average sound velocity throughout the global timber fibers for the tested pole. The presence of any decay, deterioration, checks, holes, unbalanced external static loads, or other internal anomalies, which decrease the mechanical properties of the pole, compared with a sound, on-grade pole, can lead to a decrease of its bending strength and stiffness (ASC 2015). Consequently, the decrease of average sound velocity throughout timber fibers is, in theory, detectable. A device that can detect a decline or deviation in acoustic performance of standing poles may ultimately be able to detect the poles that should be taken out of service. This field test compared results from this PX device with the actual bending test data for poles that had been identified as unsound by the electric power cooperative and subsequently removed from service. The poles that were taken out of service and subsequently tested herein should have had strength performance less than that of sound, on-grade new poles. The objective of this study was to conduct field tests in an effort to determine the potential for using and adopting this novel technology of the PX device as a means of assessing utility poles.

MATERIALS AND METHODS

During and as part of an 8-10 yr cyclic inspection, a local electric power cooperative identified the poles that were no longer serviceable and removed them from service. Of the nearly 8046.7 km of powerlines used, approximately 200 wood utility poles were identified for removal for various reasons such as decay, splits, wood pecker damage, and insect damage. The electric power cooperative's inspection program may include visual and nondestructive techniques such as sounding and boring, as a means of in-situ assessment of each individual pole. Before those poles were removed from service, PX specialists tested poles being used in the field with the PX device. Of the poles that were taken out of service, 50 were subjected to evaluation and testing at the Mississippi State University (MSU). Defects in these poles consisted primarily of ground-line decay or damage, splits or shake, and holes in the top. These were primarily class 4 poles ranging from 10.67 to 13.72 m in length. All poles were southern yellow pine (*Pinus* spp.) wood, and had been treated with a preservative such as creosote or pentachlorophenol.

Once on-site at the MSU Laboratory, each pole was measured with the PX device again. For this action, 17 of the poles were reinstalled in the ground and tested vertically in a manner consistent with a modified American Society for Testing and Materials (ASTM) D 1036 standard (ASTM 2012). Then, the PX device was placed on the surface of the utility pole approximately 1.22 m above the marked ground line, and the pole was hit (accelerated) with a 0.907-kg hard rubber mallet (Fig 1). These 17 poles were measured for strength and stress properties but not stiffness. Breaking force was taken as the cosine of the angle of the cable attached to the pole, compared with a level horizontal line. In this manner, an actual perpendicular force was estimated. The stress was measured by taking into account the moment of inertia of the pole section at the point of breakage, as well as the distance from the breaking point to the attachment of the cable. The remaining 33 poles were tested destructively by bending as per ASTM (2012) in horizontal orientation and secured in a pole-testing fixture. In the field, all of these poles were tested by the PX device 6 mo before tests at the MSU Laboratory. These poles were tested for strength, stress, and stiffness. Only one utility pole was omitted from the MOE reporting because the deflection data loggers recorded an error during testing.

RESULTS

On the basis of these descriptive statistics from the MSU testing in July 2015, the poles had less than half of the tip load required for class 4 poles, ie 1088.62 kg (Table 1). Next, the actual values (from MSU testing) vs the predicted values (from the PX device) were correlated. The r^2 value between the actual tip load and the predicted load, per the PX device was 0.5580 (Fig 3). The r^2 value for only those 17 poles that were tested upright was 0.7298 (Fig 4). The poles that were tested horizontally (33 poles) had an r^2 value of 0.5448 (Fig 5). Most probably, this relationship was seen because these poles were tested by the PX device and then broken (tested destructively) under similar conditions at the MSU Laboratory yard on the same day as opposed to the horizontally broken poles (tested destructively by bending as per ASTM [2012]) that were tested by the PX device in the field 6 mo before the test in the laboratory.

DISCUSSION

The correlations between the actual and predicted bending strengths were reasonably good. As a means of comparison, r^2 values in the 0.50-0.70 range are commonly observed when testing the stress of in-grade structural lumber. Erickson and Wood (1960) recorded that most of the coefficients of correlations were about $r^2 = 0.7$. It was reasonable to infer that if the

Table 1. Summary statistics of actual performance compared with the results from the PX device.

	N	Average	SD
Maximum load (Newtons)	50	4417	2290
Predicted maximum load (Newtons, from PX device)	50	4154	1276
Maximum bending stress (MOR as MPa)	50	27.6	10.6
Stiffness (MOE as MPa)	32	9380	2480

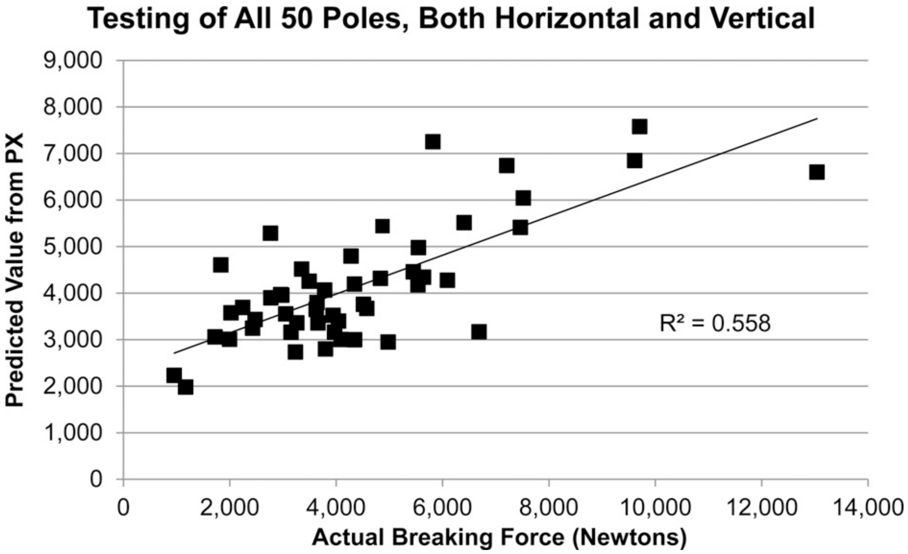

Figure 3. Correlation between actual and predicted maximum bending loads (Newtons) for all poles (50), including those tested upright and set in the ground as well as those tested horizontally in a fixture.

PX device was also used on new treated poles, the correlation would go up because the strength, stiffness, and acoustical properties would be greater for new on-grade poles. Among the poles that were tested, the PX device appears to show potential for separating poles based on residual strength. Although controls (sound poles) were not included in this study, it is assumed that the testing of sound poles with their greater stiffness would increase the r^2 values. Similar to this study, Freitas et al (2013) evaluated utility poles using ultrasonic inspection to determine the poles that could be used and those that needed to be discarded, and they showed similar results to this study by using an ultrasound device. They concluded that their analysis tool was adequate and efficient in indicating decay on utility poles. Because there is no perfect system of field assessment, there is always room to improve on existing technologies that are available for field inspectors,

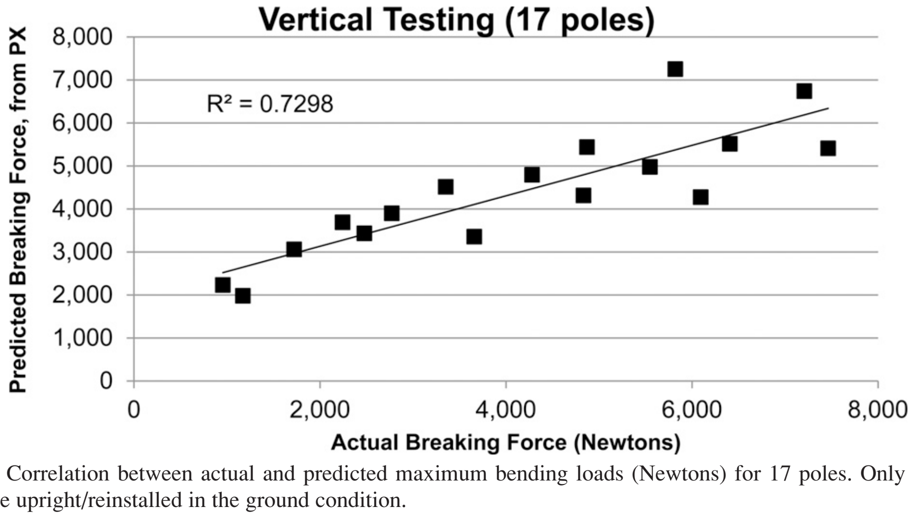

Figure 4. Correlation between actual and predicted maximum bending loads (Newtons) for 17 poles. Only those poles tested in the upright/reinstalled in the ground condition.

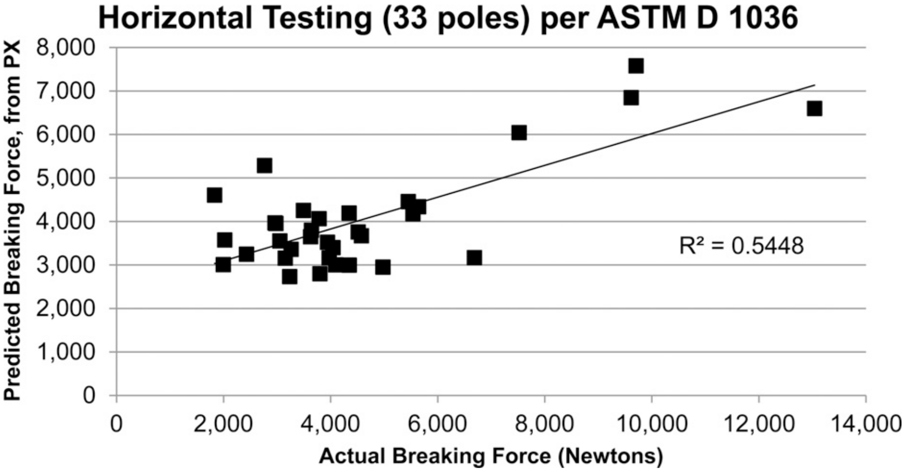

Figure 5. Correlation between actual and predicted maximum bending loads (Newtons) for 33 poles. Only those poles tested in the horizontal pole-testing fixture, per ASTM (2012).

particularly if the nondestructive technique provides some type of quantitative assessment.

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