Verification of ANSI O5.1 Strength Values for Southern Pine Poles Through Current Full-sized Destructive Testing

H. Martin Rollins
Jason M. Rollins
H. M. Rollins Company, Inc.
Gulfport, Mississippi

R. Daniel Seale
Department of Sustainable Bioproducts
Mississippi State University

T. Archie McMillan, Jr.
Baldwin Pole & Piling Company, Inc.
Bay Minette, Alabama

ABSTRACT

There have been recent reductions in the design strength values for visually graded Southern Pine lumber. This reduction in strength has been attributed to the increasing use of timber from intensively managed forests that produce higher growth rates than the historic average. To assess the potential impact of the changing timber resource, 92 pieces of Southern Pine poles meeting the ANSI O5.1 standard for a 40-foot class 3 pole were randomly selected from the stock of commercial producers located across the Southern Pine pole producing region from Texas through the Carolinas. These poles were destructively tested in bending following the procedures of ASTM D1036. The results of this testing produced an adjusted Modulus of Rupture (MOR) value of 8127 psi, which compares favorably to the MOR strength value of 8000 psi for Southern Pine found in ANSI O5.1 – 2008.

INTRODUCTION

The long term demand for forest products, including paper and solid wood products, has resulted in improvement in silvicultural practices that increase both the growth rate and yield per acre of Southern Pine (SP) from SP plantations. While the increased rate of growth may be beneficial in terms of providing fiber for paper production, it can have detrimental impacts on strength properties for some solid wood products (Larson 2001).

SP poles account for more than 80% of all utility poles produced in the United States. Douglas Fir and Western Red Cedar account for most of the balance (Vlosky 2009). Utility poles are produced in accordance with a national standard, ANSI O5.1 – 2008. This standard is a visual grading standard that includes limitations on a variety of defects and physical characteristics, including rate of growth.

The ANSI O5.1 – 2008 standard contains strength values for the different wood species. The strength value is a modulus of rupture (MOR) in bending. For SP, the strength value is 8000 psi (ATIS 2008). This strength value is derived from data from full-sized cantilever testing of specimens in the green condition. The green test values are adjusted for oversize and worst-case conditioning effects to arrive at the published value. The values in the 2008 standards are considered to be mean strengths. The National Electrical Safety Code (NESC) references ANSI O5.1 for wood pole strength values (IEEE 2011).

In utility line design, cantilever loading is normally the controlling design criteria for lines designed to meet the requirements of the NESC, which is adopted by almost all states. In a cantilever load situation, the outer fibers of the pole see the highest stress. In fact, a circular cross section missing a center section equal to one-half the diameter has only lost 6.25% of its section modulus and therefore 6.25% of its bending strength.

The recent reduction in design strength values for SP lumber is associated with the exposure of juvenile wood of lower density and strength on the cut faces of dimension lumber. The Southern Pine wood pole industry, as represented by the Southern Pressure Treaters’ Association (SPTA), decided to undertake full-scale destructive testing of poles in order to address any uncertainty that may have been created by the change in lumber design values.

The objective of this research was to evaluate whether changes in the resource base for SP utility poles had resulted in reduced strength of the poles being produced today. Since juvenile wood is located in the center core of the stem and it is subjected to very low stresses in cantilever loading, the strength impacts found in testing of sawn lumber were not expected to be observed in testing of full-sized pole specimens.
MATERIALS AND METHODS

The ANSI O5.1 standard requires that full-sized testing be conducted in accordance with ASTM standard D1036 (ASTM 2012). This method involves simple cantilever loading of the specimen which is placed in a test fixture with the assumed pole groundline even with the upper support. The load is applied at a point two feet from the tip at a specified strain rate until failure occurs. The primary purpose of this testing of SP poles was to develop data on the modulus of rupture (MOR), so certain aspects of the test, such as defect mapping, were streamlined or omitted.

The first step of the study was to develop data on the growth rate of distribution poles from current production in order to assess the representativeness of the specimens ultimately provided for testing. This data on growth rate was also used for the computation of an estimate of expected strength of a representative sample based on data from earlier testing, and the correlation of strength and growth rate.

Ten pieces of 40-foot class 3 poles were obtained from each of ten commercial pole producers located throughout the production region. This class and length was selected because it is one of the most popular sizes, and its larger class circumference was more likely to reveal any impact from more rapid growth. The facilities that provided the test specimens were instructed to select the pieces from their recently peeled untreated pole inventory to ensure that the poles would be “green”, or above the fiber saturation point, as required by the test method. The locations of facilities providing test specimens included Arkansas, Texas, Louisiana, Northern Mississippi, Southern Mississippi, Southwestern Alabama, Southeastern Alabama, Georgia, South Carolina, and North Carolina.

Each participating facility was instructed to randomly select the 10 specimens from their existing inventory. The goal was to ensure there was no biased towards more dense material. In fact, the specimens from some locations were relatively uniform and all from fast grown stock. This is assumed to be reflective of the source of the raw materials being processed at the time by a particular facility. It would be expected that samples produced from one facility at different times would have different growth characteristics based on the source of the raw materials being processed at the time. Sampling from many sources throughout the growing region was intended to reduce the effect of any short-term temporal differences that may occur at an individual facility.

DISCUSSION

The initial phase of this study was the determination of the growth rate profile of the universe of SP distribution poles being produced today. This was accomplished by having facilities across the producing region conduct a survey of the existing inventory of both treated and untreated stock over a range of pole sizes. Facilities were asked to provide growth rate data on a random sampling of two classes of poles in each length from 30 feet through 50 feet. Data from over 1400 poles was provided. Figures 1 through 6 present the results of the growth rate study.

![Figure 1. 30' Poles – Pole Survey](image-url)
Figure 2. 35’ Poles – Pole Survey

Figure 3. 40’ Poles – Pole Survey
Figure 4. 45’ Poles – Pole Survey (2”)

Figure 5. 45’ Poles – Pole Survey (3”)

AWPA Proceedings Vol. 110, 2014

Page 4
Figure 6. 50’ Poles – Pole Survey

For each pole length, the observed rate of growth was higher for the larger diameter class. From this study an overall growth rate profile was developed. It was hypothesized that the growth rate profile could be used to develop an “expected” average strength value based on an analysis of the historic ANSI break test database sorted by growth rate. There was limited data on specimens with some of the more rapid growth rates, but the results of the analysis of the historic ANSI data did show a general increase in strength with slower rate of growth.

Figure 7 shows the growth rate profile of the existing production as determined from the recent data, and the regression equation for strength versus growth rate from the existing ANSI break test database. Combining the two produced an “expected” green MOR of 8870 psi if a sample matching the observed growth rate profile was tested. This value, when adjusted based on ANSI O5.1 minimum dimensions and a 15% reduction for conditioning, produced a value above the 8000 psi MOR value in Table 1 of ANSI O5.1 for SP. Therefore, it was anticipated that a truly representative sample of current production would provide results that showed that the current strength value was still valid.
As shown in Figure 8, the growth rate exhibited by the test specimens was higher than the average rate of growth for this pole size in the initial growth rate survey, so the results of this strength testing should be conservative.

Figure 8. 40 Class 3 Poles
The test specimens were randomly selected by the 10 producers participating in the study. Each producer was given a unique marking code to identify samples from that location. These sample codes were maintained as confidential. All samples were shipped by truck to the pole break test facility at Baldwin Lighting, Inc., in Bay Minette, Alabama. Baldwin Lighting had recently constructed a pole break test facility to test the pre-stressed concrete poles it produces, when required by its customers.

After all poles were received at the facility, they were individually inspected for conformance to the ANSI O5.1 standard and were assigned a specimen number between 1 and 100. Specimen numbers were randomly assigned.

An increment core from the surface to a depth of three inches was taken from each specimen at approximately three feet from the butt for determination of moisture content and dry density. Measurements of moisture content and density were made by Mississippi State University (MSU) personnel after transportation to the MSU Forest Products Laboratory. An increment core from one specimen was either not taken, or it was lost in transit. The average specific gravity of the samples was 0.5396 based on the dry weight and green volume of the cores, and this value is likely higher than would have been determined from a full cross section of the specimen. The average moisture content was 73.7% on a dry weight basis.

Each specimen was inspected for defects limited by the ANSI O5.1 standard. Several specimens had knots approaching, but still below, the maximum allowable in the standard. The face of each pole, as defined in the ANSI O5.1 standard, was marked on each pole. The circumference at six feet from the butt, at the tip, and at the load point 38 feet from the butt were measured and recorded for each specimen. Tree age, average growth rate, and summerwood percent, as observed in the butt, were recorded for each specimen. It should be noted that observed tree age was determined by counting growth rings in the butt and that the pole machine process may have removed several growth rings, resulting in a reported tree age several years lower than actual. Several specimens were identified as not meeting the growth rate requirements in the butt. The standard states that if these specimens met the growth rate requirement at six feet from the butt, the poles would be acceptable. It was decided to make the final determination of growth rate conformance at the time of the break test when a chainsaw would be available to cut the pole at six feet from the butt after the conclusion of the test. Ultimately, eight specimens were found to not meet the ANSI O5.1 growth rate requirements.

The cantilever break test was conducted in accordance with ASTM D1036. The poles were placed horizontally into the test fixture with the groundline aligned with the upper bracket and metal shims were inserted until the pole was reasonably tight. The actual contact with the pole surface was a wooden member as required by the ASTM standard. The wood member was not initially machined to a 6-inch radius as recommended by the standard, but it did adopt a shape conforming to the pole surface after only a few tests were completed. The poles were placed in the test fixture such that the load was applied perpendicular to the face of the pole in order to minimize rotational torque as specified in the test standard. Most of the poles were reasonably straight, and there were no issues observed with rotational torque during the test. The upper portion of the pole was supported on a dolly which rolled on an oiled metal surface to reduce friction to the minimum possible. The load was applied by an electric winch attached to a large front-end loader located behind a concrete barrier. The cable was run through a block to reduce the strain rate. Load was measured with a calibrated load cell with a remote readout so that the persons operating the winch and observing the load could be behind a concrete barrier for safety. Based on the pole dimensions and using the specified strain rate of 0.001 in./in.-min. and Equation 1 from ASTM D1036, the planned rate of loading was approximately 11 inches per minute. At this loading rate, failure was expected in 6 to 10 minutes. At defined load increments, the winch feed was stopped long enough to allow the necessary measurement and recording of load, horizontal displacement of the load point and longitudinal displacement of the load point. Longitudinal rotation of the pole butt in the test fixture was measured at a load of approximately 2000 pounds. Load was applied until failure and the maximum load was recorded. Notes were made regarding the type and location of failure and any other significant observations. A video recording was made of each test.

Most failures were tension failures initiating at, or near, the groundline as expected. Most of the failures were catastrophic in nature, although some specimens did not fail they simply continued to deflect without increasing load.

The data from each test was subsequently used to compute an actual modulus of rupture (MOR) and modulus of elasticity (MOE), based on the actual dimensions. The ASTM standard requires that the longitudinal movement of the load point be considered in the MOR calculations. The load point actually moves toward the butt as the pole deflects, and the observed and recorded transverse displacement must also be corrected to reflect the fact that the observed measurement is no longer perpendicular to the original axis of the pole. In addition, the transverse displacement measurements have to be corrected for the fact that the cribbing used in the fixture compresses as the load is applied, effectively allowing the pole to rotate longitudinally slightly about a point between the two support points in the fixture. This rotational deflection is removed from the corrected transverse displacement measurement before MOE computations are made. Figures 9 and 10 show how the change in geometry affects the observed measurements.
Once all of these geometric corrections were performed, the calculated green strength values for MOR for the 92 conforming pieces was 8770 psi based on actual groundline dimensions. Adjusting the observed values to the minimum class groundline dimension, which is used in line designs, the value becomes 9561 psi. The ANSI O5.1 strength derivation also includes a reduction depending upon the worst-case type of conditioning used for the species. For SP, the conditioning factor is 0.85 which is applicable to material that is steam conditioned. Application of this factor results in an ANSI O5.1 Table 1-equivalent MOR strength value of 8127 psi, which compares favorably to the 8000 psi value for SP presently found in Table 1 of the standard. Very few SP poles are steam conditioned today, so the use of this factor in calculating an average strength is conservative.
The primary focus of this study was the development of an MOR valued based on present production. However, measurements were also taken to enable the computation of an estimated modulus of elasticity (MOE) value. Butt rotation measurements were made at a transverse load of approximately 2000 pounds. After making the geometric corrections discussed earlier, the computed MOE value was $1.41 \times 10^6$ psi, based on actual dimensions and $1.86 \times 10^6$ psi based on class minimum dimensions. It is possible that at the load at which the MOE calculation was made, approximately 2000 pounds, the pole was stressed beyond the proportional limit, and therefore the actual MOE may be higher. However, since the measurement of butt movement in the test fixture was only made at this load, calculation of MOE at other loads could not be made without some assumption regarding what the butt movement was at that load. Development of an estimate of MOE was not the focus of this study, and the above values are similar to other published values for the species (EPRI 1985).

The results display some general trends regarding the relationship of MOR strength versus other pole properties. The data shows a positive trend of increasing strength with increasing tree age, increasing specific gravity, increasing MOE, and increasing number of rings per inch. These general trends are all in agreement with historic trends for SP wood products. These trends are evident on Figures 11 through 15.

![Figure 11. Groundline MOR Strength vs. Tree Age](image-url)
Figure 12. Groundline MOR Strength vs. Growth Rings in Outer 2 Inches

Figure 13. Groundline MOR Strength vs. Summerwood Percent
Figure 14. Groundline MOR Strength vs. Specific Gravity

Figure 15. Groundline Strength (MOR) vs Modulus of Elasticity (MOE)
On each of these figures, several data points are marked with colors. The three lowest strength poles are colored yellow. The pole with the highest number of growth rings in the outer two inches is red. The pole with the highest strength but meeting only the minimum growth rate requirements is amber, and the highest strength pole is violet. An examination of the figures will reveal that the specimen with the most rings per inch was only of average strength due to its low summerwood percentage. The strongest pole had 15 annual rings in the outer two inches and 50% summerwood. The strongest pole that met only the minimum growth rate properties of eight annual rings in the outer two inches with 50% summerwood was among the strongest poles tested and was only about 28 years old. The three weakest poles were all less than 25 years old with eight annual rings in the outer two inches with 50% summerwood present.

One disconcerting fact associated with the study was the fact that 8 of the original 100 specimens were found to not meet the growth rate limitations in the standard. The limitation in paragraph 5.1.4 of the standard refers to average rate of growth measured in the butt, or alternatively at six feet from the butt. However, the standard does not define how the average is to be obtained, and some of the more rapid growth poles did have non-uniform growth rates around the circumference. Based on the results of this study, a recommendation was made to the ASC O5 committee responsible for the ASNI O5.1 standard to provide clarity in the method for determination of the average growth rate. The ASC O5 committee has acted on this request, and it is expected that the new ANSI O5.1 will contain language that clearly defines how the average growth rate is to be determined. If the data from the 8 non-conforming pieces was included in the data set, the calculated ANSI-equivalent MOR would have been 7973 psi, which is essentially equal to the 8000 psi value in the standard.

It was also informative to note that none of the poles failed at a defect limited by the standard. Although no detailed defect mapping was accomplished as part of this study, the poles were inspected for conformance to the standard. Several poles were found to have knots near the upper limits in terms of individual knot sizes or the sum of all knots in a one-foot section. The fact that no pole failed at a defect provides subjective confirmation of the adequacy of the present defect limitations in the standard.

CONCLUSIONS

This study provided insight into the potential impact of the changing resource base used for the production of Southern Pine utility poles. The study did confirm that the average rate of growth of the poles being produced today is faster than that of the distribution poles included in the ASTM studies (Wood 1960), which became the basis of the strength values that have been in the standard since 1963 (Wood 1965). However, this study shows that rapid growth material with high summerwood percentages may be as strong as slower growth material with lower summerwood percentages.

The results of this study confirm that SP distribution poles being produced today still exhibit an MOR strength comfortably meeting the value of 8000 psi found in Table 1 of ANSI O5.1. The growth rate requirement in the standard continues to provide a basis that will ensure that the strength of the pole meets the expected value.

Future researchers may want to evaluate whether poles with as few as three rings per inch, but with a higher summerwood percentage, may provide adequate strength.

REFERENCES