# Impact of Growth Characteristics on Properties of 2 by 8 Southern Yellow Pine Structural Lumber

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## Abstract

Southern pine is one of the most important softwood resources in the United States, and the majority of southern pine is for lumber production, more specifically for construction. The lumber used for construction is required to meet strength-specifications as a method of ensuring the strength values within different classes. Most of the southern pine lumber is visually graded, which is based on knot, slope of grain, and wane. However, the presence of pith is not included in the visual grading system. The presence of pith indicates presence of juvenile wood, which has a negative effect on mechanical properties. The objective of this study was to evaluate the effect of pith on rings per inch, percentage of latewood, modulus of elasticity (MOE), and modulus of rupture (MOR) in 292 samples of southern pine No. 2 2 by 8 lumber. Lumber without pith had significantly greater MOE (11.1 vs. 10.0 GPa), MOR (39.7 vs. 36.4 MPa), and specific gravity (12% moisture content [MC]; 0.55 vs. 0.52) than did lumber with pith. The results show that the presence of pith is an important factor that can improve lumber grading, and it could be included in the visual grade system.

Wood is a biological material; consequently, its properties are influenced by a variety of factors that cannot be controlled. Genetics and various environmental factors interact in complex ways during the development of wood within a living tree. Knowledge of mechanical properties of wood and wood products such as lumber are essential for the proper and efficient use of this material. The major southern pines (*Pinus taeda*, *P. palustris*, *P. echinata*, and *P. elliottii*) are the principal components of what is referred to as the southern pine species group. The high utility, strength, stiffness, and treatability make the southern pine the most important group of species used for lumber in the Southeast (Gaby 1985).

Grading is necessary to minimize differences between the materials because of the variation within species. Mackay (1981) states that the purpose of grading rules is to maintain a standard value between mills manufacturing the same or similar woods while yielding a product with a uniform quality. Visual grading and machine grading are the two methods used to grade lumber. The use of these two methods allows a producer to make more efficient use of the available lumber source.

Visual grading method is the most commonly used technique to grade structural lumber, and it determines the allowable design values that are assigned to various grades. Visual grades are based on the properties of clear wood from the species grouping, and the estimated effect of various growth and manufacturing defects on the strength of lumber products from these species (Montero et al. 2011). This type of classification can be made by a manual operation or an automatic grading system.

The design properties associated with stress grades are edgewise bending modulus of elasticity (MOE), tensile strength, compression parallel to the grain, compression perpendicular to the grain, shear parallel to the grain, and extreme fiber stress in bending. In order to ensure that structural lumber conforms to allowable engineering design property values, these values are

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Table 1.—Summary of old and new design values of southern pine No. 2 2 by 8 lumber (ALSC 2013).

| Mechanical property | Calculated from | Old design value (2012) | New design value (2013) |
|---|---|---|---|
| Stiffness (Modulus of elasticity) | Mean | 11.0 GPa | 9.7 GPa |
| Bending strength (Modulus of rupture) | Nonparametric fifth percentile at 75% confidence | 10.0 MPa | 7.6 MPa |

measured or inferred through nondestructive evaluation processes such as visual grading criteria, nondestructive tests such as flat-wise bending stiffness or density, or a combination of these methods (Kretschmann 2010, Ross 2015).

Tests of a representative sample of full-size members or small-clear specimens are the methods used to establish the mechanical properties of visually graded lumber. In the United States, the design properties for the major commercial lumber species groups use a mix of these two methods. For example, the current design specification and codes for softwood dimension lumber species are derived from full-size member test results using ASTM D 1990 Standard Practice for Establishing Allowable Properties for Visually-Graded Dimension Lumber from In-Grade Tests of Full-Size Specimens (ASTM 2014a). On the other hand, tests on small-clear samples and standard ASTM D 245 Standard Practice for Establishing Structural Grades and Related Allowable Properties for Visually Graded Lumber (ASTM 2011) are still used to derive design properties for most hardwood dimension and structural timbers (Shelley 1989, Green and Kretschmann 1991, Antony et al. 2015).

Presence of pith is an easy and fast method for identification of juvenile wood and previous studies have shown that lumber containing pith consequently has high volume of juvenile wood, resulting in lumber with lower mechanical properties (Moody 1970, Winandy and Boone 1988, Kretschmann and Bendtsen 1992, Tong et al. 2009, Dahlen et al. 2014b). This study aims to investigate the impacts of presence of pith on the mechanical properties of structural southern pine No. 2 2 by 8 lumber.

## Materials and Methods

### Test material

Southern yellow pine (SYP) visually graded No. 2 2 by 8 lumber was used in this study. A total of 292 pieces of SYP lumber were sampled randomly from 18 southern pine growth region boundaries (Jones 1989) and pieces were graded either by Southern Pine Inspection Bureau (SPIB) or Timber Products Inspection (TP). No. 2 grade was selected because it represents the majority of SYP lumber grade produced. To ensure that boards were No. 2 grade, the grades were reassessed by certified graders from SPIB or TP.

### Specimen preparation and testing

Variables recorded were presence of pith, dimensions, weight, specific gravity, and moisture content (MC). Following Southern Pine Grading Rules (SPIB 2014), percentage of latewood and rings per inch of each board were also collected from both ends of each piece.

The edgewise bending testing occurred according to ASTM D 198-14 (2014b) via third-point loading on an Instron Satec testing machine. The specimens were loaded randomly to better represent the actual use. The randomized placement of samples was adopted to have a better understanding of the material. The bending test values were obtained for all lumber pieces via four-point static tests in edgewise direction using a span-to-depth ratio of 17:1 per ASTM D 198-21, where the span was 3.99 m. The rate of the load was 0.3 inches/min. Procedure followed ASTM D 4761-19 (ASTM 2019). The deflection was measured by Tinus Olsen deflectometer to determine MOE. MOR was calculated from the maximum load.

The adjustments of each piece, for MOE to standard loading conditions, was made according to ASTM D 1990 (2014a), ASTM D 2915 (2010), and Evans et al. (2001), then adjusted to 15 percent MC, and adjusted to third-point uniform loading. The MOR of each sample was adjusted to 15 percent MC according to ASTM D 1990 (2014a). To calculate fiber stress in bending (Fb; the higher the value, the stronger the wood), the dimensions of each was adjusted to 15 percent MC and then adjusted to a characteristic length of 3.66 m and divided by 2.1 safety factor according to ASTM D 1990 (2014a) and Evans et al. (2001). The specific gravity (SG) was calculated based on weight, dimensions, and MC of each piece, then adjusted to 15 percent MC.

### Statistical analysis

SAS 9.2 software (2013) was used to run statistical analysis and associated graphs, following ASTM D 2915 (2010). In addition, mean, median, standard deviation, and coefficient of variation (COV) for rings per inch, percent of latewood, SG,

Table 2.—Effect of pith on rings per inch (RPI), percentage of latewood, specific gravity (SG), modulus of elasticity (MOE), modulus of rupture (MOR), and nonparametric fifth percentile bending strength ($F_b$) at 75 percent confidence on mean and coefficient of variation (shown in parenthesis) in No. 2 2 by 8 southern pine lumber adjusted to 15 percent moisture content.

| | RPI | Latewood (%) | $SG_{15}$ | $MOE_{15}$ (GPa) | $MOR_{15}$ (MPa) | $F_b$ (MPa) |
|---|---|---|---|---|---|---|
| Overall | 4.4 (61%) | 42.5 (25%) | 0.54 (10%) | 10.6[a] (24%) | 38.2 (37%) | 9.5[b] |
| No pith | 5.3 (55%) | 45.8 (23%) | 0.55 (11%) | 11.0[a] (24%) | 39.3[c NS] (40%) | 9.3[b] |
| Pith | 3.3 (29%) | 37.5 (22%) | 0.52 (9%) | 10.0[d] (22%) | 36.4 (30%) | 9.9[e] |

[a] Indicates MOE value met 2011 design value (11.0 GPa) after rounding to nearest 0.7 GPa (ASTM D 1990 2014a).
[b] Indicates $F_b$ value met 2013 design value (7.6 GPa) after rounding to nearest 0.3 GPa (ASTM D 1990 2014a).
[c NS] Indicates no statistically differences for lumber that contained pith and lumber that did not contain pith.
[d] Indicates MOE value met 2013 design value (9.7 GPa) after rounding to nearest 0.7 GPa (ASTM D 1990 2014a).
[e] Indicates $F_b$ value met 2011 design value (10.3 GPa) after rounding to nearest 0.3 GPa (ASTM D 1990 2014a).

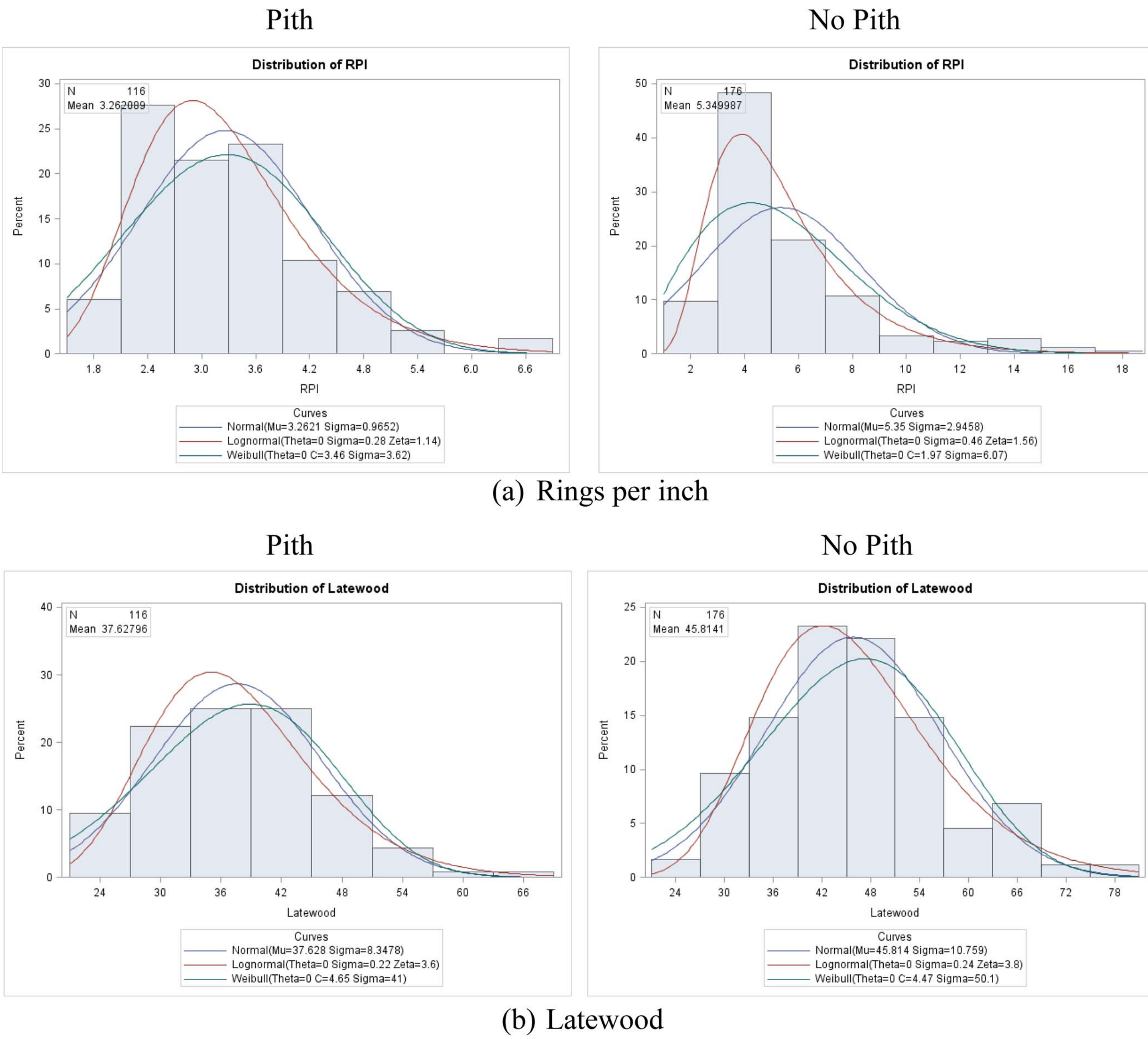


*Figure 1.—Normal, lognormal, and Weibull best fit of lumber that contained pith (n = 116) and lumber without pith (n = 176): (a) rings per inch; (b) percentage of latewood.*

MOE, and MOR for overall samples, and for samples with and without pith, were determined using the PROC UNIVARIATE. The significant differences for rings per inch, percent of latewood, SG, MOE, and MOR in samples with or without pith were found using PROC GLM at 0.05 significance level. The distribution that best fit rings per inch, percent of latewood, SG, MOE, and MOR was tested for goodness of fit using the Cramer–von Mises (CVM-sim) with normal, lognormal, and Weibull distribution selected using PROC UNIVARIATE and the histogram option in SAS. Statistical analyses and associated graphs were created following procedures from standard D 2915 (ASTM 2010).

## Results and Discussion

A comparison for the old and new design values of southern pine No. 2 2 by 8 lumber is presented in Table 1. Overall, 40 percent of the samples contained pith ($n = 116$). The number of rings per inch and percentage of latewood was significantly higher ($P < 0.0001$) for boards that did not contain pith (Table 2). Samples without pith had 40 percent greater number of rings per inch and 18 percent greater percentage of latewood. The lognormal distribution fit the rings per inch and percentage of latewood data better than did normal and Weibull distributions (Fig. 1). The boxplots reinforce the fact that boards that contained pith had significantly lower mean value for rings per inch and percent of latewood than did boards that did not contain pith (Fig. 2).

The mean for overall samples and pieces that did not contain pith met the SPIB (2014) requirements of mean value for rings per inch and percent of latewood. However, boards with pith did not meet these criteria. The coefficient of variation of rings per inch and percent of latewood for samples

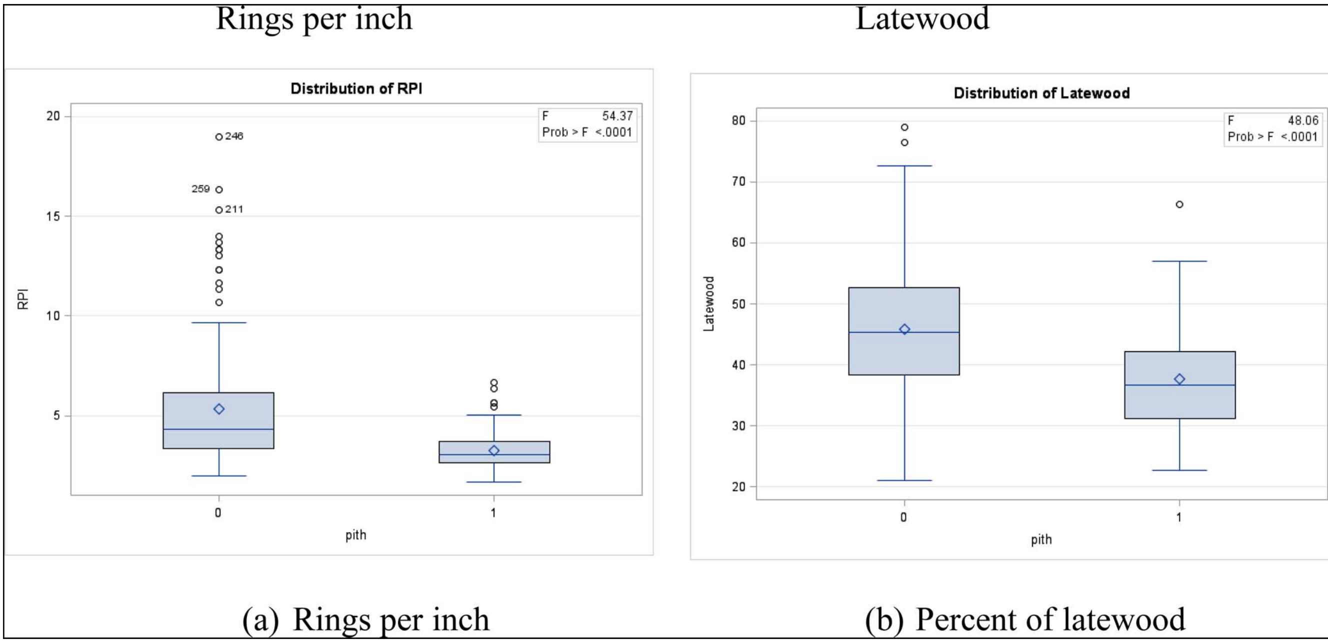


*Figure 2.—Boxplots of lumber that contained pith (n = 116) and lumber without pith (n = 176): (a) rings per inch; (b) percentage of latewood.*

without pith were lower than for samples with pith. Wood located near to the pith has wide rings per inch and high percentage of juvenile wood (Shottafer et al. 1972), and the number of rings per inch and latewood percent increase as the distance from the pith decreases (Shumway et al. 1971).

The overall SG of 2 by 8 No. 2 southern pine was 0.54, and samples without pith met the minimum SG required for southern pine lumber (SPIB 2014). The SG of boards without pith was significantly higher than for boards without pith. The lognormal distribution best fit the SG data. The histogram and boxplots of SG for lumber that contained and did not contain pith are shown in Figures 3 and 4. Lumber without pith was 5 percent greater SG than was lumber with pith (Table 2). A previous study found an average SG of 0.50 for pith wood in southern pine (Dahlen et al. 2014a), which is lower than values found in this study. This is explained by the greater presence of radial pieces; 2 by 8 lumber is mostly cut from small-diameter logs, so this type of lumber contains the pith but also mature wood on the ends of its width, elevating the SG.

The SG for all samples tested was characteristic of mature wood specific gravity (Zobel et al. 1972). The SG of mature wood of southern pine ranges from 0.46 to 0.62 (Zobel and McElwee 1958, Koch 1972, Megraw 1985), and the values found in this study are within this range. These results are also comparable to the SG value in the Wood Handbook value for loblolly pine (0.5) when adjusted to 15 percent MC.

The overall MOE of 2 by 8 No. 2 southern pine was 10.6 GPa. The overall samples and sample without pith (11.0 GPa) met the actual and the old design values; however,

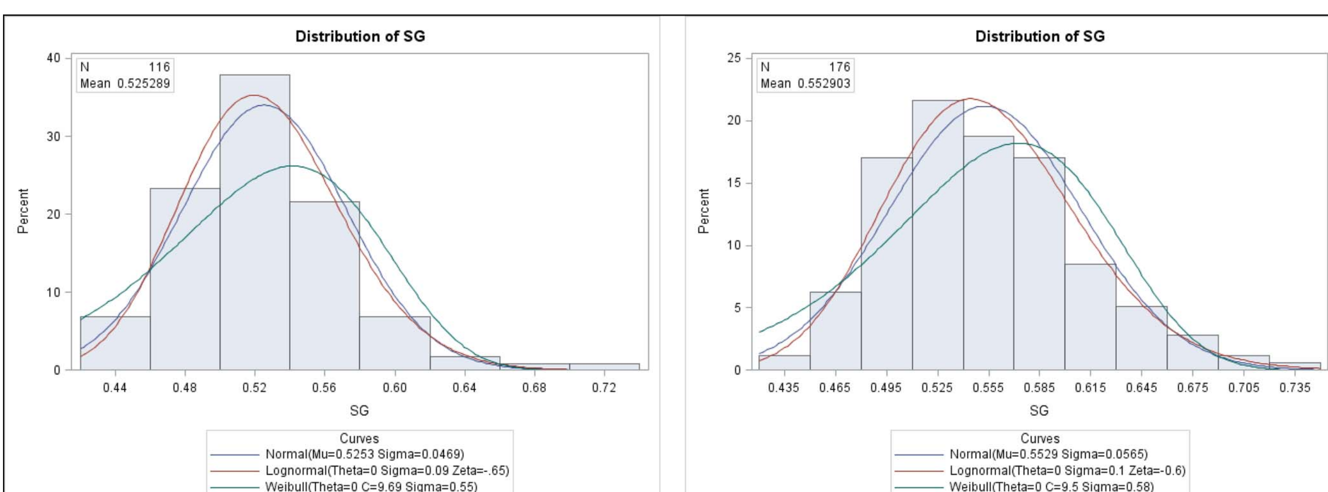


*Figure 3.—Normal, lognormal, and Weibull best of fit of specific gravity ($SG_{15}$) with lumber that contained pith (n = 116) and lumber without pith (n = 176).*

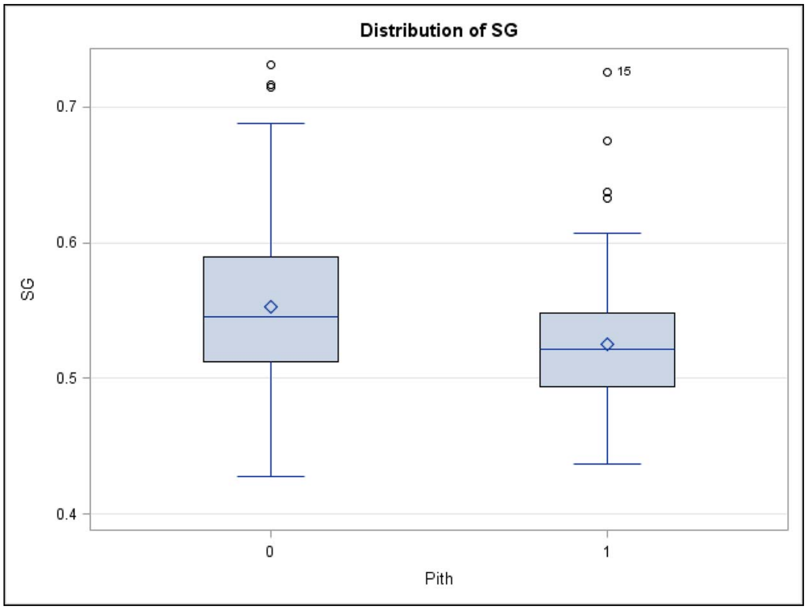


*Figure 4.—Boxplot of specific gravity ($SG_{15}$) for lumber that contained pith (n = 116) and lumber without pith (n = 176).*

lumber with pith met only the new design value of southern pine No. 2 lumber. Lumber without pith had 9 percent greater stiffness than did samples with pith, and the difference was significant ($P < 0.0001$; Table 2). Lumber with pith showed less variation than did lumber without pith, (COV of 22% vs. 24%). The histogram and boxplots reinforce the significant difference between lumber with pith and without pith (Figs. 5 and 6).

The results of this study were lower compared with No. 2 2 by 8 lumber from a 50-year-old loblolly pine plantation (12.4 GPa) reported by Biblis and Carino (1999), and clean wood average value of southern pine (12.1 GPa) reported by Bendtsen et al. (1972 [revised 1975]). The results were slightly lower than the results found by Biblis et al. (1995) for 2 by 8 No. 2 lumber from a 35-year-old loblolly pine (10.3 GPa) plantation. However, the lumber without pith had similar stiffness properties to No. 2 2 by 8 southern pine lumber (11.0 GPa) reported by Biblis et al. (1997) from two 40-year-old loblolly pine plantations, and to a previous test on southern pine Grade No. 2 2 by 8 lumber (11.0 GPa) found by Dahlen et al. (2014a). The results were also consistent with findings reported by Doyle and Markwardt (1966).

The overall MOR of 2 by 8 No. 2 southern pine was 38.2 MPa. Lumber that did not contain pith had a slightly higher mean value than did lumbar that contained pith (39.3 MPa vs. 36.4 Mpa); however, there was no statistically significant difference in MOR between samples that contained and did not contain pith (Table 2). The lognormal distribution best fit the $MOR_{15}$ for samples without pith and the Weibull distribution best fit the $MOR_{15}$ for samples with pith. The histogram and boxplots for $MOR_{15}$ with boards that contained and did not contain pith are shown in Figures 7 and 8. For the overall data, the bending strength (9.5 MPa; Table 2)

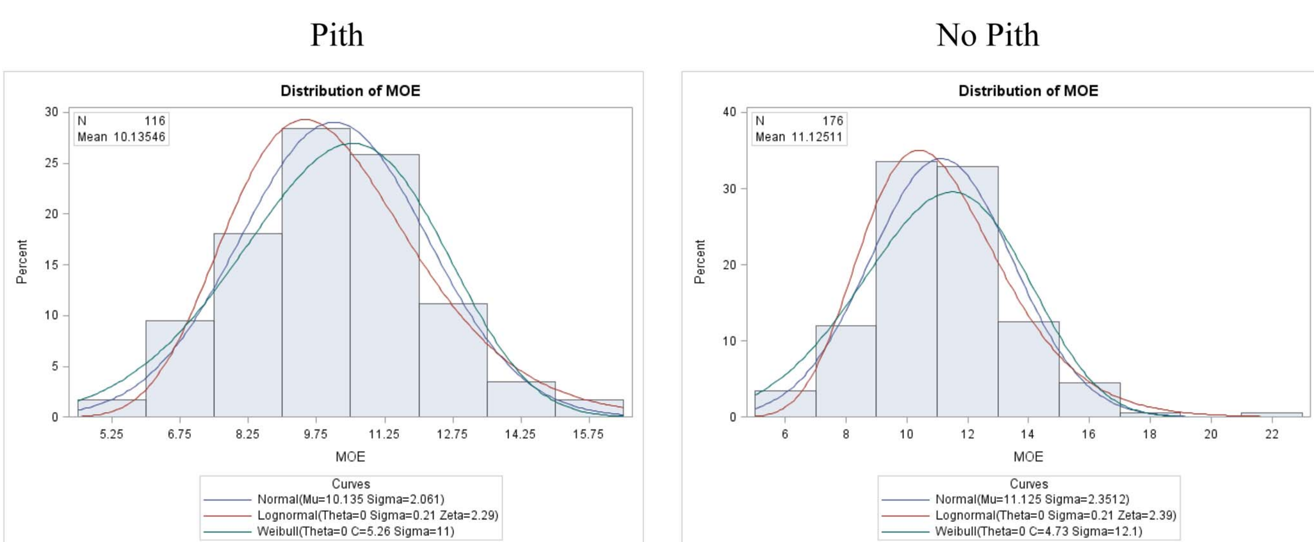


*Figure 5.—Normal, lognormal, and Weibull best of fit of modulus of elasticity ($MOE_{15}$) with lumber that contained pith (n = 116) and lumber without pith (n = 176).*

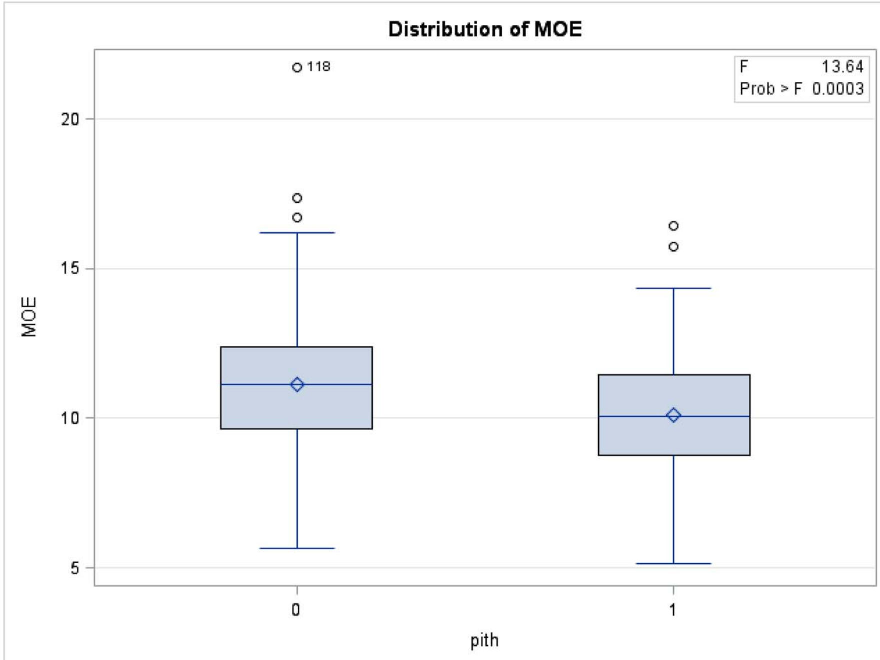


*Figure 6.—Boxplot of modulus of elasticity ($MOE_{15}$) for lumber that contained pith (n = 116) and lumber without pith (n = 176).*

was lower than the old design value (10.3 MPa) but greater than the new design value (7.6 MPa).

The results of all samples of this study (overall, and pieces with and without pith) had a lower MOR compared with clean wood MOR value of southern pine (50.3 MPa) reported by Bendtsen et al. (1972 [revised 1975]) and Doyle and Markwardt (1966; 41.5 MPa), and comparable to the results found by Biblis and Carino (1999) on No. 2 2 by 8 lumber from a 50-year-old loblolly pine plantation (44.1 MPa). The results were higher compared with results found by Biblis et al. (1995) for 2 by 8 No. 2 lumber from a 35-year-old loblolly pine (28.9 GPa) plantation, and No. 2 2 by 8 southern pine lumber (35.0 MP and Fb 11.4 MPa) reported by Biblis et al. (1997) from two 40-year-old loblolly pine plantations. Comparing with a previous study made by Dahlen et al. (2014a) the MOR (40.5 MPa) was lower, but the Fb (8.8 MPa) was higher, for all samples.

The bending strength results indicate that samples with pith had a higher Fb than did samples without pith (9.9 MPa vs. 9.3 MPa; Table 2). Another interesting finding is that only samples with pith met the old design value (10.3 MPa) after rounding 0.3 MPa (ASTM 2014a), which reinforces that pith has no significant effect on $MOR_{15}$ and Fb.

In comparison with a previous study in No. 2 2 by 4 southern pine lumber (Dahlen et al. 2014b), the effect of pith on SG (14% vs. 5%), stiffness (35% vs. 9%), and strength (49% vs. 7.6%) was greater than in No. 2 2 by 8 lumber. It shows that pith has an effect on lumber properties

Pith | No Pith

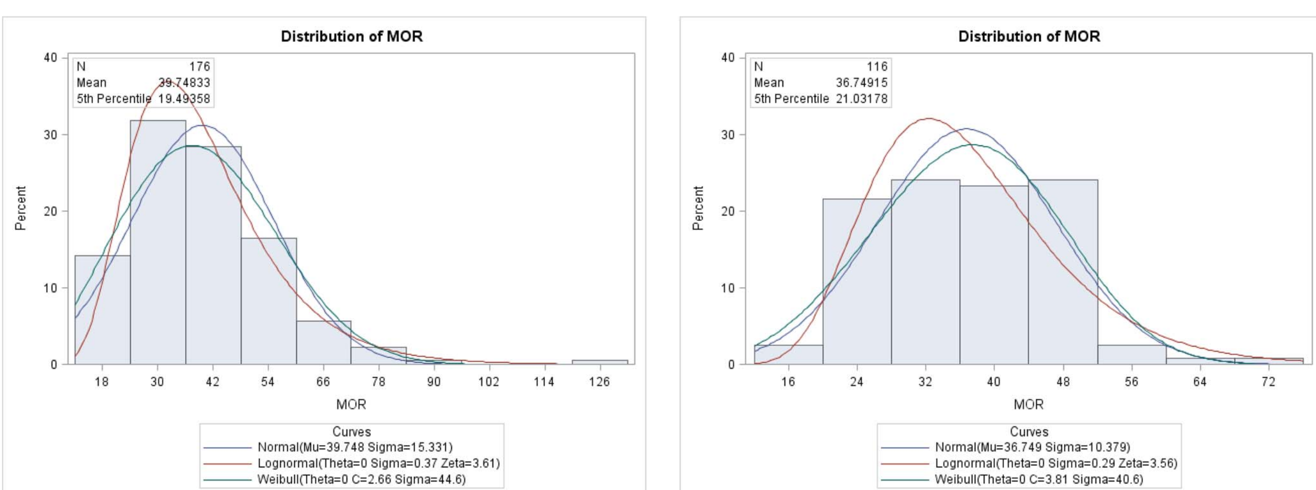


*Figure 7.—Normal, lognormal, and Weibull best of fit of modulus of rupture ($MOR_{15}$) with lumber that contained pith (n = 116) and lumber without pith (n = 176).*

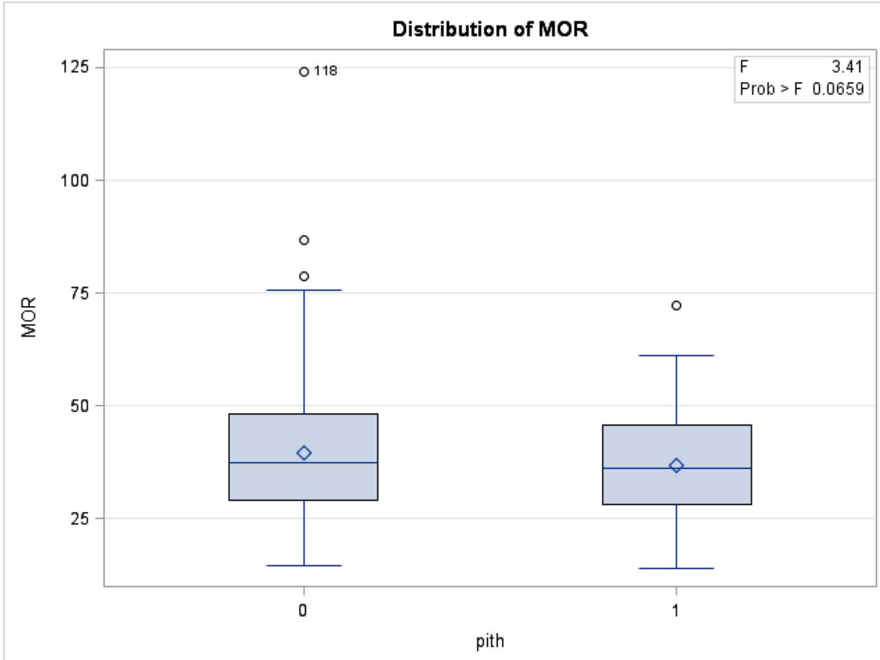


*Figure 8.—Boxplot of modulus of rupture ($MOR_{15}$) for lumber that contained pith (n = 116) and lumber without pith (n = 176).*

in 2 by 8 boards, but does not have the same impact that it has in 2 by 4s. The presence of pith had no effect on MOR, which indicates that MOR is more related to other types of reducing defects such as size of the knot. Dahlen et al. (2013) point out that MOR can vary according to knots, grain, and skip. Boards with pith, which is an indicator of juvenile wood, may contain some proportion of mature wood that makes the boards been almost as strong as the board without pith. In addition, in most of the samples the pith was located in the middle of the boards, which is a neutral axis, and it has zero stress.

## Conclusions

It was possible to evaluate the effect of pith on mechanical properties, and the results show that pith can be a feasible way to identify pieces with lower strength and stiffness. Lumber that did not contain pith had a significantly greater number of rings per inch and percent of latewood. The results also indicate that lumber without pith was significantly higher in specific gravity (SG) and stiffness (MOE). However, there was no significant difference in pieces with and without pith in terms of strength (MOR). An interesting result was for bending strength (Fb), where lumber with pith was higher in bending strength than was lumber without pith, which reinforces that pith does not have a significant effect on strength properties.

The effect of pith on southern No. 2 2 by 8s was different compared with a previous study of southern No. 2 2 by 4s, where in 2 by 4s the effect of pith was significant for stiffness and strength. This may indicate that even boards with pith and a higher percentage of juvenile wood may contain some proportion of mature wood. The presence of mature wood makes the boards with pith as strong as the board without pith. Furthermore, most of the time pith appeared in the middle of the boards, which is a neutral axis, and it has zero stress and no effect on strength.

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