# Probability Distributions of Portuguese Maritime Pine Strength

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Strength data of Portuguese maritime pine which has been gathered in 1990 has been combined in a data set. The data has been analysed for mechanical properties such as bending strength, modulus of elasticity as well as density. Visual grades have been determined using the Portuguese standards (NP4305) and were analysed for their strength profiles. Normal, lognormal and Weibull distributions have been determined and compared to the dataset.

## 1. Introduction

In 1990 strength data was gathered in different material sizes. Strength profiles have been determined in accordance with European standards EN384 and the standards used for testing followed EN408.

Characteristic values and the strength profiles of the subsamples have been determined and the scatter in mean and characteristic values for bending strength, modulus of elasticity and density were analysed statistically.

| Sample | Year | No. | Sizes | | |
|---|---|---|---|---|---|
| | | | Width (mm) | Depth (mm) | Length (mm) |
| 1 | 1990 | 291 | 40 | 100 | 2000 |
| 2 | 1990 | 310 | 50 | 150 | 3000 |

Table 1- Samples of Portuguese Maritime Pine

## 2. Visual Grades

According to Portuguese standard NP4305 two grades (EE and E) and reject (R) were considered. The characteristic density values for strength classes EE and E are 490 and 460 kg/m3. Mean values are approximately 25% higher. The characteristic values for the modulus of elasticity for classes EE and E are 9.38 and 8,0 kN/mm2. Mean values are 50% higher. The MOR characteristic values for classes EE and E are 35 and 18 N/mm2. The test results database can be provided by the authors.

| No. | Width | Depth | | EE | E | R | Whole |
|---|---|---|---|---|---|---|---|
| 1 | 40 | 100 | n | 67 | 177 | 47 | 219 |
| | | | % | 23 | 61 | 16 | 100 |
| 2 | 50 | 150 | n | 48 | 214 | 48 | 312 |
| | | | % | 15 | 70 | 15 | 100 |

Table 2- Visual grades and yield for each subsample

## 3. Test Results

If all samples are regarded as one the dataset contains more than 620 test results. Statistical coefficients have been determined for this basic data as well as the graded data and are gathered in Tables 3 and 4, respectively.

| Property | Density | MOE | MOR |
|---|---|---|---|
| Average | 587 | 12048 | 52.0 |
| Standard Deviation | 75 | 3606 | 22.2 |

Table 3- Basic Properties of Ungraded Maritime Pine

| | | | Density $kg/m^3$ | | Modulus of Elasticity $N/mm^2$ | | Bending Strength $N/mm^2$ | |
|---|---|---|---|---|---|---|---|---|
| Grade | n | % | Average | St.dev | Average | St.dev | Average | St.dev |
| EE | 115 | 19 | 619 | 72 | 13857 | 3485 | 72.0 | 16.3 |
| E | 391 | 65 | 589 | 74 | 12157 | 3362 | 52.0 | 20.1 |
| R | 95 | 16 | 537 | 53 | 9411 | 3209 | 29.4 | 12.9 |

Table 4- Basic Properties for Maritime Pine

In table 5 the correlation coefficients between the different parameters are given[1]. They are approximately the same, although the effect of the bending strength on the modulus of elasticity is higher.

| Property | Density | Modulus of Elasticity | Bending strength |
|---|---|---|---|
| Density | 1.0 | | |
| Modulus of elasticity | 0.56 | 1.0 | |
| Bending strength | 0.59 | 0.62 | 1.0 |

Table 5- Correlation coefficients

The existence of a depth effect has been studied by fitting a power-equation to the basic data. The depth effect could be described using the following relationship:

$$k_h = \left(\frac{150}{h}\right)^{0.2142}$$

## 4. Frequency distributions and characteristic values

For the three grades (data adjusted for the depth effect) as well as for the full (ungraded) dataset, the distribution functions have been determined. In all cases it was found that Weibull and Normal distributions described the data better than log-normal distributions[2]. The parameters of the distributions have been gathered in Table 6. In figures 1 and 2 the data and the distributions are shown. The cumulative frequency distributions of the three grades are shown in figure 3.

| | Normal | | Lognormal | | Weibull (2-parameter) | |
|---|---|---|---|---|---|---|
| Dataset | m | s | m | s | m | v |
| All data | 52.0 | 22.2 | 3.85 | 0.49 | 58.6 | 2.51 |
| Grade EE | 72.0 | 16.3 | 4.25 | 0.24 | 78.4 | 5.05 |
| Grade E | 52.0 | 20.1 | 3.86 | 0.42 | 58.4 | 2.81 |
| Reject | 29.4 | 12.9 | 3.28 | 0.46 | 33.2 | 2.43 |

Table 6- Distribution parameters of Portuguese Maritime Pine

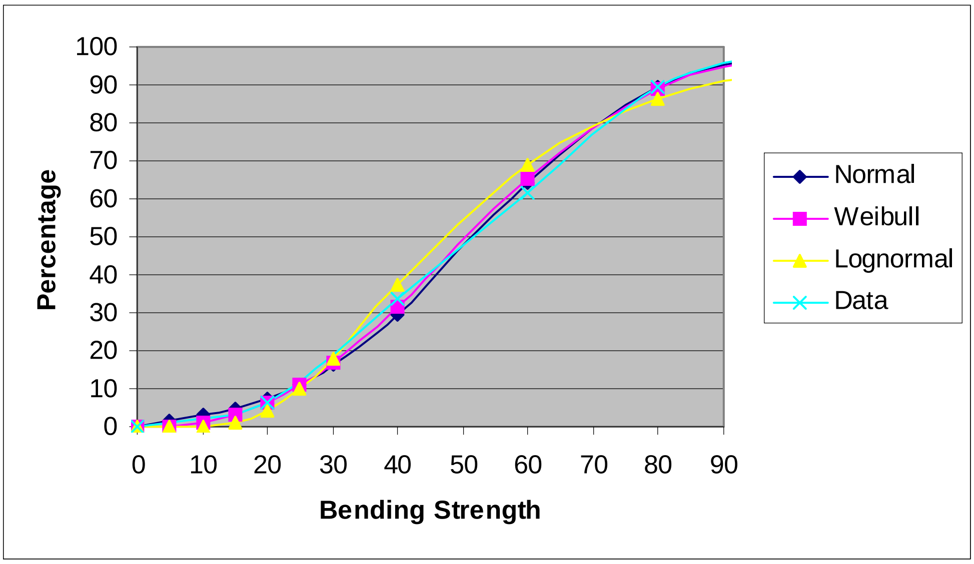


Figure 1 – Full distribution of Portuguese maritime pine bending strength data

From the lower tail shown in Figure 2 it can be concluded that Normal and Lognormal give an over and underprediction of the 5-th percentile value of the strength data whereas the two-parameter Weibull distribution is close to the bending strength data.

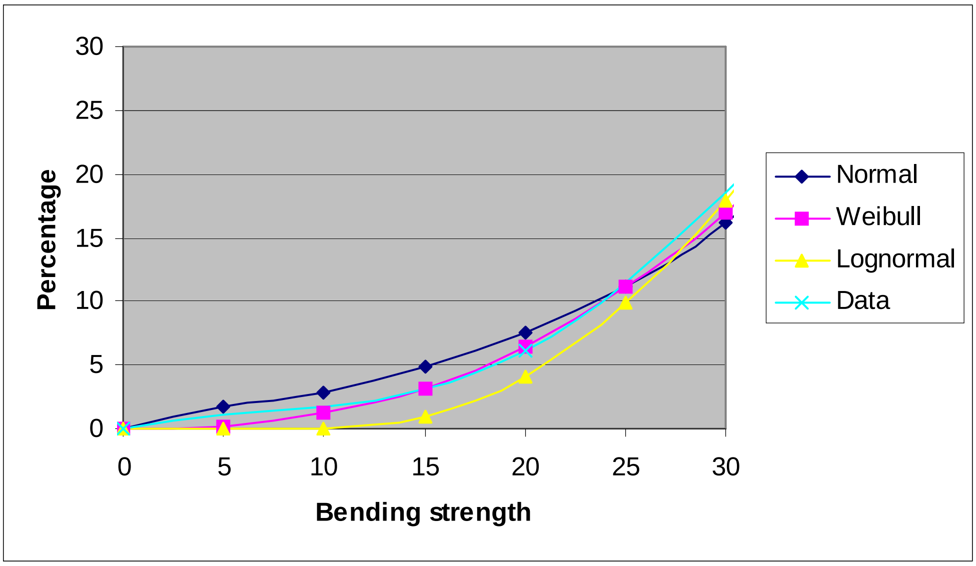

Figure 2 – Lower table of Portuguese maritime pine bending strength data

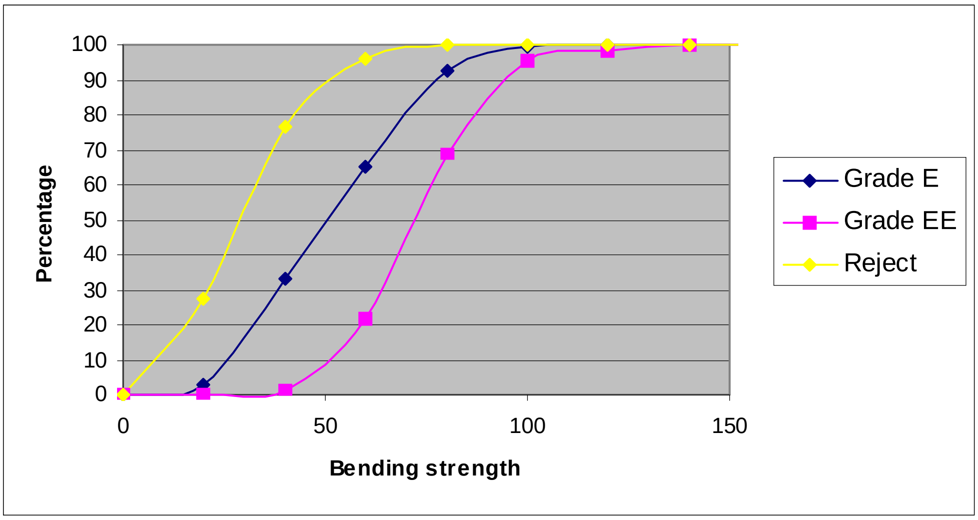

Figure 3 – Cumulative frequency distributions of grades EE, E and Reject

## References


1. Ang AHS, Tang,WH (1975), Probability Concepts in Engineering Planning and Design, Vol I, J.Wiley.
2. Ang AHS, Tang,WH (1984), Probability Concepts in Engineering Planning and Design, Vol II, J.Wiley, 1984.