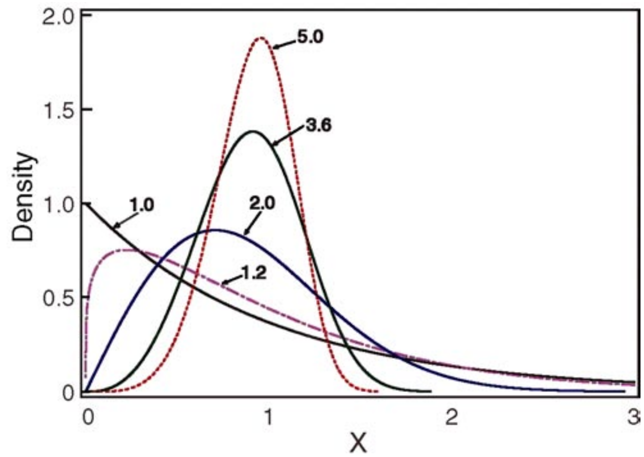
Research in Progress
Forest Products Laboratory

Using the Weibull Distribution to Estimate Lumber Properties

Results of mechanical tests on lumber, wood composites, and wood structures are often summarized by a distribution function fit to the data. This fitted distribution can then be used in calculating properties based on percentiles of the data, in reliability-based design calculations, or in simulations of the performance of wood structures. The Weibull distribution (named after Waloddi Weibull, a Swedish physicist who used it in 1939 to describe the breaking strength of material) is playing an increasingly important role in this type of research and has become a part of several American Society of Testing and Materials (ASTM) standards. Its popularity with researchers is due in part to one of the parameters—the shape parameter—which allows it to look like a variety of other distributions, such as the normal, lognormal, and exponential distributions. The figure illustrates how the shape of the distribution changes as the shape parameter changes. This flexibility to model experimental results makes the Weibull distribution a powerful tool for Forest Products Laboratory (FPL) researchers as they work on projects designed to meet major Forest Service goals, such as improved utilization of wood from small-diameter trees.



Weibull density functions for different shape parameters.

Background

To summarize research results and get property estimates or simulation results needed in wood utilization research, the distribution fitted to the data must offer several capabilities. These capabilities can be grouped into six categories:

1. Methods must be available to fit the distribution to a data set and provide statistically sound estimates of the parameters of the distribution that uniquely define the distribution, such as the mean and variance of a normal distribution. A great deal of research has been published in the statistical literature on this question. However, the effect that different ways of estimating a parameter has on estimating lower tail percentiles from censored data has not been widely researched. This information is needed for many types of wood research.
2. The variability of parameter estimates needs to be known for any type of estimation procedure used. This is especially important if the fitted

distribution is going to be used in simulations of the structural performance of wood assemblies and if the estimates come from censored data. Again, the statistical literature has focused primarily on complete samples.

3. We need to be able to estimate percentiles of the population from the fitted distribution and provide tolerance limits and confidence intervals for these estimates. FPL research has developed such procedures for complete data sets. Work is needed to extend this to censored data sets and to compare FPL methods to some other methods that have been suggested.
4. After fitting the distribution to a data set, we need to know how to evaluate if it really fits the data or is an inappropriate distributional form for the data. FPL research has developed these goodness-of-fit tests for complete data sets. This needs to be extended to censored data sets.
5. A computer program with user manual needs to be readily available for researchers to get the information discussed in categories 1 to 4 for both complete and censored data sets. FPL has written such a program for complete data sets, but it needs to be documented. An extension to censored data sets will require completion of the research discussed in each category.
6. Because mechanical properties of lumber are often related in some way to each other (for example, specimens with above-average bending strength often have above-average tensile strength), the distributions should be expandable to at least two variables with some type of relationship between them. This bivariate distribution is especially needed for simulations of the performance of specimens under combined loading situations. Initial work on a bivariate Weibull distribution has been done at FPL, but the theoretical form of such a distribution must be evaluated using real data. This will require looking at aspects of categories 1 to 5 above for the bivariate case for both complete and censored samples.

Objective

The objective of this study is to develop capabilities for the Weibull distribution that allow it to be a more powerful and readily available tool for researchers working on improved wood utilization.

Approach

The approach to developing new capabilities for the Weibull distribution is a mixture of theoretical statistical development and computer simulations. Methods of estimating tolerance limits, goodness-of-fit, and other aspects of the Weibull distribution usually begin with theoretic development of possible solutions. However, these solutions often need to be verified or critical values for tests need to be found through extensive computer simulations. For example, tests of the goodness-of-fit for a Weibull distribution fit to a complete data set can be developed theoretically. However, the critical values for such a test depend upon the shape parameter and the sample size. This requires extensive computer simulations to develop the critical value and then statistical modeling of the critical values to provide a method of predicting the critical values for any combination of sample size and shape parameter.

Expected Outcomes

Results of this research will provide a powerful tool that can be used to improve our ability to summarize wood utilization research results, provide improved estimates of material properties used to design wood structures, and allow more realistic simulations of wood performance in structural applications. The results should also affect ASTM standards on wood properties and design.

Timeline

Research results are expected periodically over the period from June 2003 through the end of 2007.

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