Elastic Limit: Strength Properties of Living Trees

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In developing assessments for stability of standing trees, a number of physical and visual techniques can be used. One assessment technique is a ìpulling testî where a cable winch is attached to the tree. The force used to pull on the tree is measured and recorded. Trees are not pulled until failure. Small, finely tuned length measuring devices (elastometers) are placed on the tree trunk, especially around or over visible faults. The elastometers provide information to the assessor regarding impending fiber failures.

Elastometers measure the change in length of wood fibers closest to the stem surface just below the bark. When these measuring devices show an approach to the elastic limit, the cable pressure is gently and slowly released. The amount of force needed to approach the elastic limit will vary by each individual treeís structural condition. This assessment process can be used to estimate tree stability and to derive the wind load which could lead to catastrophic failure.

To complete this type of assessment process, it is critical to estimate in advance the elastic limit of a particular tree species. The easiest means to estimate the elastic limit for a tree is to use published wood mechanical property tables where many samples from any species were tested. The test samples are small, clear, straight-grained wood blocks taken from living trees and still in a green, undried condition. Testing provides an estimate across a tree species. Each individual tree will vary from their species value.

The wood mechanical property terms used here are: Modulus of Elasticity (MOE) measured in mega-pascals; Maximum Crushing Strength which is the compressive force applied parallel to the wood grain in mega-pascals; and, the Elastic Limit which is a percent (usually less than 1/3 of one percent) calculated by dividing Maximum Crushing Strength of the sample by its MOE. Note the Elastic Limit listed below has been corrected for shear deflection in the test samples (i.e. Elastic Limit X 0.91).

Scientific & Common Tree Name	Modulus of Elasticity (MPa)	Maximum Crushing Strength (MPa)	Elastic Limit (%)
Acer rubra red maple	9,600	22.6	.22
Acer saccharinum silver maple	6,500	17.2	.24
Acer saccharum sugar maple	10,700	27.7	.24
Carya spp. hickory	10,600	30.8	.26
Carya glabra pignut hickory	11,400	33.2	.26
Carya ovata shagbark hickory	10,800	31.6	.26
Carya illinoensis pecan	9,400	27.5	.26
Carya tomentosa mockernut hickory	10,800	30.9	.26

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Scientific & Common Tree Name	Modulus of Elasticity (MPa)	Maximum Crushing Strength (MPa)	Elastic Limit (%)
Celtis occidentalis hackberry	6,600	18.3	.26
Chamaecyparis thyoides Atlantic white cedar	5,200	16.5	.29
Fagus grandifolia American beech	9,500	24.5	.24
Fraxinus spp. ash	9,800	28.3	.26
Fraxinus americana white ash	9,900	27.5	.26
Fraxinus pennsylvanica green ash	9,700	29.0	.27
Gleditsia triacanthos honeylocust	8,900	30.5	.31
Juglans nigra black walnut	9,800	29.6	.27
Juniperus virginiana Eastern redcedar	4,500	24.6	.50
Liquidambar styraciflua sweetgum	8,300	21.0	.23
Liriodendron tulipifera yellow-poplar	8,400	18.3	.20
Taxodium distichum baldcypress	8,100	24.7	.28
Magnolia grandiflora Southern magnolia	7,700	18.6	.22
Nyssa aquatica water tupelo	7,200	23.2	.29
Nyssa sylvatica black gum	7,100	21.0	.27
Picea rubens red spruce	9,200	18.8	.18
Pinus spp. pine	8,680	23.4	.25
Pinus echinata shortleaf pine	9,600	24.3	.23
Pinus elliottii slash pine	10,500	26.3	.23
Pinus glabra spruce pine	6,900	19.6	.30
Pinus palustris longleaf pine	11,000	29.8	.25
Pinus rigida pitch pine	8,300	20.3	.23
Pinus clausa sand pine	7,000	23.7	.31
Pinus serotina pond pine	8,600	25.2	.26
Pinus strobus Eastern white pine	6,800	16.8	.23
Pinus taeda loblolly pine	9,700	24.2	.23
Pinus virginiana Virginia pine	8,400	23.6	.26
Platanus occidentalis American sycamore	7,300	20.1	.26
Populus deltoides Eastern cottonwood	7,000	15.7	.20
Prunus serotina black cherry	9,000	24.4	.25

Scientific & Common Tree Name	Modulus of Elasticity (MPa)	Maximum Crushing Strength (MPa)	Elastic Limit (%)
Quercus spp. oak	9,300	25.3	.25
Quercus alba white oak	8,600	24.5	.26
Quercus coccinea scarlet oak	10,200	28.2	.26
Quercus falcata Southern red oak	7,900	20.9	.24
Quercus nigra water oak	10,700	25.8	.22
Quercus falcata var. pagodaefolia cherrybark oak	12,300	31.9	.24
Quercus laurifolia laurel oak	9,600	21.9	.21
Quercus lyrata overcup oak	7,900	23.2	.26
Quercus michauxii swamp chestnut oak	9,300	24.4	.24
Quercus phelios willow oak	8,900	20.7	.21
Quercus prinus chestnut oak	9,400	24.3	.24
Quercus rubra Northern red oak	9,300	23.7	.24
Quercus stellata post oak	7,500	24.0	.29
Quercus velutina black oak	8,100	23.9	.27
Quercus virginiana live oak	10,900	37.4	.31
Robinia pseudoacacia black locust	12,800	46.9	.34
Salix nigra black willow	5,400	14.1	.24
Sassafras albidum sassafras	6,300	18.8	.27
Tilia americana American basswood	7,200	15.3	.19
Tsuga canadensis Eastern hemlock	7,400	21.2	.26
Ulmus spp. elm	8,100	21.5	.25
Ulmus americana American elm	7,700	20.1	.24
Ulmus rubra slippery elm	8,500	22.9	.25

Data derived from: Green, D.W., J.E. Winandy, & D.E. Kretschmann. 1999. Mechanical Properties of Wood. Chapter 4 in **Wood Handbook ñ Wood As An Engineering Material**. USDA-Forest Service, Forest Products Laboratory, General Technical Report FPL-GTR-113. Madison, Wisconsin.