Black Locust Lumber: A Sustainable Alternative

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Ted Zoli from HNTB Corporation
Don Lavender from Landscape Forms
Black Locust Gate
Black Locust Boardwalk at Spider Island
Black Locust Lumber: A Sustainable Alternative
San Diego, November 1, 2011

Black Locust Paving
Black Locust Lumber: A Sustainable Alternative
San Diego, November 1, 2011

Black Locust Bench

Lucy Vincent Beach During Irene Hurricane
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Black Locust Chair 2007

Black Locust Posts

Black Locust as Site Furniture
Black Locust Arbor and Decking

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Black Locust Growth at Princeton University
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Black Locust Bench Brooklyn Bridge Park - Pier 6, 2011
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Black Locust Lumber: A Sustainable Alternative
San Diego, November 1, 2011

Black Locust at 1976 Courtyard at Princeton University
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Black Locust Color Change: freshly cut and after couple of weeks
Black Locust (Robinia pseudoacacia) was the first forest tree species to be imported from North America to Europe at the beginning of the 17th century.

Locust was introduced to Europe from North America by Jean Robin, the royal chief gardener of Paris in 1601. Today, no other European country has as much of it as Hungary does 852 acres.

Thus, it is no wonder that black locust is considered to be a Hungarian species in folklore. It prefers warm climates and nutrient-rich sandy soils (its climatic requirements are close to those of grapes).
**Black Locust** Botanical Characteristics

**Leaves** are made of pinnately compound of 7-19 leaflets (terminal leaflets present) on a central stalk 20-30cm long, 2 spines (modified stipules at the base of each leaf, leaflets oval, 30-50 mm long, dull green, bristle tipped, smooth margined.

**Pea like**, fragrant flowers appear in May or June after leaves emerge. Perfect flowers are pollinated by insects, primarily bees.

**Small pods** contain 4-8 hard coated seeds. Crops occur every 2 years, starting at the age of 3-6. The best seed production is between 15-60 years of age.
Rapid Spread of Black Locust

Black Locust Growth

- adaptability to a wide range of conditions
- favorable breeding properties
- frequent and abundant seed production
- excellent coppicing
- high survival percentage of seedlings
- fast growth and high yield
- in Europe, damage only by minimal diseases and insects
Black locust was introduced in Hungary between 1710 and 1720. The first large black locust forests were established at the beginning of the 19th century on the Great Hungarian Plain to stabilize the wind-blown sandy soil.
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Distribution of Black Locust
Black Locust Form

Natural

Selected
Black Locust Form

Black Locust Grove US - Black Locust Nursery Hungary
Forest Research Institute, Kecskemét, Hungary

Distribution of Main Tree Species in Hungary

Distribution of Black Locust % Within Other Stands

Research Goals:

• to determine the site requirements for Robinia tree species
• to improve new cultivars (clones)
• to improve technical level of propagation material production
• to improve growing technology related to plantation forestry
• to translate the archived research results into the forestry practice

Dr. Kordy Redei Black locust (Robinia pseudoacacia L.) Growing in Hungary. Hungarian Forest Research Institute 2003
Black Locust Propagation

Seeds

Root cuttings
Forty-nine cultivars have been developed in Hungary. They were selected to increase wood production as well as nectar production.

www.na.fs.fed.us

There are 9-10 ha of clone trials

In choosing seed production stands the primary feature is the stem form, then the quality of the stem.

There are 383 ha of such stands in Hungary. Clonal varieties have to be propagated vegetatively. The root cuttings have proven to be most successful.

Dr. Karoly Redei Black locust (Robinia pseudoacacia L. Growing in Hungary. Hungarian Forest Research Institute 2003
98% of black locust reproductive materials are produced by seedlings derived from phenotypically selected and registered seed stands.

“phenotype: the physical and biochemical characteristics of an organism as determined by the interaction of its genetic constitution and the environment”

\[
\text{genotype} + \text{environment} = \text{phenotype}
\]

Dr. Karoly Redei Black locust (Robinia pseudoacacia L.) Growing in Hungary. Hungarian Forest Research Institute 2003

The right dimensions of initial spacings are most important for the timber growing perspective.
<table>
<thead>
<tr>
<th>Yield Class</th>
<th>Age</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>40</td>
<td>excellent quality sawlogs</td>
</tr>
<tr>
<td>Yield Class I-II</td>
<td>rotation 35-40 years</td>
<td>good quality sawlogs</td>
</tr>
<tr>
<td>Yield Class III-IV</td>
<td>rotation 30 years</td>
<td>some sawlogs and high proportion of poles, and props</td>
</tr>
<tr>
<td>Yield Class IV-VI</td>
<td>rotation 20-25 years</td>
<td>props and other smaller dimension and fuelwood</td>
</tr>
</tbody>
</table>

Black Locust Forest 40 year old, Nyirseg (North-east Hungary)
In Hungary, *Robinia* is planted only in marginal landscape conditions, where oak forest can’t be established.

Generally, the optimal conditions for black locust growing is rather limited. It needs well-aerated soil, without too much moisture, ideally sites with periodic water supply, water table 1.5-2.5m.

The spread of black locust in Hungary was caused by:

- the need to **fix loose shifting sands**
- demand for afforestation of abandoned agricultural land
- abundant seed yield, vitality, excellent ability for sprouting, and ability to fix free atmospheric nitrogen
- wide range of uses for its wood (tool manufacture, fuelwood, vineyard poles and props, pit-wood, etc)
- bee foraging by its flowers
Micropropagated plants of four promising clones were planted near Kecskemet in spring 2000.

In the nursery there are two stands of locust: 11 and 9 years old.

According to new Hungarian national afforestation plan about 700,000 ha of abandoned agricultural fields are to be afforested in next 50 years, which will create about 35-40% of the plantations of black locust.
Black Locust Wood Properties

**High natural durability**

**Heavy and hard**, good strength values that clearly exceed those of the oak.

It is difficult to split, tough, *elastic and easy to bend*.

The degrees of shrinkage - as measured by the high density - are low. Once dried, the wood has a **good stability**. The drying takes place very slowly. Due to deviation of fibers and growth tensions *Robinia* wood tends to warp and crack.

However, a sufficient predrying in open air and the sealing of ends allow very good results in technical drying.

Planed surfaces are tight and flat, and can be processed further without problems.

All connections with nails, screws or adhesives are very durable. However, pre-drilling is required.

The wood is **highly acidic** and gets discolored by metals in connection with humidity, Additionally the metals corrode. Timber joints or stainless steel need to be used for mounting.

The dry **wood is odorless**. Specific ingredients (flavonoids) may possibly evoke allergic skin reactions (dermatitis, eczema) in case of sensitive persons.

The heartwood has high **natural resistance against wood destructive fungi and insects**. *Robinia* is the only kind of wood growing in Europe having resistance class 1-2 according to DIN EN 350-2.

Weight (fresh): - 930 kg/m³
Weight (kiln dried): 0,66 - 0,79 g/cm³
Compression strength*: 55 - 75 N/mm²
Bending strength*: 120 - 160 N/mm²
Impact resistance*: 110 - 210 kJ/m²

*air dried (12-15% wood moisture)  © Eurobinia 2011
**Black Locust** Cell Structure

**Black locust**

**Wood density** is one of the most important wood properties; it is mass of the wood divided by its volume at given moisture content.

For locust it is **740 average bulk density** at 12% moisture content (kg./m³)

Vessel elements conduct water, thick **fibrous cell walls** of black locust are responsible for its high density and mechanical strength of wood.

<table>
<thead>
<tr>
<th></th>
<th>Moisture content</th>
<th>Specific gravity (^b)</th>
<th>Modulus of rupture (kPa)</th>
<th>Modulus of elasticity (^c) (MPa)</th>
<th>Work to maximum load (^d) (kJ m(^{-3}))</th>
<th>Impact bending (mm)</th>
<th>Compression parallel to grain (kPa)</th>
<th>Compression perpendicular to grain (kPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Black locust</strong></td>
<td>Green</td>
<td>0.66</td>
<td>95,000</td>
<td>12,800</td>
<td>106</td>
<td>1,120</td>
<td>46,900</td>
<td>8,000</td>
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<tr>
<td></td>
<td>12%</td>
<td>0.69</td>
<td>134,000</td>
<td>14,100</td>
<td>127</td>
<td>1,450</td>
<td>70,200</td>
<td>12,600</td>
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<tr>
<td><strong>Northern red oak</strong></td>
<td>Green</td>
<td>0.56</td>
<td>57,000</td>
<td>9,300</td>
<td>91</td>
<td>1,120</td>
<td>23,700</td>
<td>4,200</td>
</tr>
<tr>
<td></td>
<td>12%</td>
<td>0.63</td>
<td>99,000</td>
<td>12,500</td>
<td>100</td>
<td>1,090</td>
<td>46,600</td>
<td>7,000</td>
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</table>
## Black Locust Mechanical Properties

### MECHANICAL PROPERTIES

<table>
<thead>
<tr>
<th>Category</th>
<th>Ipe</th>
<th>Jarrah</th>
<th>Maple</th>
<th>Northern Red Oak</th>
<th>Redwood (Young-growth)</th>
<th>Teak</th>
<th>Alaskan Yellow Cedar</th>
<th>Black Locust</th>
<th>Purpleheart</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drying Method &amp; Moisture Content</td>
<td>Air Dry</td>
<td>Kiln Dry</td>
<td>Kiln Dry</td>
<td>Kiln Dry</td>
<td>Kiln Dry</td>
<td>Kiln Dry</td>
<td>Kiln Dry</td>
<td>Kiln Dry 8% - 8%</td>
<td>Kiln Dry 12%</td>
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<tr>
<td>Density Lbs/Ft³</td>
<td>64</td>
<td>54</td>
<td>39</td>
<td>47</td>
<td>26</td>
<td>40</td>
<td>29</td>
<td>43</td>
<td>61</td>
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<tr>
<td>Specific Gravity</td>
<td>0.92</td>
<td>0.67</td>
<td>0.63</td>
<td>0.63</td>
<td>0.35</td>
<td>0.55</td>
<td>0.48</td>
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<td>0.79</td>
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<tr>
<td>Static Bending</td>
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<td></td>
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<td></td>
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<tr>
<td>Modulus of Rupture (psi)</td>
<td>22,600</td>
<td>16,200</td>
<td>15,800</td>
<td>14,300</td>
<td>7,900</td>
<td>13,710</td>
<td>11,354</td>
<td>19,400</td>
<td>19,200</td>
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<td>Modulus of Elasticity (Million psi)</td>
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<td>1.88</td>
<td>1.83</td>
<td>1.82</td>
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<td>1.55</td>
<td>1.30</td>
<td>2.05</td>
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<tr>
<td>Work to Maximum Load [Ability to Absorb Shock] (in-lb per in³)</td>
<td>27.6</td>
<td>16.5</td>
<td>14.5</td>
<td>5.2</td>
<td>12.0</td>
<td>13.0</td>
<td></td>
<td>18.4</td>
<td>17.6</td>
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<td>Impact Bending</td>
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<td></td>
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<td></td>
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<tr>
<td>Height of 50lb. hammer drop (inches) causing complete failure</td>
<td>39</td>
<td>44</td>
<td>15</td>
<td>29</td>
<td>57</td>
<td>44</td>
<td></td>
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<tr>
<td>Compression Parallel to Grain</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Maximum crushing strength (psi)</td>
<td>13,010</td>
<td>8,870</td>
<td>7,830</td>
<td>6,760</td>
<td>5,220</td>
<td>7,605</td>
<td>7,520</td>
<td>10,800</td>
<td>10,320</td>
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<tr>
<td>Compression Perpendicular to Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fiber stress at proportional limit</td>
<td>1,470</td>
<td>1,010</td>
<td>520</td>
<td>910</td>
<td>1,830</td>
<td>—</td>
<td></td>
<td></td>
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<tr>
<td>Shear Parallel to Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Maximum shearing strength (psi)</td>
<td>2,060</td>
<td>2,130</td>
<td>2,330</td>
<td>1,780</td>
<td>1,110</td>
<td>1,890</td>
<td>880</td>
<td>2,480</td>
<td>2,220</td>
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<tr>
<td>Tension Perpendicular to Grain</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Maximum tensile strength (psi)</td>
<td>800</td>
<td>250</td>
<td>487</td>
<td>370</td>
<td>640</td>
<td>529</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Load perpendicular to grain (lbs.) Represents the resistance of the wood to wear and to marring</td>
<td>3,680</td>
<td>1,910</td>
<td>1,450</td>
<td>1,290</td>
<td>420</td>
<td>430</td>
<td>500</td>
<td>1,700</td>
<td>1,860</td>
</tr>
</tbody>
</table>
Moisture content of wood depends on relative humidity and temperature of surrounding air.

Wood moisture:
- > 30%
- ≈ 30%
- < 30%

Free water
Bound water part of the fiber structure
Wood tends to reach a moisture content that is in equilibrium with the relative humidity and temperature of the surrounding air.

<table>
<thead>
<tr>
<th>Temperature (°F ºC)</th>
<th>5% RH</th>
<th>10% RH</th>
<th>15% RH</th>
<th>20% RH</th>
<th>25% RH</th>
<th>30% RH</th>
<th>35% RH</th>
<th>40% RH</th>
<th>45% RH</th>
<th>50% RH</th>
<th>55% RH</th>
<th>60% RH</th>
<th>65% RH</th>
<th>70% RH</th>
<th>75% RH</th>
<th>80% RH</th>
<th>85% RH</th>
<th>90% RH</th>
<th>95% RH</th>
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<tbody>
<tr>
<td>30 (-1.1)</td>
<td>1.4</td>
<td>2.6</td>
<td>3.7</td>
<td>4.6</td>
<td>5.5</td>
<td>6.3</td>
<td>7.1</td>
<td>7.9</td>
<td>8.7</td>
<td>9.5</td>
<td>10.4</td>
<td>11.3</td>
<td>12.4</td>
<td>13.5</td>
<td>14.9</td>
<td>15.5</td>
<td>18.5</td>
<td>21.0</td>
<td>24.3</td>
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<tr>
<td>50 (10.0)</td>
<td>1.4</td>
<td>2.6</td>
<td>3.6</td>
<td>4.6</td>
<td>5.5</td>
<td>6.3</td>
<td>7.1</td>
<td>7.9</td>
<td>8.7</td>
<td>9.5</td>
<td>10.3</td>
<td>11.2</td>
<td>12.3</td>
<td>13.4</td>
<td>14.8</td>
<td>16.4</td>
<td>18.4</td>
<td>20.9</td>
<td>24.3</td>
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<tr>
<td>70 (21.1)</td>
<td>1.3</td>
<td>2.5</td>
<td>3.5</td>
<td>4.5</td>
<td>5.4</td>
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<td>6.9</td>
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<td>14.4</td>
<td>16.0</td>
<td>17.9</td>
<td>20.5</td>
<td>23.9</td>
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<tr>
<td>90 (32.2)</td>
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<td>2.3</td>
<td>3.4</td>
<td>4.3</td>
<td>5.1</td>
<td>5.9</td>
<td>6.7</td>
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<td>13.9</td>
<td>15.4</td>
<td>17.3</td>
<td>19.8</td>
<td>23.3</td>
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<tr>
<td>110 (43.3)</td>
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<td>2.2</td>
<td>3.2</td>
<td>4.0</td>
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<td>5.6</td>
<td>6.3</td>
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<td>7.7</td>
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<td>14.7</td>
<td>16.6</td>
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<td>130 (54.4)</td>
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<td>3.7</td>
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<td>12.5</td>
<td>14.0</td>
<td>15.8</td>
<td>18.2</td>
<td>21.5</td>
</tr>
<tr>
<td>150 (65.6)</td>
<td>0.9</td>
<td>1.8</td>
<td>2.6</td>
<td>3.4</td>
<td>4.1</td>
<td>4.8</td>
<td>5.5</td>
<td>6.1</td>
<td>6.7</td>
<td>7.4</td>
<td>8.1</td>
<td>8.8</td>
<td>9.7</td>
<td>10.6</td>
<td>11.8</td>
<td>13.1</td>
<td>14.9</td>
<td>17.2</td>
<td>20.4</td>
</tr>
</tbody>
</table>
## Equilibrium Moisture Content

### Table 2—Equilibrium moisture content (EMC) of wood, exposed to outdoor atmosphere, in U.S. locations-con.

<table>
<thead>
<tr>
<th>State</th>
<th>City</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug.</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
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<tbody>
<tr>
<td>NM</td>
<td>Albuquerque</td>
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<td>9.3</td>
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<td>8.6</td>
<td>9.6</td>
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<tr>
<td>NM</td>
<td>Clayton</td>
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<td>9.1</td>
<td>9.9</td>
<td>9.7</td>
<td>10.6</td>
<td>10.8</td>
<td>10.4</td>
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<td>NM</td>
<td>Roswell</td>
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<td>8.3</td>
<td>9.1</td>
<td>9.9</td>
<td>10.5</td>
<td>9.7</td>
<td>10.0</td>
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<tr>
<td>NV</td>
<td>Elko</td>
<td>13.3</td>
<td>12.5</td>
<td>11.1</td>
<td>10.0</td>
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<td>8.7</td>
<td>7.3</td>
<td>7.4</td>
<td>8.0</td>
<td>9.1</td>
<td>11.8</td>
<td>13.2</td>
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<tr>
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<td>Ely</td>
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<td>10.9</td>
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<td>9.3</td>
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<td>7.2</td>
<td>7.7</td>
<td>8.0</td>
<td>9.2</td>
<td>10.9</td>
<td>11.9</td>
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<tr>
<td>NV</td>
<td>Las Vegas</td>
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<td>7.0</td>
<td>5.5</td>
<td>5.0</td>
<td>4.0</td>
<td>4.5</td>
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</table>
Black Locust Typical Moisture Content

- Live tree: ~60% MC
- Freshly cut tree: 35%
- Cut logs: air dry 35% - 25/20%
- Lumber: dependent on use and equilibrium moisture content in a specific location
Dimensional Change of Wood

The shrinkage is about 5% to 10% in the tangential direction and about 2% to 6% in the radial direction (Walker et al., 1993).

Typical moisture content-shrinkage curves. The lower moisture content the bigger shrinkage takes place.

Black locust
Radial 4.6%
Tangential 7.2%
Volumetric 10.2%
Dimensional Change of Wood

Quarter Sawn  Regular Sawn

>15%

15%

<15%

slab board  side plank  middle plank  heart plank
Relationship of MC and Wood Strength

Effect of moisture content on wood strength properties

A tension parallel to grain
B bending
C compression parallel to grain
D compression perpendicular to grain
E tension perpendicular to grain
Why Kiln Dry Wood?

- wood will eventually dry to about 20% MC in typical outdoor conditions, but might twist, crack, and warp, while kiln drying allows for achieving lower MC in stable and controlled conditions
  - will have MC and dimensions similar to average, which avoids damage of finishing materials/construction
  - dry wood finishes better
  - reduces shipping weight

Figure 13–3. End view of board showing development of drying stresses (a) early and (b) later in drying.
Kiln Drying

Dehumidifier Kiln

- airflow
- temperature
- humidity

Moisture stress relationship during six stages of kiln drying 2 inch thick red oak
Black Locust Hydrothermal treatment (steaming)

Color changes affected by steaming under pressure as a function of controlling parameters: \textit{temperature and time}

Bending strength and hardness of wood samples \textbf{decreased} during the treatment.

"Generally, mechanical properties decayed with higher steaming temperature and/or longer treatment time. Bending strength of black locust was influenced by steaming time rather than temperature".  

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About 8500 ha of black locust is harvested yearly in Hungary. Together with thinnings, the annual timber volume felled in black locust stands amounted to 1.1-1.6 million m³ gross on average for the last 5-7 years. The average age of a tree is 31.

In Hungary:
10% veneer and sawlog
9% short wood for saw milling plants
5% pit-wood
14% pole, props, chips
41% thick fuelwood
5% thin fuelwood
16% wastewood in the forest

**Main products:**
sawn wood in edged and unedged forms
sawn furniture lathe, wooden handle
barrel staves
sawn poles (beam, railroad sleepers)

**Secondary products:**
parquet-frieze
pallet board for loading
lathe for fence
board for mining purposes
sawn props
Lamarck Company

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Eurobinia Company
Kajászó

San Diego, November 1, 2011
Dunaker Company

**Products:**
- Construction wood, 14-16%
- Traditional sawn stakes posts
- Split stakes and posts
- Quadratic posts
- Cylindrical posts, as grown
- Traditional sawn tutors
- Quadratic tutors
- Quadratic stakes for plants’ support
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Sawmill Stefan

Products
» Thermo-Wood
» Burning
» Floor boards and parquet
» Conifer and Hardwood strips
» Building construction elements
» Terrace, balcony, gang-board
» Enclosure and garden wooden houses
» Firewood
Dreweko is a firm with 50 years of experience in wood flooring; they have a proven track record as being the best in the business.

Specialize in:
- industrial parquets
- hand-scraped floors
- balusters and pillars
“In the last two centuries, native European oak forests have undergone a dramatic decline related to increasing human pressure for agriculture and urbanization. Oak forests were either completely eradicated and transformed into agricultural landscapes or replaced by second-growth formations (...) Black locust forests and agrarian landscapes replaced native forests (...)

Oak forest exploitation and black-locust invasion caused severe shifts in epiphytic lichen communities in Northern Italy. Juri Nascimbene, Lorenzo Marini
Department of Biology, University of Padova, via U. Bassi 58/B, I-35121 Padova, Italy
Black Locust

is native to the United States

The US Geological Survey provides a distributional map of black locust's native range in North America.

Black locust grows rapidly

Seedlings may grow 1m even in the first year

- between 2-5 years, the annual growth might be even 2m in good conditions
- it takes 30-40 years to achieve quality sawlogs

Ipe (Brazilian Walnut)

80% of logging Ipe in the Brazilian Amazon is illegal

each day at least 80,000 acres (32,300 ha) of forest disappear from Earth. At least another 80,000 acres (32,300 ha) of forest are degraded.

Ipe grows sporadically in the rainforest and generally one or two are found per acre

- Ipe trees reach heights of 140 feet with trunk diameters of 6 feet.

Ipe -- a Brazilian rainforest hardwood

Some FSC wood is available, but best to avoid.

Guide to Endangered Trees | Rainforest Action Network
http://ran.org/content/guide-endangered-trees-0#ixzz1ZpqhUFzK
## Construction Material Properties

### Physical Properties Comparison

<table>
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<th>Ipe</th>
<th>Black Locust</th>
<th>Northern Red Oak</th>
<th>Alaskan Yellow Cedar</th>
<th>Pine</th>
<th>Concrete</th>
<th>Steel</th>
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<td>0.69</td>
<td>0.63</td>
<td>0.42</td>
<td>0.40</td>
<td>NA</td>
<td>NA</td>
<td>0.91 to 0.95</td>
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<td><strong>density (Lbs/ft³)</strong></td>
<td>64</td>
<td>43</td>
<td>47</td>
<td>30</td>
<td>27</td>
<td>145</td>
<td>490</td>
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<td><strong>max tensile strength (perpendicular to grain) (psi)</strong></td>
<td>3,680</td>
<td>1,700</td>
<td>1,010</td>
<td>500</td>
<td>580</td>
<td>0</td>
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<td>854</td>
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<td><strong>max crushing strength (psi)</strong></td>
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<td>10,800</td>
<td>6,760</td>
<td>7,520</td>
<td>5,320</td>
<td>7,500</td>
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<td>1,806</td>
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<td><strong>modulus of rupture (psi)</strong></td>
<td>22,600</td>
<td>19,400</td>
<td>14,300</td>
<td>11,354</td>
<td>9,427</td>
<td>4,000</td>
<td>29-30 million</td>
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<td><strong>modulus of elasticity (MPa)</strong></td>
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<td>12,500</td>
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<td>8,900</td>
<td>21,720</td>
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<td>2-3</td>
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<td>1</td>
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<td><strong>manufacturing and delivery process</strong></td>
<td>felling, milling, and shipping</td>
<td>felling, milling, shipping, air and kiln drying,</td>
<td>felling, milling, shipping, air and kiln drying, finish</td>
<td>felling, milling, shipping, air and kiln drying, finish</td>
<td>sourcing and making materials for mixture of: Portland cement, fly ash, slag cement, aggregate, water, and chemical admixtures</td>
<td>intensive process of sourcing and smelting of iron and carbon</td>
<td>producing a composition of 50% wood and 50% plastic fibers</td>
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Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011
<table>
<thead>
<tr>
<th>Black Locust</th>
<th>Ipe</th>
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<tr>
<td><strong>Dimensions:</strong></td>
<td><strong>Dimensions:</strong></td>
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<tr>
<td>26 mm x 80 mm by 2400 mm</td>
<td>1 inch x 3 inch by 8 feet</td>
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<tr>
<td>(1.02 inch x 3.15 inch by 7.87 feet)</td>
<td>(25.4 mm x 3.15 inch by 7.87 feet)</td>
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<td>moisture content 8%</td>
<td>moisture content 16% -18%</td>
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<td><strong>5.44 USD SF</strong></td>
<td><strong>7.19 USD SF</strong></td>
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<td>in an order of one full container</td>
<td>Price includes shipping from Brazil</td>
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<td>Price includes shipping from Hungary plus merchandise fee</td>
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Black Locust Lumber: A Sustainable Alternative
San Diego, November 1, 2011
Concept Design

- Structural System - Small Diameter Timber
  - Sustainable
  - Cost-effective
  - Durable – Black Locust
  - Lightweight – Transport & Erect Whole Spans

- Offsite Prefabrication
  - Minimize NYC Labor Cost &
  - Maximize Competition for Fabrication

- Trail Bridge Ideals
  - Rough Cut System
  - Replaceable Deck
Timber Highway Bridges – US Inventory

- **State Owned Bridges in US**
  - ~25,000 Full Timber Bridges
  - ~50,000 Bridges with Timber Decks
  - 1 out of every 8 highway bridges
  - Typically 10-60 ft spans

- **US Department of Agriculture**
  - Forest Service ~ 7500 Timber Bridges

- **Railroad Bridges**
  - 1500 miles
  - ~1/3 the Inventory of Class 1 Railroads
  - Average Bridge Age > 40 years
100 Year Old Timber Bridges

Wood Street Railroad Bridge, Built 1909, IL
Holcomb Creek Railroad Bridge, Built 1905, WA
Underslung Suspension Bridge:

- Highly efficient form
- Material palette from BBP
- Small dia. Black Locust, steel cables, & bronze connections

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DECK PLAN

VIEW B–B

SECTION A–A

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Squibb Park Bridge
Black Locust Timber:

- Sustainable
- Small diameters – harvested young
- Fast growth
- Locally sourced
- Rot resistant – no coating required

- Strong: 10,000 psi (vs. concrete at 4,000 psi)
- Lowest shrinkage of domestic woods

Stainless or Galvanized steel cables & hardware
Black Locust Lumber: A Sustainable Alternative
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Squibb Park Bridge: GREEN, ROUGH CUT TIMBER IN A WET ENVIRONMENT
Timber Piles – standard and proprietary connections
Comparative Behavior – Steel vs Timber
Loaded Beam Tests at SwRI
Figure 1. Timber pole in the 15 m long lathe at TTT Ltd
Structural Systems - Triakonta:

Round members
Problematic connections
Black Locust Lumber: A Sustainable Alternative
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Squibb Park Bridge

Turning a Black Locust Log, Cornell University, 2010

Triakonta Compression 1

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<th>Load (kN)</th>
<th>Displacement (cm)</th>
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<tr>
<td>150</td>
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<td>250</td>
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Squibb Park Bridge
Structural Systems – Prestressed Segmented Arch:

Round members
Problematic connections
Dowel-Nut Connections:

Predominant failure modes
Figure 3. Round Timber telecommunication towers up to 40 m in height even in typhoon regions

Figure 4. Annular band connection with steel bands that clamp into lathed grooves
**Machine Stress Graded Lumber:**

- Compression, tension, & bending
- Expensive laboratory-style equipment
- Need battery of test data
  - Calibrate design values
  - Establish appropriate factors of safety
“Improvised Guitar Tuner”:

- Sound wave sampling
- Inexpensive equipment
- Rapid evaluation
- Accepted method in Europe, Japan, Brazil
- Free software
The Potential to Use Black Locust in Mass Production in the US

• Though the propagation and growth rates of Black Locust are phenomenal, obtaining prime lumber trees require careful selection.

• The best lumber trees are found within the woods competing with other trees for sunlight. Specimens on vacant lots and the periphery of wooded areas tend to be of lesser value for prime lumber.

• Ideal age of a Black Locust tree for prime lumber yield is 20 to 30 years old.
• Trees older than 30 years tend to be infested with the Black Locust Borer.
• There are many products that utilize the lesser grades such as pallet components, greenhouse poles, rustic parquet flooring, landscape mulch, biomass fuel and firewood.
• 100% of the tree is purposefully used.
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Processing

• Sawing and grading follow the NHLA guide rules with exceptions
  – Conventional methods and equipment are utilized.
  – #1 Grade (can have knots, splits, checks, wormholes, encased bark).
  – Premium Grade (sound knots less than 90% of the surface, cracks less than 1/12 length of the board) This grade would somewhat compare to FAS grade for other North American Hardwoods.
  – Premium Grade Plus (Landscape Forms Specification is the top 5% to 6% of the best of the best).

• Kiln drying
  – Black Locust is a difficult and challenging wood to dry.\textit{Why?}
    – For the same reasons it’s so resistant to decay.
    – Tyloses and robinetin extractives fill the grain structure restricting the passage of moisture to the outside surface of the board where it evaporates.
  – Patience is a virtue. Drying Black Locust cannot and should not be rushed.
  – Rushing the kiln drying process will result in case-hardening and a low-grade product.
    – The outside of the board is much dryer than the inside. This builds up undesirable internal/external stresses that result in excess distortion of the milled lumber.
  – Dry kiln schedule of T3-A1 for stock over 6/4 must be followed with high vigilance in testing and documenting MC (moisture content).
  – A more aggressive kiln dry schedule of T6-A1 is used for thinner stock.
Working Black Locust

• Working characteristics
  – Black Locust cuts, saws, drills, sands, shapes relatively easily as long as it is properly dried and keenly sharpened cutting edges are maintained.
  – Screw retention is very good.
  – Finishes are applied and well taken. (Interior furniture applications only).
  – Exceptional steam bending properties.
  – Janka Hardness is 1700. Compare this to the industry benchmark of 1290 for red oak, Black Locust is a hard and wear-resistant wood.
    – Jarrah is at 1910.
    – Ipe is at 3684.

• Gluing
  – Special considerations are a prerequisite.
    – Proprietary research at Landscape Forms is yielding successful mechanical and chemical adhesive bonds.
Weathering

• Color
  – Black Locust characteristically ages in the elements into darker grays.
  – Fresh cut color is a yellowish-tan with brown streaks or areas.
  – During the first few weeks in the elements Black Locust turns a golden brown.
  – In 6 to 12 months the wood transitions to a light then to a darker gray patina.

Un-weathered  Golden brown  Darker gray patina

• Checking and cracking
  – It’s the nature of wood that some checking and cracking occur. Black Locust is no exception.
  – Black Locust is however a stable wood for use in the outdoors.
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Biological

• Black Locust has remarkable biological decay resistance
  – High concentration of Robinetins.
  – Robinetins are a class of flavonoids.
  – Flavonoids are antioxidants.

• Slow oxidation (decay)
  – All biological matter sooner or later goes through a physiological process called slow oxidation.
    – Rapid oxidation we’d call combustion.
  – Slow oxidation degrades stable bio-matter molecules into unstable free radical molecules.
  – These in turn release more free radicals forming oxidation chains degrading adjacent molecules, thus propagating further decay.
    – Classic example is the saying “All it takes is one rotten apple……….”
  – Antioxidants work to significantly reduce the oxidation process by suppressing and neutralizing free radical oxidation chains from being established.
  – They also create a hostile environment for bioorganisms that feed on the cellulose.
  – Robinetins and tyloses are absent in the sapwood which is NOT resistant to decay.
  – Only the heartwood of Black Locust is decay resistant.

• Black Locust extractives as a preservative
  – Limited laboratory research has been conducted on extracting the Robinetins, tannic acids and other biochemical substances from Black Locust and pressure treating species unsuitable for exterior use with positive results.
  – This is not a commercially viable endeavor but it is scientific validation of the biological basis for the decay resistance of the extractives found in Black Locust.
Mechanical resistance to decay

- Black Locust is a “Ring Porous” wood meaning the large xylem vessels in the spring wood are even larger than the xylem vessels of the summer wood. White Oak, Ash and Elm are examples of other ring porous wood species. The xylem vessels are easily observed without magnification.
  - Diffuse porous wood species such as Maple, Birch, Beech have xylem vessels of small (very tiny actually) and uniform distribution.
- Black Locust heartwood xylem vessels are filled with tyloses which greatly restricts the passage of water through the wood. This makes Black Locust a choice wood for the structural components in boat building.
  - Tyloses are food storage cells that form in the heartwood just under the sapwood as it transforms into heartwood. Tyloses are absent from the sapwood and cambium layers. Here again, the sapwood of Black Locust is NOT resistant to decay.
Why isn’t black locust wood more popular in US?

Why it should be:
- it is a great sustainable resource
- high durability of wood
- great decay and fungi resistance
- no treatment involved in the processing
- it is a great substitute for exotic species

Why it is not:
- not a popular species
- the tree is smaller than exotic species
- in the US the literature seems to overstate the locust borer problem
- lack of experience in locust management and wood processing
thank you