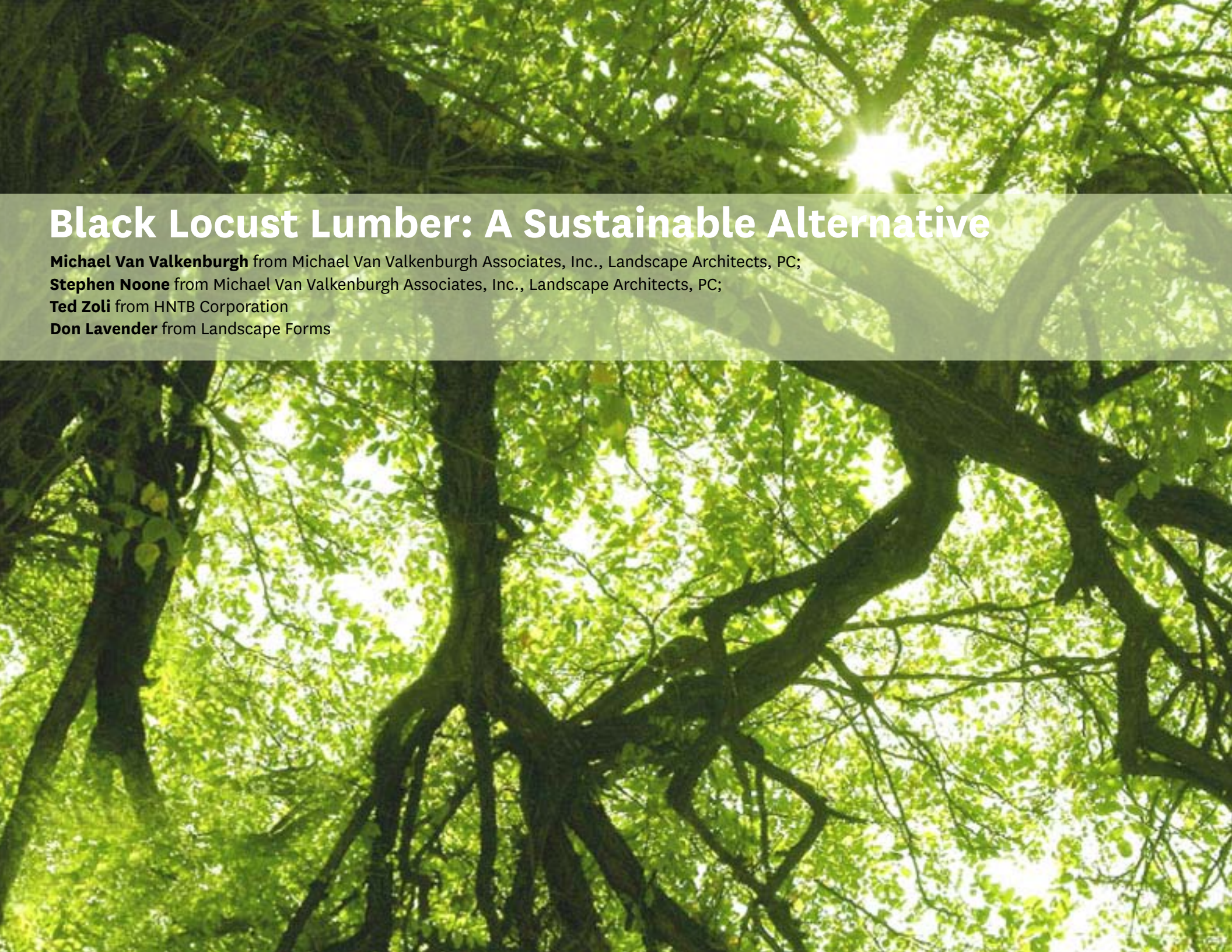
Black Locust Lumber: A Sustainable Alternative

Michael Van Valkenburgh from Michael Van Valkenburgh Associates, Inc., Landscape Architects, PC;
Stephen Noone from Michael Van Valkenburgh Associates, Inc., Landscape Architects, PC;
Ted Zoli from HNTB Corporation
Don Lavender from Landscape Forms



Black Locust Gate

Black Locust Boardwalk at Spider Island

Black Locust Paving

Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Black Locust Bench

Lucy Vincent Beach During Irene Hurricane

Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Black Locust Chair 2007

Black Locust Posts

Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Black Locust Arbor and Decking

Black Locust Growth at Princeton University

Black Locust Bench Brooklyn Bridge Park - Pier 6, 2011

Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

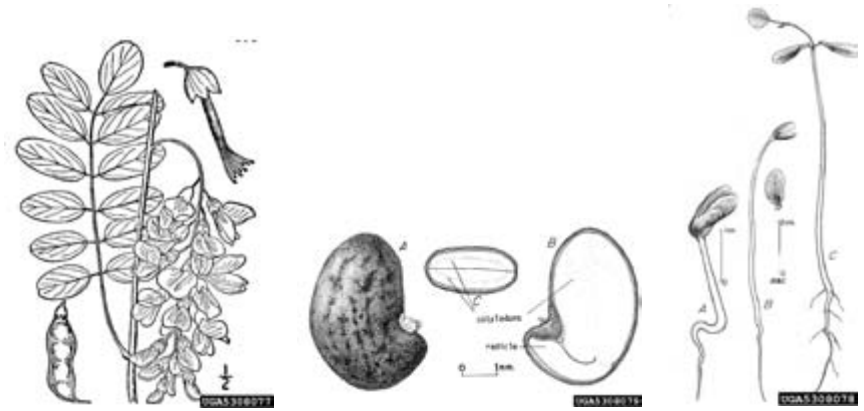
Black Locust at Duke Mills

Black Locust at Duke Mills

Black Locust at 1976 Courtyard at Princeton University

Black Locust Color Change: freshly cut and after couple of weeks

Black Locust History



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.

USDA NRCS PLANTS Database United States

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.



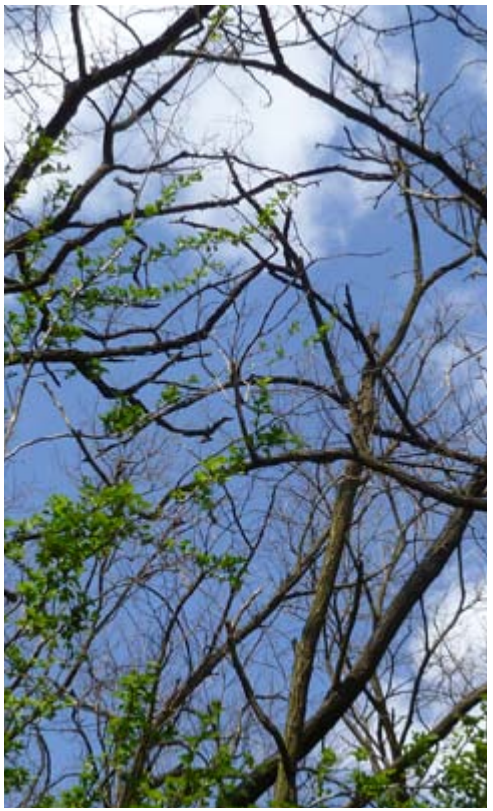
Pea like, fragrant flowers appear in May or June after leaves emerge. Perfect flowers are pollinated by insects, primarily bees.



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

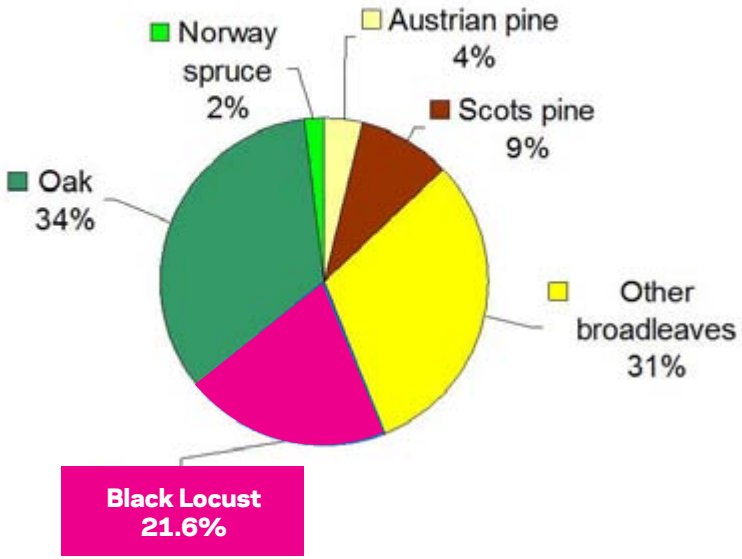


Black Locust Growth

- 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

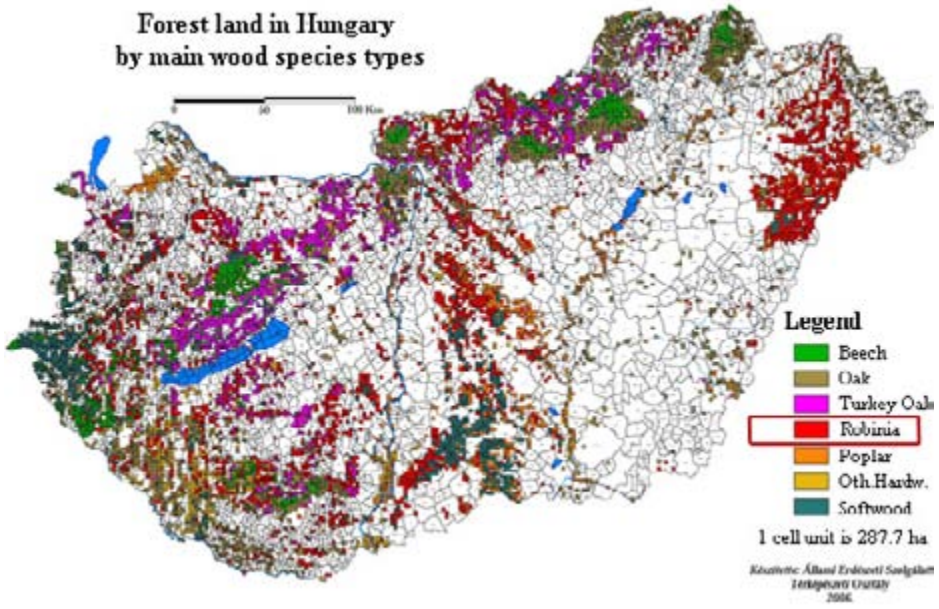
Spread of Black Locust

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.

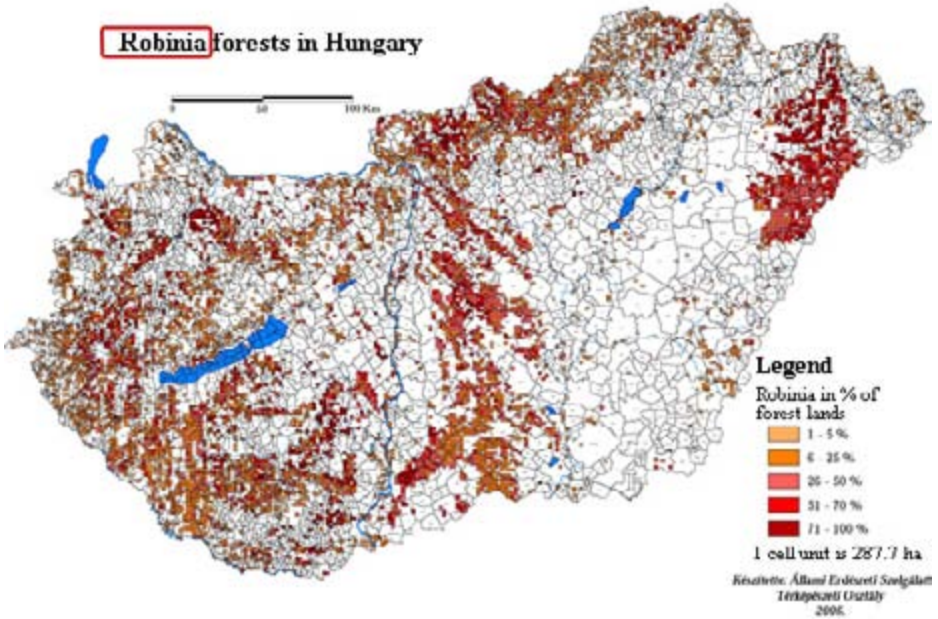


Species Distribution in Hungary

Distribution of Black Locust



Distribution of Main Tree Species in Hungary



Distribution of Black Locust % Within Other Stands

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

Black Locust Propagation

Cultivars

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

Stand Establishement

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"

genotype + environment = phenotype

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

Black Locust Plantations

Excellent quality stem Age: **40**	excellent quality sawlogs
Yield Class I-II **rotation 35-40 years**	good quality sawlogs
Yield Class III-IV **rotation 30 years**	some sawlogs and high proportion of poles, and props
Yield Class IV-VI **rotation 20-25 years**	props and other smaller dimension and fuelwood

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

Black Locust Propagation Prognosis

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 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

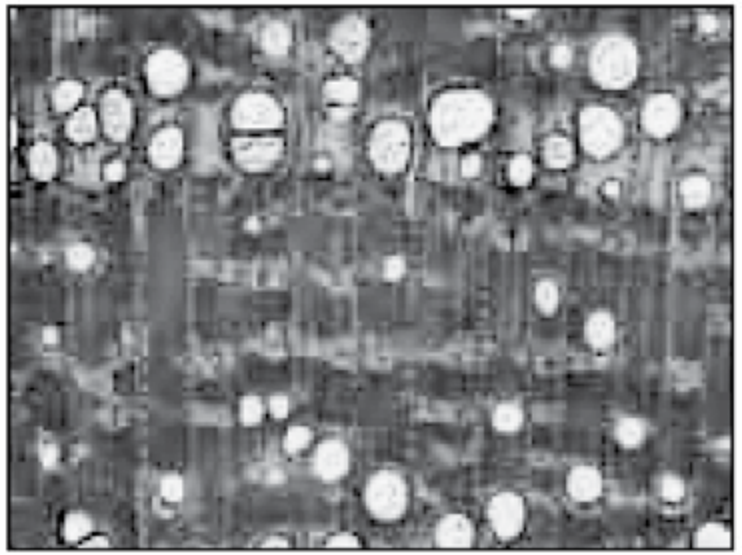
*air dried (12-15% wood moisture)

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./m^3)



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

	Moisture content	Specific gravity[b]	Static bending: Modulus of rupture (kPa)	Static bending: Modulus of elasticity[c] (MPa)	Static bending: Work to maximum load (kJ m^{-3})	Impact bending (mm)	Compression parallel to grain (kPa)	Compression perpendicular to grain (kPa)
Black locust	Green	0.66	95,000	12,800	106	1,120	46,900	8,000
	12%	0.69	134,000	14,100	127	1,450	70,200	12,600
Northern red oak	Green	0.56	57,000	9,300	91	1,120	23,700	4,200
	12%	0.63	99,000	12,500	100	1,090	46,600	7,000

Black Locust Mechanical Properties

MECHANICAL PROPERTIES

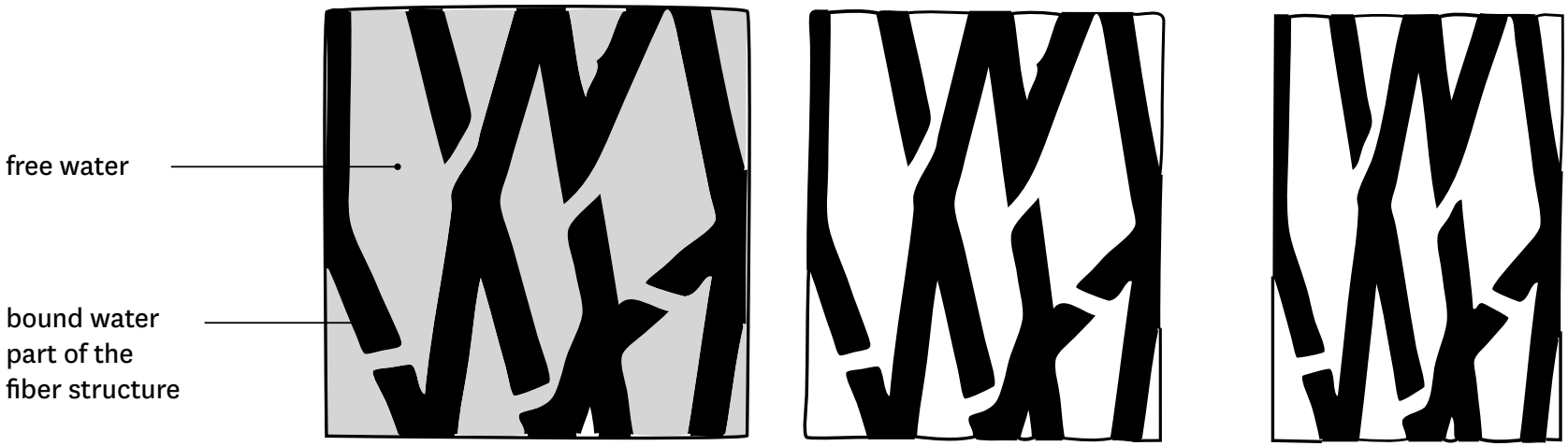
Category	Ipe	Jarrah	Maple	Northern Red Oak	Redwood (Young-growth)	Teak	Alaskan Yellow Cedar	Black Locust	Purpleheart
Drying Method & Moisture Content	Air Dry	Kiln Dry 8% - 12%	Kiln Dry 6% - 8%	Kiln Dry 6% - 8%	Kiln Dry 12% - 15%	Kiln Dry 12%	Kiln Dry 15% or less	Kiln Dry 6% - 8%	Kiln Dry 12%
Density Lbs/Ft3	64	54	39	47	26	40	29	43	61
Specific Gravity	0.92	0.67	0.63	0.63	0.35	0.55	0.48	0.69	0.79
Static Bending:									
Modulus of Rupture (psi)	22,600	16,200	15,800	14,300	7,900	13,710	11,354	19,400	19,200
Modulus of Elasticity (Million psi)	2.92	1.88	1.83	1.82	1.1	1.55	1.30	2.05	2.27
Work to Maximum Load [Ability to Absorb Shock] (in-lb per in3)	27.6		16.5	14.5	5.2	12.0	13.0	18.4	17.6
Impact Bending:									
Height of 50lb. hammer drop (inches) causing complete failure			39	44	15	—	29	57	44
Compression Parallel to Grain:									
Maximum crushing strength (psi)	13,010	8,870	7,830	6,760	5,220	7,605	7,520	10,800	10,320
Compression Perpendicular to Grain:									
Fiber stress at proportional limit			1,470	1,010	520	—	910	1,830	—
Shear Parallel to Grain:									
Maximum shearing strength (psi)	2,060	2,130	2,330	1,780	1,110	1,890	880	2,480	2,220
Tension Perpendicular to Grain:									
Maximum tensile strength (psi)				800	250	487	370	640	529
Load perpendicular to grain (lbs.). Represents the resistance of the wood to wear and to marring:	3,680	1,910	1,450	1,290	420	430	500	1,700	1,860

landscapeforms

431 Lawndale Avenue, Kalamazoo, MI 49048 P 800.521.2546 F 269.381.3455
www.landscapeforms.com specify@landscapeforms.com

Moisture content of wood depends on

relative humidity and temperature of surrounding air



Equlibrium Moisture Content (EMC)

Wood tends to reach a moisture content that is in equilibrium with the relative humidity and temperature of the surrounding air.

Table 1—Dependence of equilibrium moisture content (EMC) of wood on relative humidity (RH) and temperature

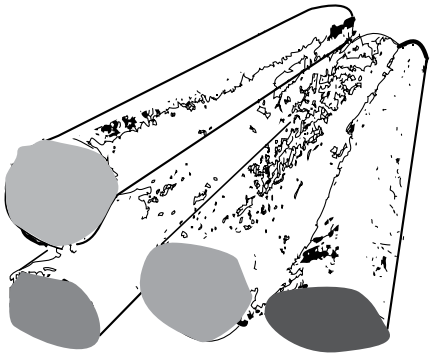
	EMC (%)																	
Temperature (°F (°C))	5% RH	10% RH	15% RH	20% RH	25% RH	30% RH	35% RH	40% RH	45% RH	50% RH	55% RH	60% RH	65% RH	70% RH	75% RH	80% RH	85% RH	90% RH	95% RH
30 (-1.1)	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.4	13.5	14.9	16.5	18.5	21.0	24.3
50 (10.0)	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3
70 (21.1)	1.3	2.5	3.5	4.5	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9
90 (32.2)	1.2	2.3	3.4	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3
110 (43.3)	1.1	2.2	3.2	4.0	4.9	5.6	6.3	7.0	7.7	8.4	9.2	10.0	11.0	12.0	13.2	14.7	16.6	19.1	22.4
130 (54.4)	1.0	2.0	2.9	3.7	4.5	5.2	5.9	6.6	7.2	7.9	8.7	9.4	10.3	11.3	12.5	14.0	15.8	18.2	21.5
150 (65.6)	0.9	1.8	2.6	3.4	4.1	4.8	5.5	6.1	6.7	7.4	8.1	8.8	9.7	10.6	11.8	13.1	14.9	17.2	20.4

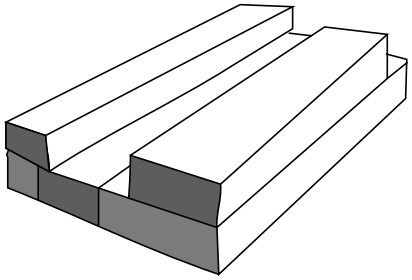
Table 2—Equilibrium moisture content (EMC) of wood, exposed to outdoor atmosphere, in U.S. locations-con.

State	City	EMC (%)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug.	Sep	Oct	Nov	Dec
NM	Albuquerque	10.4	9.3	8.0	6.9	6.8	6.4	8.0	8.9	8.7	8.6	9.6	10.7
NM	Clayton	10.5	10.1	9.7	9.1	9.9	9.7	10.6	10.8	10.4	9.8	10.5	10.8
NM	Roswell	10.7	9.6	8.0	7.4	8.1	8.3	9.1	9.9	10.5	9.7	10.0	10.2
NV	Elko	13.3	12.5	11.1	10.0	9.5	8.7	7.3	7.4	8.0	9.1	11.8	13.2
NV	Ely	12.2	11.8	10.9	9.7	9.3	8.0	7.2	7.7	8.0	9.2	10.9	11.9
NV	Las Vegas	8.5	7.7	7.0	5.5	5.0	4.0	4.5	5.2	5.3	5.9	7.2	8.4
NV	Reno	12.3	10.7	9.7	8.8	8.8	8.2	7.7	7.9	8.4	9.4	10.9	12.3
NV	Winnemucca	12.9	11.7	10.4	9.1	8.7	7.7	6.1	6.3	7.2	8.7	11.3	13.2
NY	Albany	13.5	12.8	12.4	11.4	12.0	12.4	12.6	13.6	14.3	13.8	13.9	14.2
NY	Binghamton	15.0	14.3	13.7	12.5	12.6	13.2	13.2	14.3	15.1	14.4	15.0	15.7
NY	Buffalo	15.0	14.9	14.2	12.6	12.2	12.4	12.3	13.2	13.7	13.7	14.6	15.2
NY	Islip	13.2	12.7	12.8	12.5	12.4	12.4	13.3	13.6	13.9	13.7	13.4	12.8
NY	New York	12.2	11.9	11.5	11.0	11.5	11.8	11.8	12.4	12.6	12.3	12.5	12.3
NY	Rochester	14.3	14.3	13.7	12.5	12.3	12.6	12.6	13.6	14.4	14.2	14.6	15.4
NY	Syracuse	14.2	13.9	13.4	12.2	12.3	12.6	12.7	13.8	14.6	14.1	14.6	15.1
OH	Akron	14.6	13.9	13.2	12.2	12.4	12.8	13.0	14.0	14.1	13.5	14.0	14.8
OH	Cincinnati	14.5	13.8	13.1	12.2	12.6	12.9	13.2	13.9	13.9	13.2	13.9	14.8
	Cleveland	14.6	14.2	13.7	12.6	12.7	12.7	12.8	13.7	13.8	13.3	13.8	14.6
OH	Columbus	14.2	13.7	12.6	12.0	12.6	12.6	13.0	13.7	13.8	13.1	13.9	14.6
OH	Dayton	14.5	14.1	13.4	12.4	12.3	12.3	12.6	13.4	13.7	13.2	14.4	15.2
OH	Mansfield	15.4	14.9	13.8	12.6	12.8	13.0	13.2	14.1	14.1	13.4	14.6	16.0
OH	Toledo	14.9	14.3	13.8	12.8	12.4	12.7	13.3	14.3	14.4	13.8	14.7	15.8
OH	Youngstown	15.3	14.8	13.9	12.6	12.5	12.8	13.2	13.7	14.3	13.8	14.6	15.7
OK	Oklahoma City	13.2	12.9	12.2	12.1	13.4	13.1	11.7	11.8	12.9	12.3	12.8	13.2
OK	Tulsa	13.3	12.7	12.1	12.1	13.7	13.5	12.2	12.5	13.8	12.8	13.1	13.5

Black Locust Typical Moisture Content

Live tree → **Cut logs** → **Lumber**





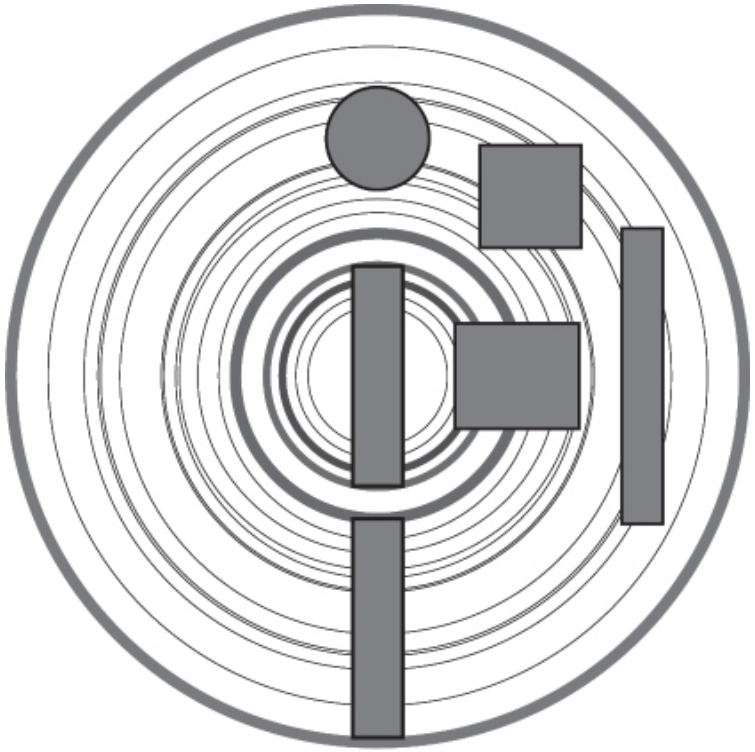
~60% MC

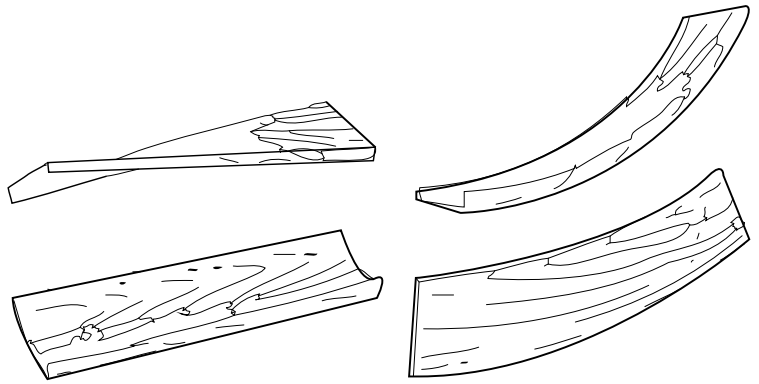
freshly cut tree
35%

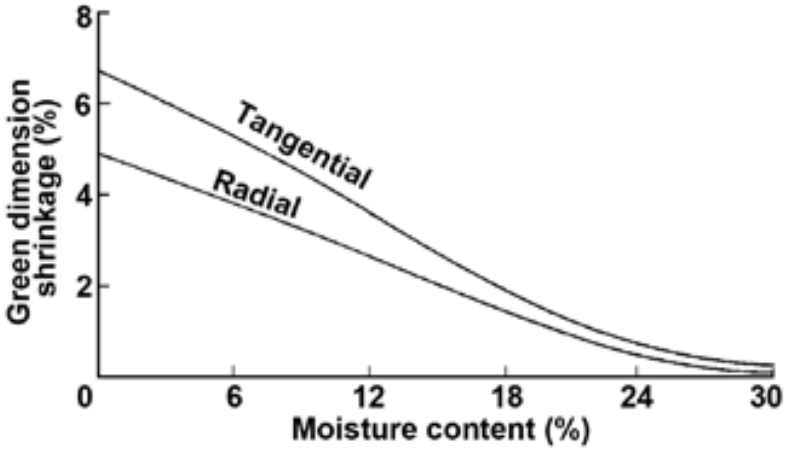
air dry
35% - 25/20%

dependent
on use and equilibrium
moisture content
in a specific location

Dimensional Change of Wood





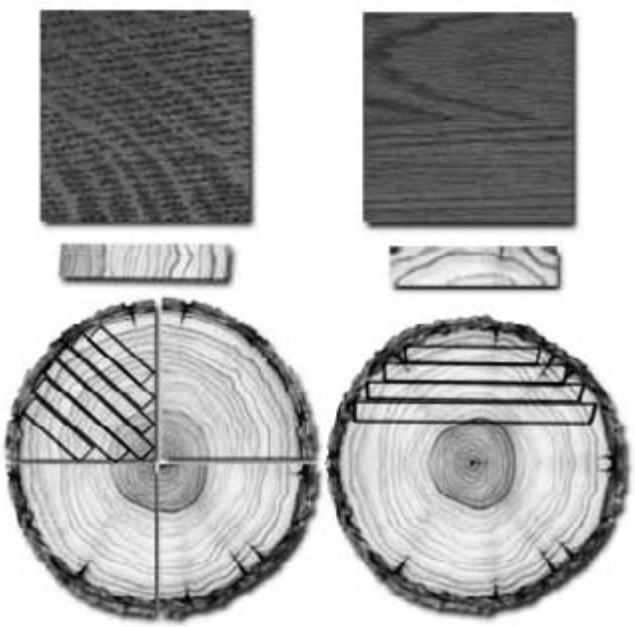


Black locust
Radial 4.6%
Tangential 7.2%
Volumetric 10.2%

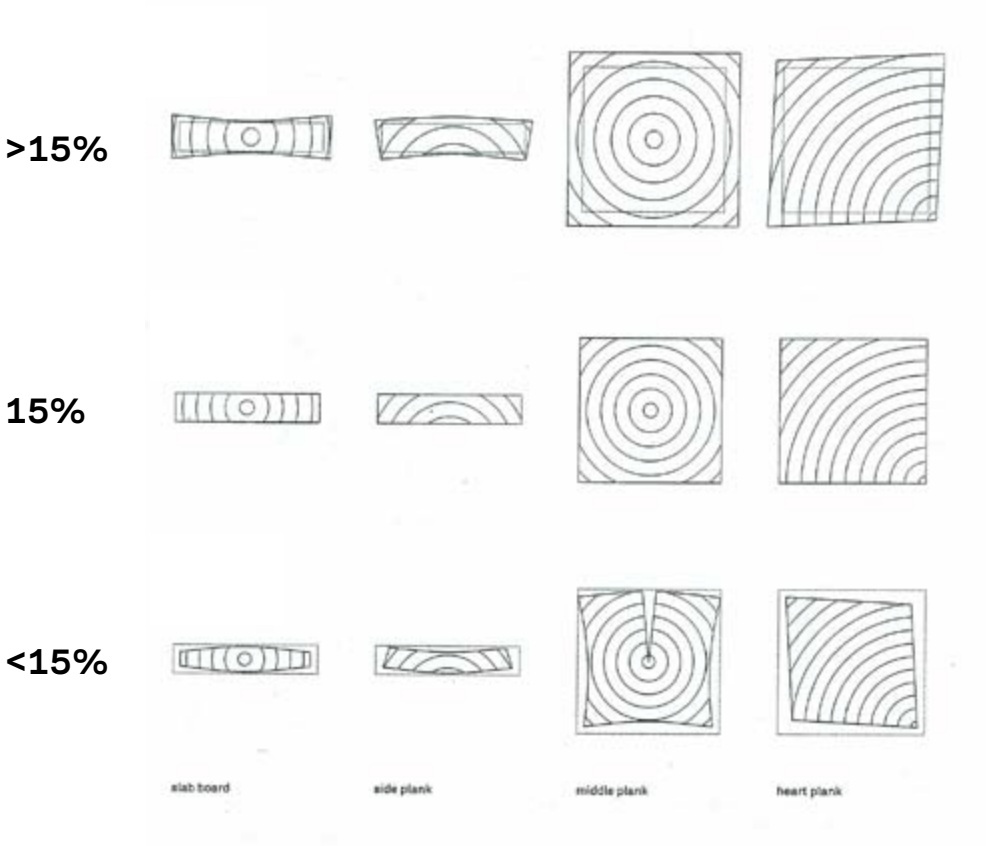
The shrinkage is about 5% to 10% in the tangential direction and about 2% to 6% in the radial direction (Walker et al., 1993).

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

Dimensional Change of Wood

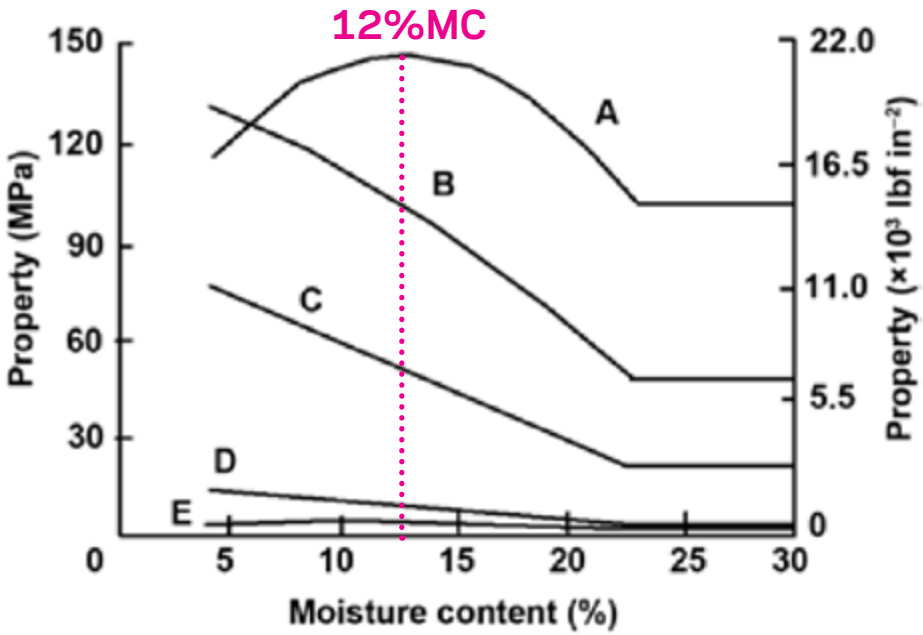


Quarter Sawn Regular Sawn



Relationship of MC and Wood Strength

Effect of moisture content
on wood strength properties



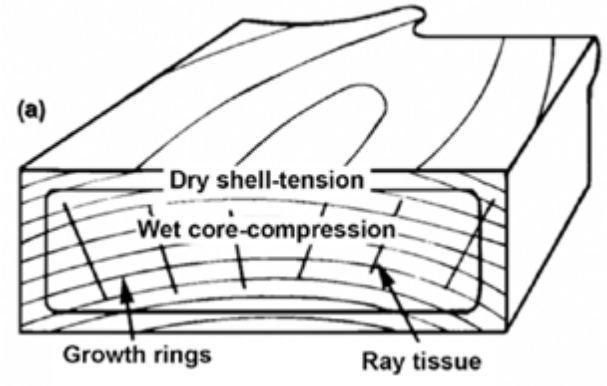
A tension parallel to grain
B bending
C compression parallel to grain
D compression perpendicular to grain
E tension perpendicular to grain

Mechanical Properties of Wood. Wood handbook. Wood as Engereering Material. US Department of Agriculture

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 avoides damage of finishing materials/construction
• dry wood finishes better
• reduces shipping weight



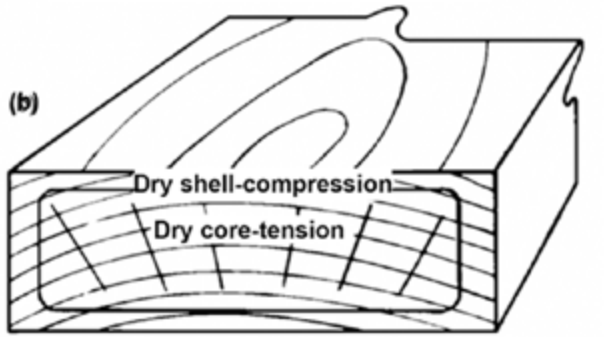
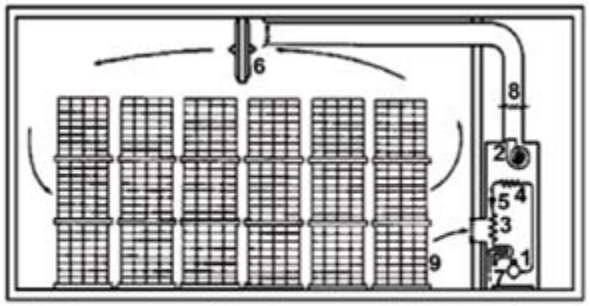
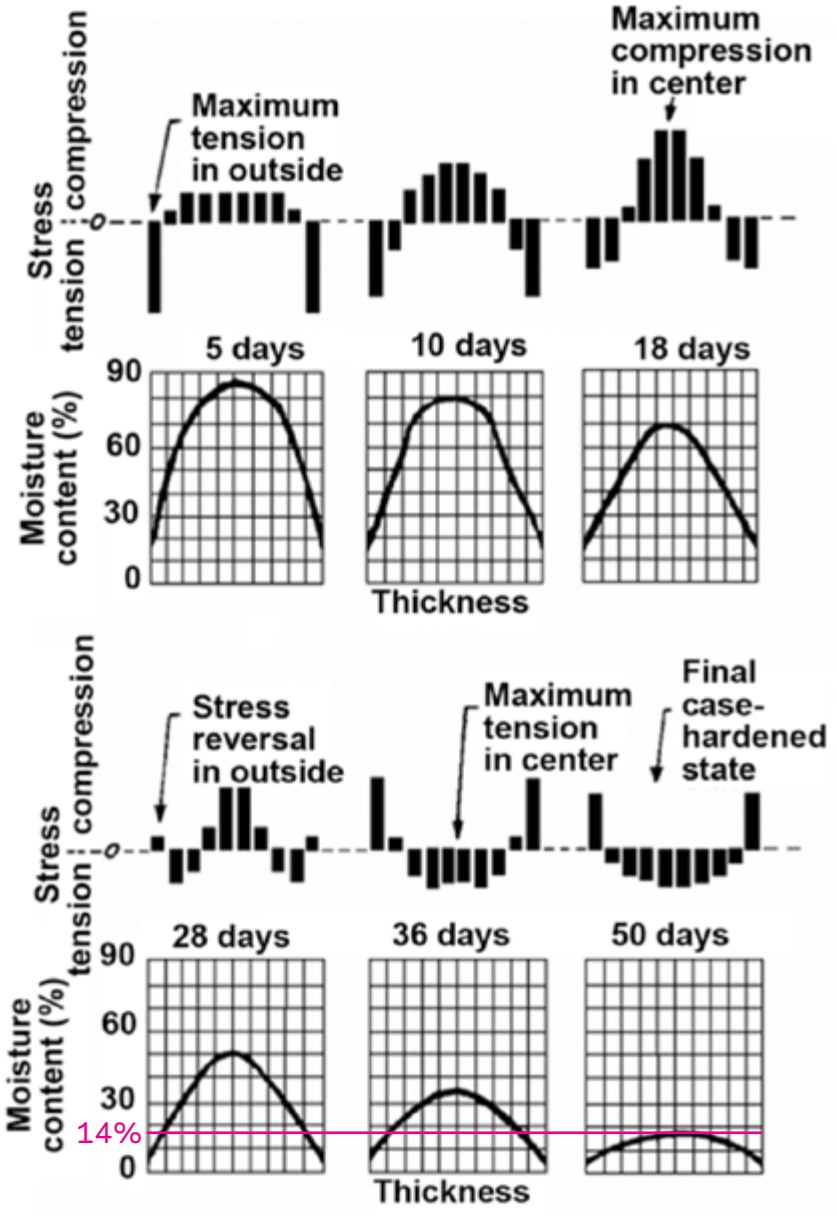


Figure 13–3. End view of board showing development of drying stresses (a) early and (b) later in drying.

Dehumidifier Kiln



airflow
temperature
humidity



Moisture stress relationship
during six stages of kiln drying 2 inch thick red oak

Dry Kiln Operator's Manual - USDA Agricultural handbook AH-188

Black Locust Hydrothermal treatment
(steaming)

Color changes affected by steaming under pressure as a function of controlling parameters: **temperature and time**

Color Homogenization and Colorization

Bending strength and hardness of wood samples 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".

- Inco-XCopernicus Projects No. PL 96-4114. Hydrothermal treatment (steaming) under atmospheric and pressure conditions. L.Tolvaj, S. Molnar. H. G. Richter, T. Riehl. page 11.

Black Locust:
Wood Applications in Hungary

About 8500 ha of black locust is harvested yearly in Hungary.

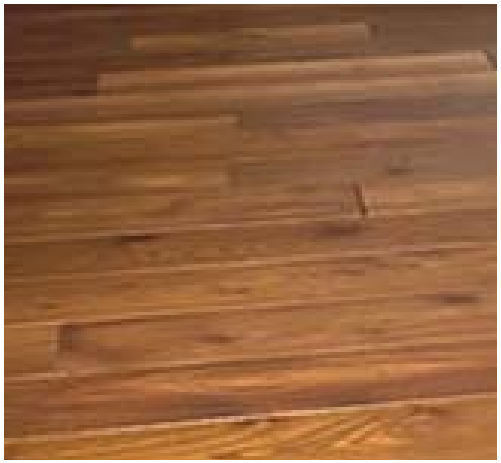
Together with thinnings, the annual timber volume felled in black locust stands amounted to 1.1-1.6 million m^3 gross on average for the last 5-7 years.

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



Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Eurobinia Company

Kajászó

Eurobinia Company

Kajászó

Eurobinia Company

Kajászó

Dunaker Company

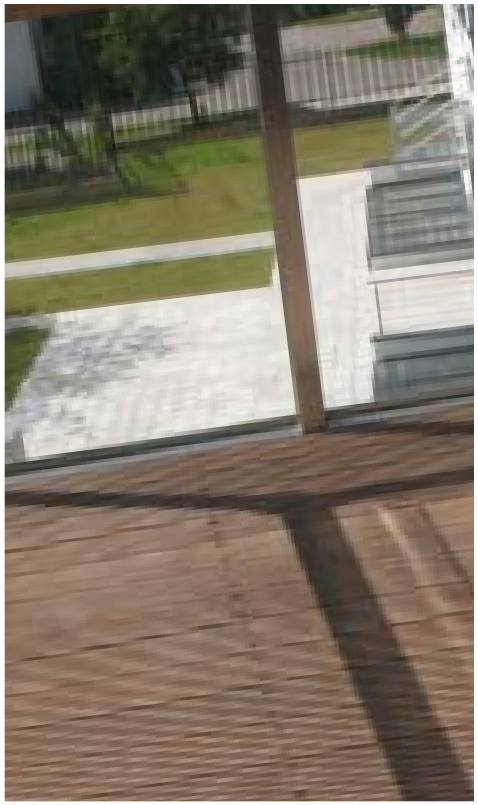
Products:

* **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

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



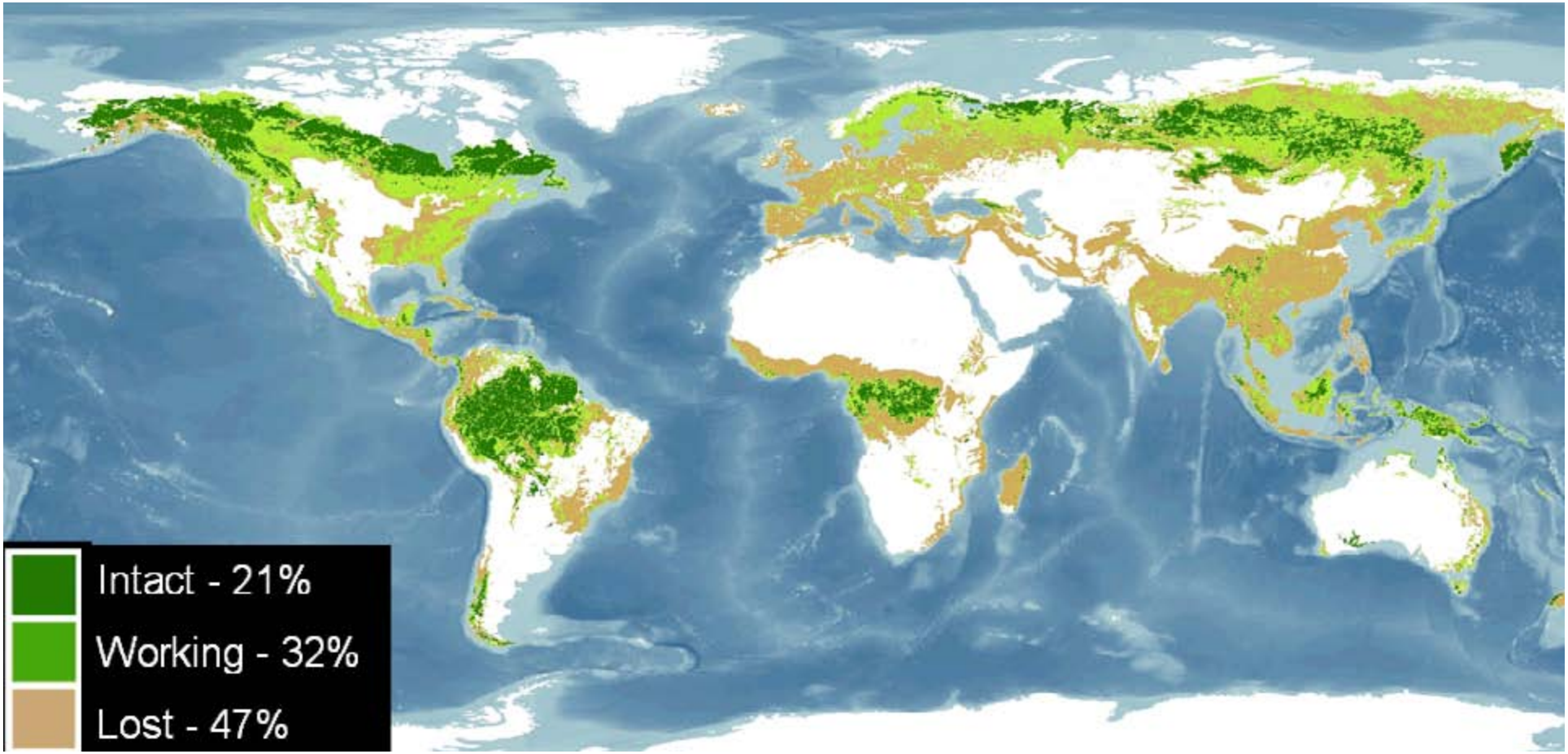
Black Locust Lumber: A Sustainable Alternative
San Diego, November 1, 2011

Dreweko

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

Decrease in Forest Resources



Decrease in Natural Resources

Map credit: World Resources Institute

"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

original vs current extents

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.

there are globally **2.5 million** ha around the world and there is a global tendency to plant more of it

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

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

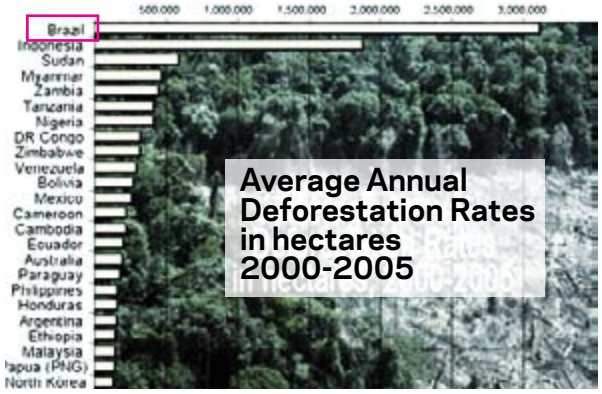
Ipe (Brazilian Walnut)

original vs current extents

Ipe *(a group of 7 species native to rainforest)* in **South and Central America**

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.



http://rainforests.mongabay.com/0801.htm#tables

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

	Ipe	Black Locust	Northern Red Oak	Alaskan Yellow Cedar	Pine	Concrete	Steel	Trex
specific gravity	0.92	0.69	0.63	0.42	0.40	NA	NA	0.91 to 0.95
density (Lbs/ft^3)	64	43	47	30	27	145	490	-
max tensile strength (perpendicular to grain) (psi)	3,680	1,700	1,010	500	580	0	40,000	854
max crushing strength (psi)	13,010	10,800	6,760	7,520	5,320	7,500	40,000	1,806
modulus of rupture (psi)	22,600	19,400	14,300	11,354	9,427	4,000	29-30 million	1,423
modulus of elasticity (MPa)	21,600	14,100	12,500	11,000	8,900	21,720	200,000	1,2
decay resistance 1 - very resistant 2 - resistant 3 - moderately resistant	1	1-2	2	2-3	3	1	1	1
manufacturing and delivery process	felling, milling, and shipping	felling, milling, shipping, air and kiln drying,	felling, milling, shipping, air and kiln drying	felling, milling, shipping, air and kiln drying, finish	felling, milling, shipping, air and kiln drying, finish	sourcing and making materials for mixture of: Portland cement, fly ash, slag cement, aggregate, water, and chemical admixtures	intensive process of sourcing and smelting of iron and carbon	producing a composition of 50% wood and 50% plastic fibers

Black Locust vs IPE

Price Comparison

Black Locust

Dimensions:

26 mm x **80** mm by **2400** mm

(1.02 inch x 3.15 inch by 7.87 feet)

moisture content 8%

5.44 USD SF

in an order of one full container

Price includes shipping from Hungary plus merchandise fee

Ipe

Dimensions:

1 inch x **3** inch by **8 feet**

(25.4 mm x 3.15 inch by 7.87 feet)

moisture content 16% -18%

7.19 USD SF

Price includes shipping from Brazil

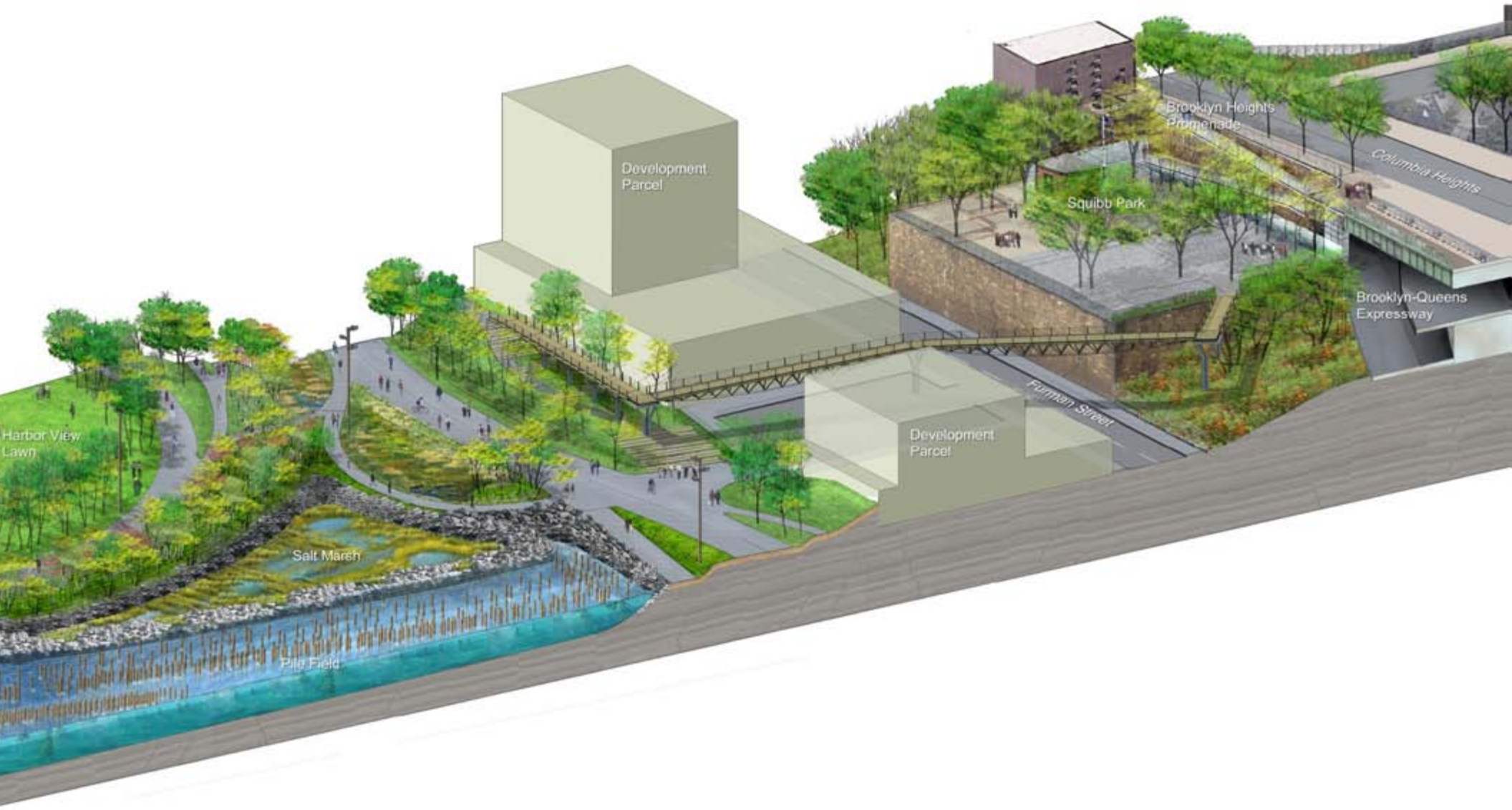
Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Squibb Park Bridge

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

Squibb Park Bridge



Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Squibb Park Bridge

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

Squibb Park Bridge

100 Year Old Timber Bridges

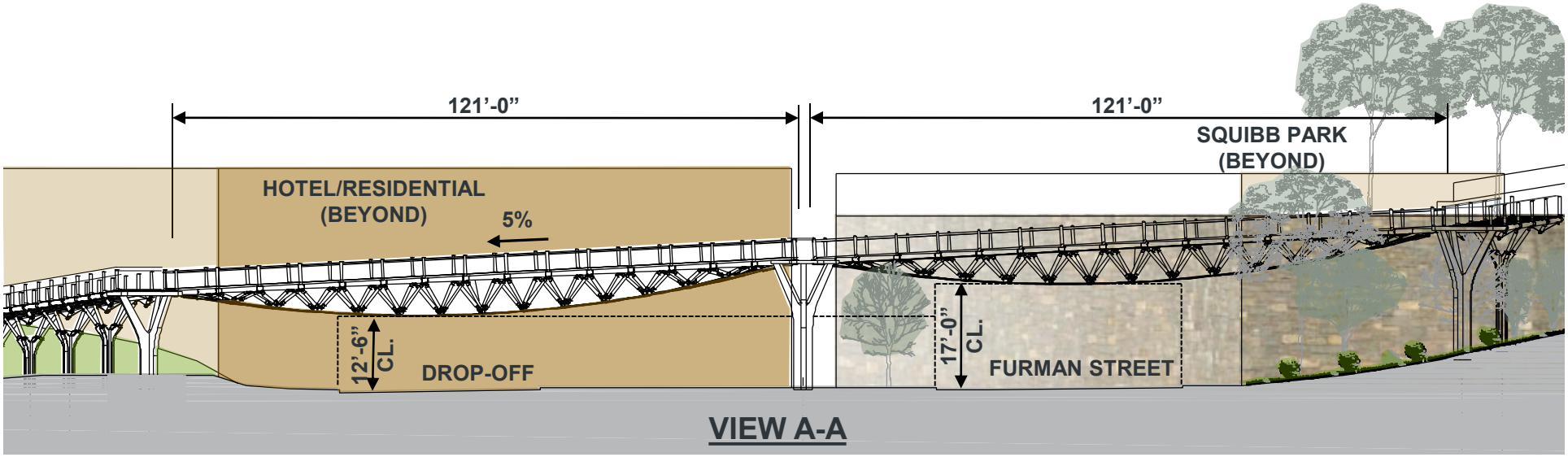
Wood Street Railroad Bridge, Built 1909, IL

Holcomb Creek Railroad Bridge, Built 1905, WA

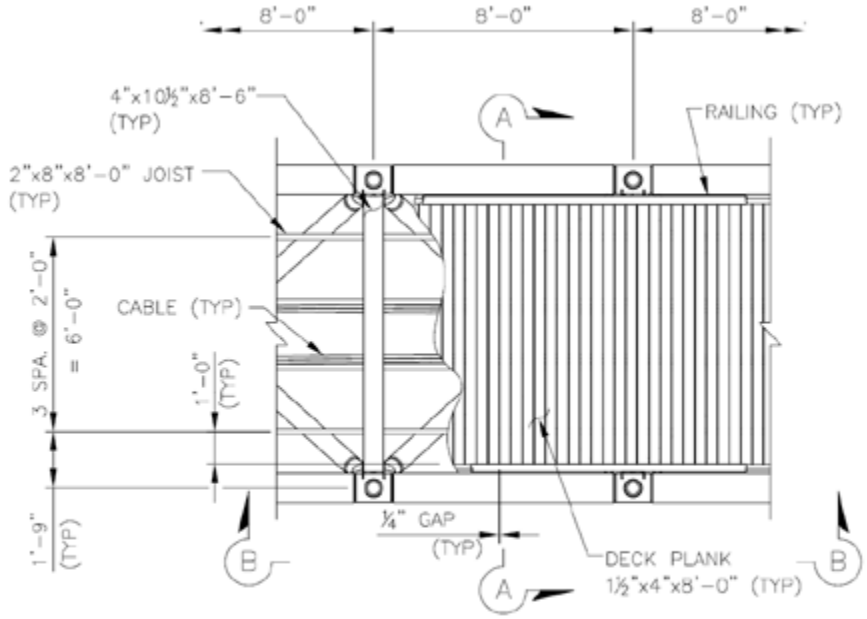
PLAN

Underslung Suspension Bridge:

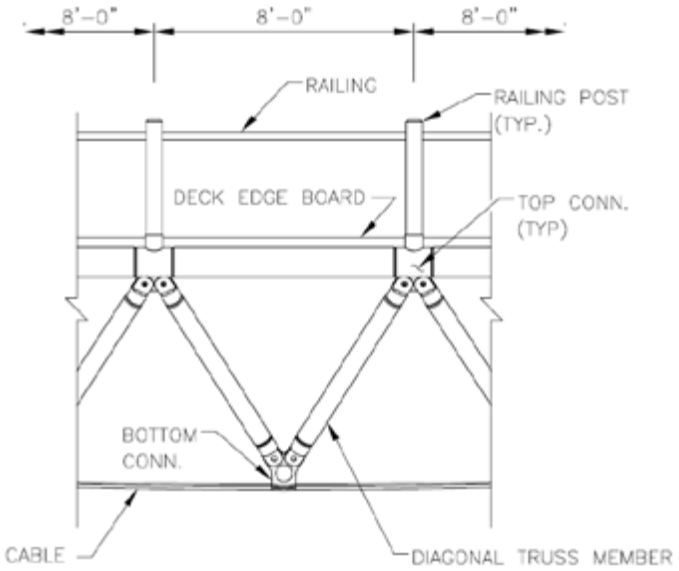
- Highly efficient form
- Material palette from BBP
- Small dia. Black Locust, steel cables, & bronze connections



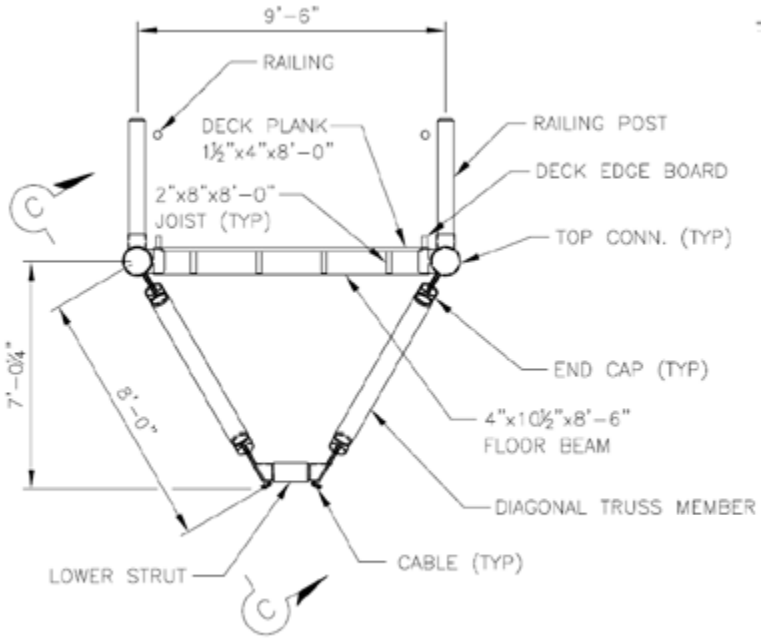
VIEW A-A



DECK PLAN



VIEW B–B



SECTION A–A

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)

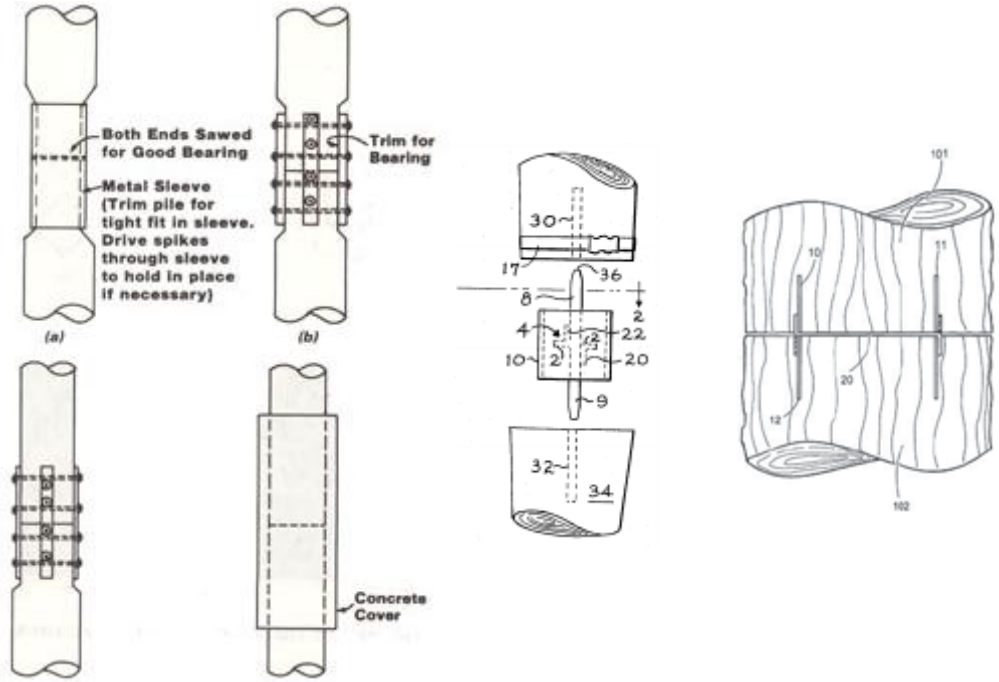
- Lowest shrinkage of domestic woods

Stainless or Galvanized steel cables & hardware

Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Squibb Park Bridge : GREEN, ROUGH CUT TIMBER IN A WET ENVIRONMENT



Timber Piles – standard and proprietary connections

Black Locust Lumber: A Sustainable Alternative

San Diego, November 1, 2011

Squibb Park Bridge: Decking

Comparative Behavior – Steel vs Timber
Loaded Beam Tests at SwRI

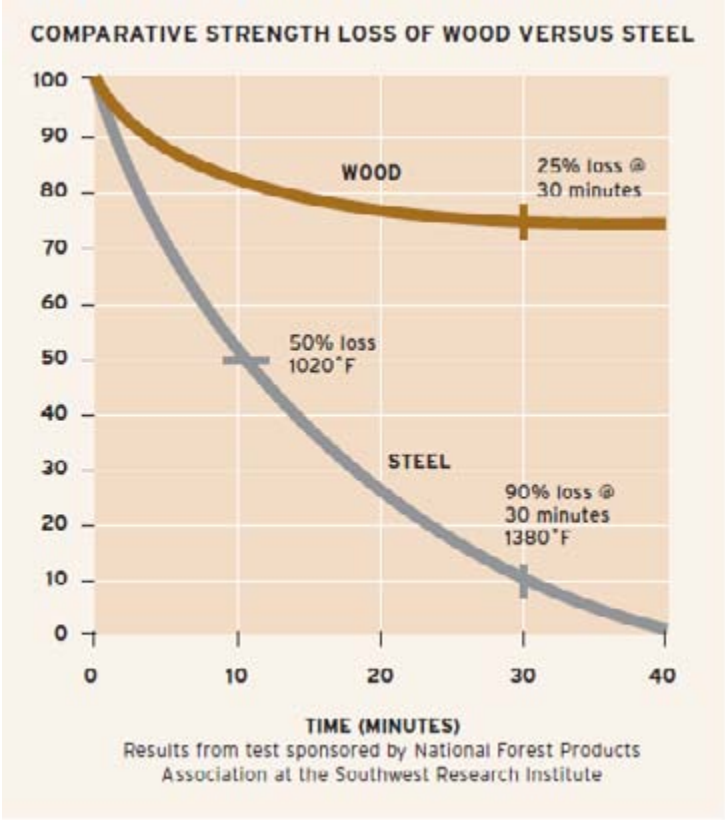


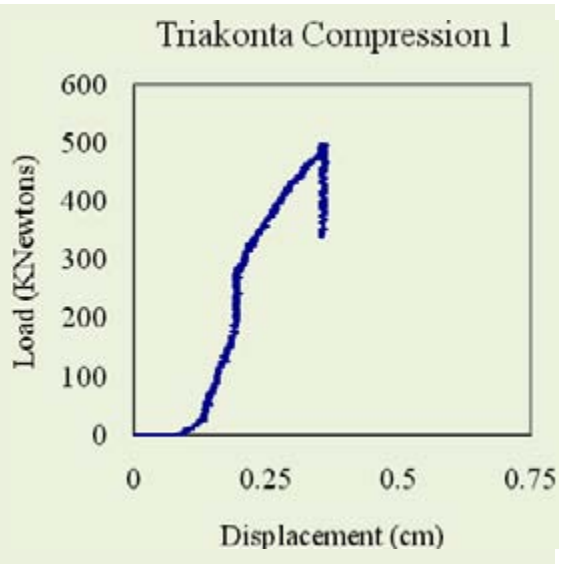
Figure 1. Timber pole in the 15 m long lathe at TTT Ltd

Structural Systems - Triakonta:

Round members
Problematic connections

Squibb Park Bridge

Turning a Black Locust Log, Cornell University, 2010



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

Black Locust Lumber: A Sustainable Alternative

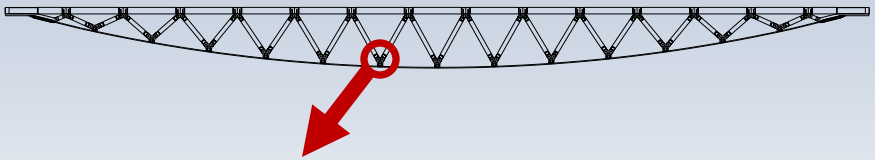
San Diego, November 1, 2011

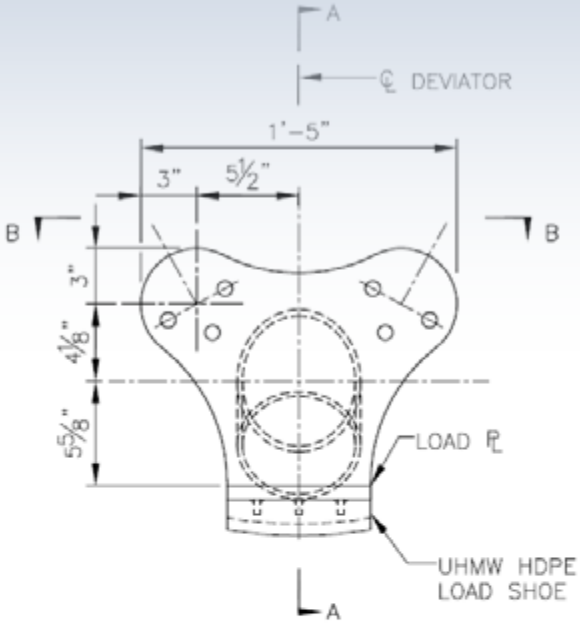
Squibb Park Bridge

Black Locust Lumber: A Sustainable Alternative

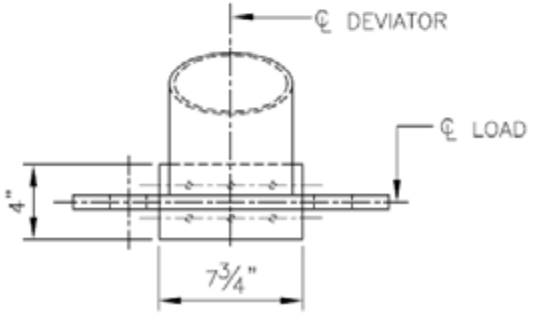
San Diego, November 1, 2011

Squibb Park Bridge

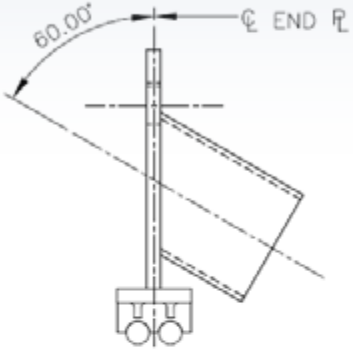


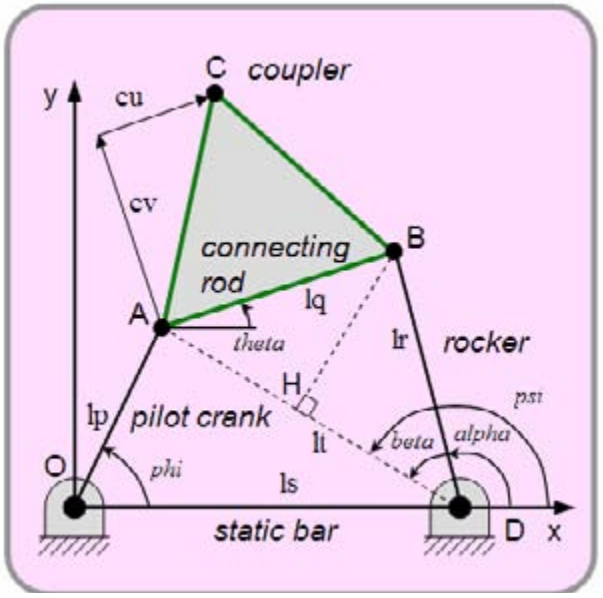


CABLE DEVIATOR



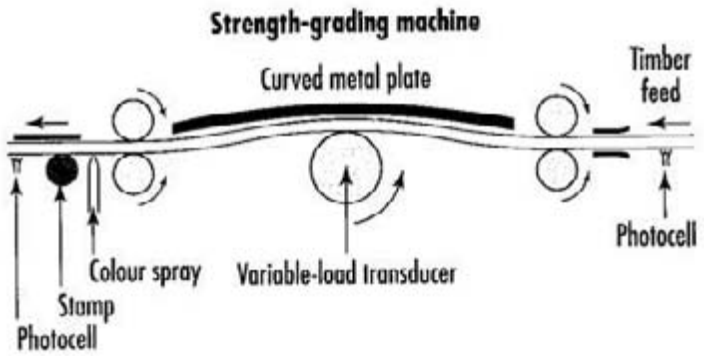
VIEW B–B

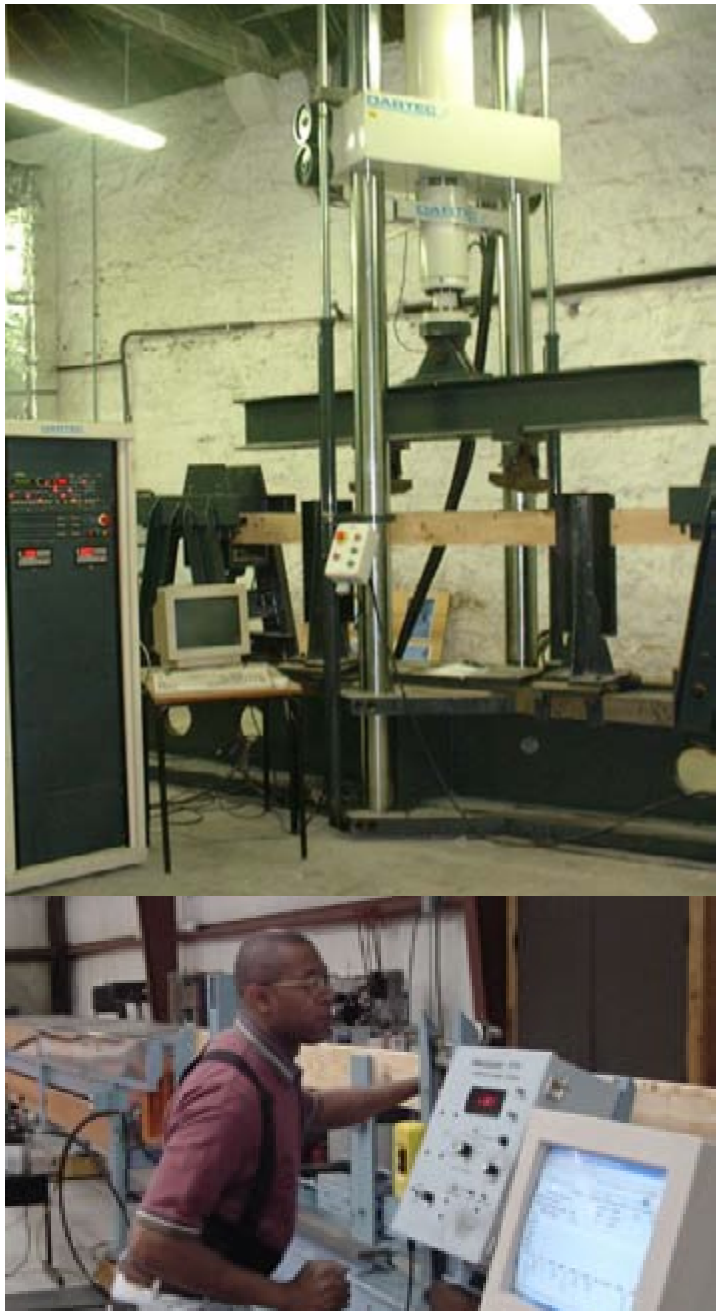




Four Bar Linkage

Machine Stress Graded Lumber:

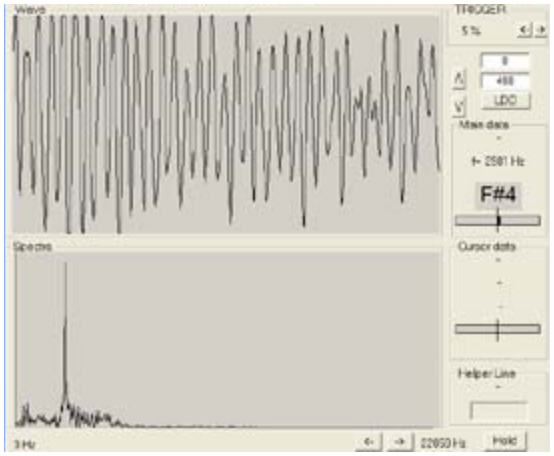




- **Compression, tension, & bending**
- **Expensive laboratory-style equipment**
- **Need battery of test data**
  - **Calibrate design values**
  - **Establish appropriate factors of safety**

“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.

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…….***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.

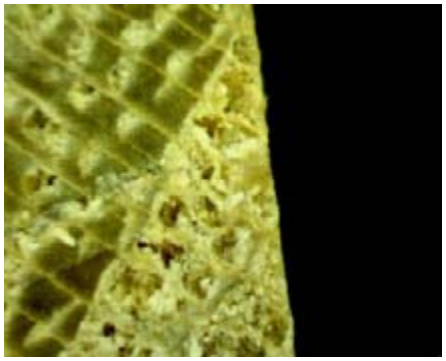
Biological

- 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.

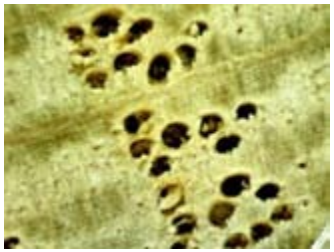
Mechanical

- 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.

End view of Black Locust board



End view of tyloses filled Black Locust. 100X



End view of Red Oak 100X. Note the open xylem.

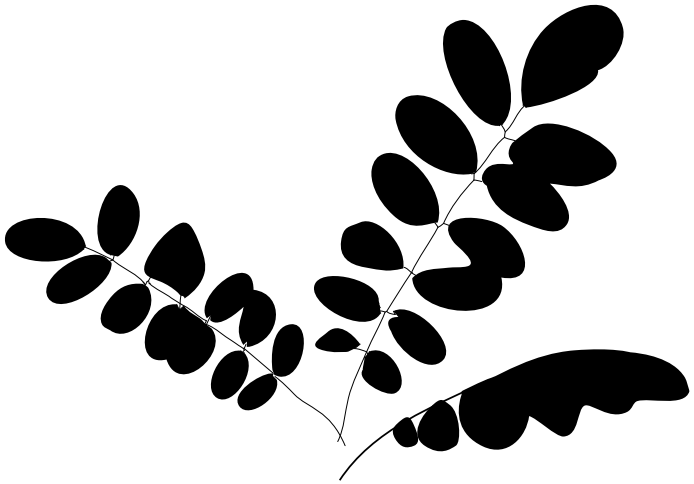
Why isn't black locust wood more popular in US?

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