WORLD FOREST GROUP

A BETTER TIMBER MAT

Technical Paper: A Better Timber Mat

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EXECUTIVE SUMMARY

The purpose of this Technical Report is to explain the Whys and Hows of Stronger, Standardized, and Safer through an analysis of the strength and working characteristics of hardwood mats manufactured from *Eucalyptus grandis*. We use Southern Red Oak (SRO) as an example for comparison purposes.

Relative to Southern Red Oak, Eucalyptus mats are found to have:

- 32+% greater crushing strength, 40+% greater bending strength
- 20% lighter weight for lower delivered initial costs,
- 19% harder surface for greater resistance to surface gouging.
- As durable to rot and insects as Southern red oak mats.

A stronger and standardized mat means lower ongoing operating costs (less failures and lower transport costs). Stronger and standardized implies safer.

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INTRODUCTION

A Better Timber Mat

You need A Better Timber Mat, one that is Stronger, Standardized, and Safer.

Stronger means your mat will take more load and use.

Standardized means each mat you buy will be the same and that the variability between mats is small. Same mat design. Better materials. One species. Eucalyptus.

We believe our mats are safer because a strong, standardized timber mat is a safe timber mat. Strong timbers come from strong species. Plantation eucalyptus has known mechanical properties, is stronger than domestic USA hardwoods, and has less variability than domestic hardwoods. Strong raw materials, consistently well-manufactured makes a reliable, standardized timber mat. Reliable and standardized = safer.

Mat Value

World Forest Group's Eucalyptus mat provides more mat value inch for inch, dollar for dollar. These mats are affordable, can take the load and use, last a long time, and have uniform quality.

Mat cost, which is part of mat value, is normally driven by four factors:

- Purchase price,
- Strength in use,
- Durability (such as hardness, rot and insect resistance), and
- Transport cost.

All things being equal, a stronger, standardized, and safer mat is better mat value than a weaker, non-standardized mat.

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BACKGROUND

The Industry Today – Relying on Mixed Hardwoods

Most hardwood mats produced today are from mixed domestic hardwoods. The industry has long accepted mixed hardwoods as a common and standard source of raw material for crane / swamp / access mats. Hardwood mats typically perform better than softwood mats and have a longer useful life.

Although some mats are also made from SRO one industry expert estimates SRO mats at only 1% of the total mats in use.

If SRO is only 1% of the mat market, why do we use SRO as a comparison species? Because it's one of the strongest and best-known species, and if Eucalyptus can perform equal to or better than SRO it can outperform normal mixed hardwood mats.

Using mixed species hardwood to build mats means the final product has highly variable working characteristics and durability. That's because the wood used comes from 15-20 species from naturally grown mixed species forests. Different species may exist in the same mat. The result is that mat properties tend to vary considerably.

Eucalyptus – An Alternative to Mixed Hardwoods

World Forest Group's Eucalyptus mats are made of sustainably produced plantation timber and offer greater strength than USA hardwood mats of similar dimension. Because we use a single species of plantation grown wood, we can produce a more uniform product.

Eucalyptus is a hardwood, originally from Australia, is now grown extensively in plantations throughout the world, and makes up a significant portion of the world's 700 million acres of plantation forests.[i]

The working characteristics of Eucalyptus species from which World Forest Group makes its mats have been studied extensively and these species have been grown for over 100 years in Brazil.[ii]

Measuring Strength Characteristics - Sources of Data

There are two American standards and one European standard for reliable data.

1. The US Forest Service Forest Products Laboratory (USFS FPL) publishes the definitive sourcebook for wood species. The *Wood Handbook: Wood as an Engineering Material* is available free here. Chapter Five shows testing data for all domestic and Canadian woods and many imported species including eucalyptus[iii].
2. The second source, the American Wood Council, publishes their National Design Specifications for Wood Construction (NDS) as well as a Supplement that lists most North American woods and their working characteristics (for example, bending strength, compressive strength, and others). Much of the NDS data originates with the FPL data with applied safety factors.
3. The (excellent and simple) Eurocode 5 specification classifies wood strength into general wood classes, where higher is better. For example, European Oak, which itself is stronger than American Oak, is class D30. Eucalyptus is class D40.

Differences between Testing Data & Design Specifications

The FPL data are *testing* data. The NDS and Eurocode data are *design specifications* using the same or similar data, with safety factors applied for real use calculations. Those safety factors are applied to answer questions such as, "How big does a post need to be to hold up a roof", or "How thick of a mat must I have on sandy soil to support a crane lifting X tons of material"?

If you are looking at comparing two different mats, for example, mixed hardwood to eucalyptus or oak to eucalyptus, then *any* of the standards will work.

But if you are doing anything with an engineering requirement then you need to use design specifications. Your engineering department already knows this.

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SOLUTION–DRIVEN BY THE NUMBERS

In this section we look at empirical data on Eucalyptus mats including:

- Basic data on Strength and Hardness of Eucalyptus wood
- Test results of Eucalyptus species from recognized authorities
- Real world sampling of World Forest Group Eucalyptus mat timbers.
- Opinions of two independent engineers

Various Strength Measurements

Some appropriate measurements for evaluating mat strength are:

- Strength of mat on a flat surface or Maximum Crushing Strength,
- "Gouging" or Hardness (measured by Janka hardness test), and
- "Bridging" purposes, or Bending Strength (Modulus of Rupture)[iv]

For most access mat users, the first two measurements will be important. For crane mat users Maximum Crushing Strength and Bending Strength will be more critical.

Eucalyptus shows higher strength characteristics than SRO.[v]

Maximum Crushing Strength

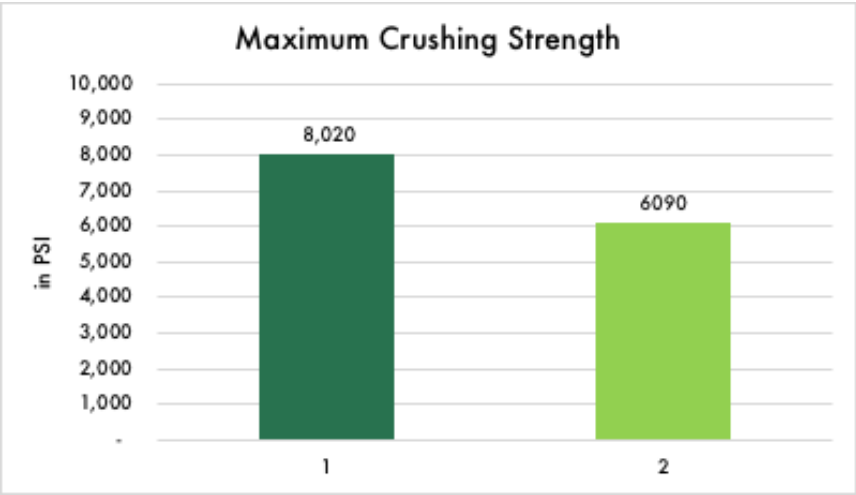

Figure 1 - Eucalyptus is 32% stronger than SRO[vi]

Hardness

One of the key issues for mat users is the impact crawlers make on wood when moving and turning. The grousers on the track are a particular source of impact. Eucalyptus has a Janka Hardness rating which is about 19% greater than SRO.

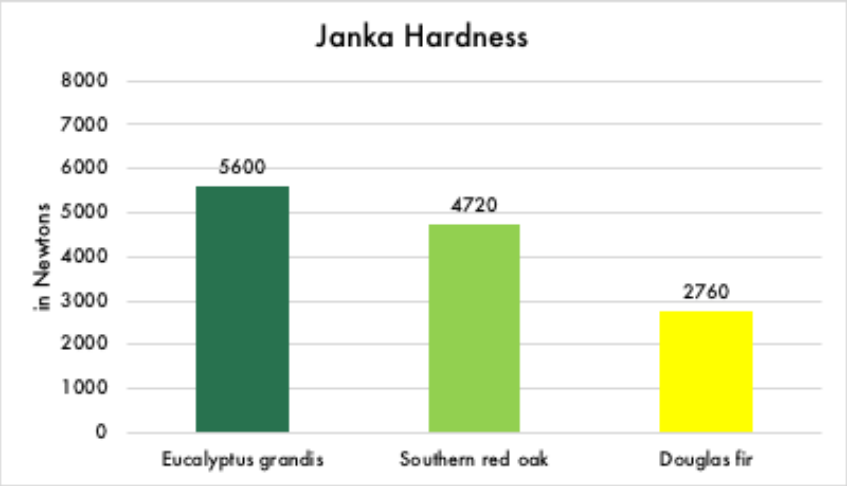

Figure 2 - Eucalyptus 19% harder than SRO and 103% harder than Douglas fir[vii]

Bending Strength

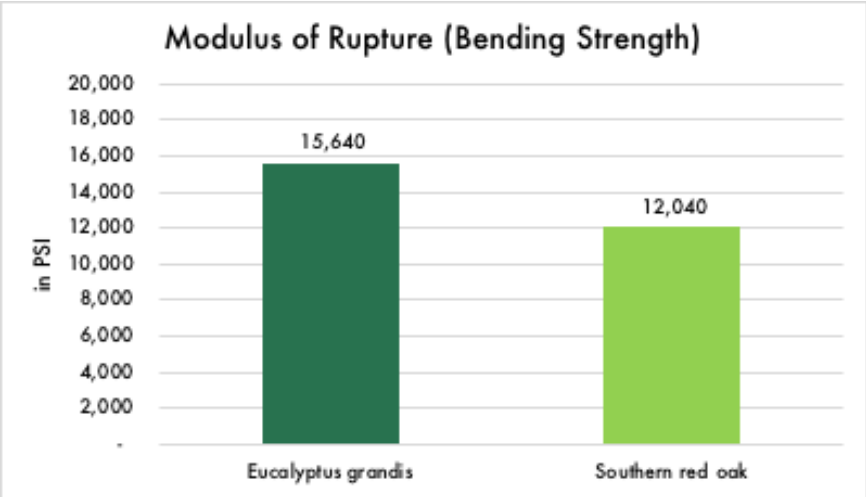

Figure 3 - Eucalyptus is ~30% stronger than SRO

In respect to bending strength or modulus of rupture: Because Eucalyptus is stronger than SRO an 8" Eucalyptus mat may compare favorably with a 9"–10" SRO mat.

The reason why 8" Eucalyptus is equivalent to a 9"–10" SRO mat is because bending strength is a function of the square of the thickness. So, even though Eucalyptus has a much higher modulus of rupture than SRO – 25%-50% depending on the kind of analysis – the thickness of the mat will dominate the calculations.

Empirical Testing

In addition to laboratory testing one can do real-life testing. World Forest Group has performed multiple *controlled* mat tests. A controlled mat test uses uniform and statistically valid methods to examine each mat tested. For example, to evaluate mat impact we might use a transect on both sides of the mats and count the impacts.

As an example, an *uncontrolled* mat test would simply compare two different types of mats on a job site without using the same machine, the same operator, the same underlying soil type, and so on. There would be no transect use to count impacts.

We have also contracted with a local university to regularly test mat timbers. We now have sufficiently large measurements of timbers (>1200) to draw strong conclusions.

Mat Testing with Track and Tire Machinery

Tracked vehicles stress the mat in respect to compressive stress and hardness. A wheeled machine exerts more compressive stress on a mat than a flat track tractor because the weight is concentrated where the tire meets the wood. A tractor with grousers will exert similar PSI as a wheel loader as the weight is distributed only across the grousers.

Figure 4 - Crawler on mats. Crawlers without grousers exert far less bending stress than wheel loaders.

Figure 5 - Bending test of 18′ x 8″ x 48″ Eucalyptus mat with 2x3 braces. No bending.

Figure 6 - Bending test with 150,000+ lbs. in bridging application of 18′ x 8″ x 48″ mat. Mat flexed less than expected indicating Eucalyptus mats are as strong as engineer predicted.

We also know that mats get bumped, scraped and dropped during their life. We periodically do a "drop test" to simulate rough handling. Results confirm that the mats perform well. In one test, it took 13 drops before the mat was compromised enough so that the mat moved from Grade A mat to Grade C mat.

Figure 7 - Drop test from 16 feet onto hard soil. Mat was dropped 13 times before moving to Grade C mat.

Decay & Durability

Decay (usually biological) and durability (usually non-biological, like weathering) of wood species has been scientifically studied for over a hundred years.[viii]

The US Forest Products Laboratory tested eucalyptus heartwood, SRO, and northern red oak and classified all as decay resistant.[ix]

From a durability point of view plantation grown eucalyptus is as durable as the oaks.[x]

Eucalyptus mats have more product uniformity because they are made from single species plantation wood. They are less likely to have weak spots that normally happen with natural grown wood. The greater strength properties make Eucalyptus more resilient to accumulated stresses, leading to longer life on a like-kind use basis *vs*. SRO.

There is reason to believe that these mats should last a long time. The exact same species from the exact area we source from are also used for fenceposts, which have constant exposure to soil. We've heard that the posts last 10-15 years. We wouldn't claim that for our mats, but they should last longer than USA mixed hardwood mats.

Independent University Testing

As part of our ongoing Quality Control we test representative samples of the ends of mat timbers.

1. *These samples are real life samples;* the samples are taken from 18-foot timbers from which we make our mats.
2. Although we have quality specifications for our timbers, *the samples are not "clear small samples"* as the US Forest Service Forest Product Laboratory (FPL) uses. FPL clear samples would generally be the best quality wood.
3. *The FPL data was done in* 1950 and was performed on samples from trees which are much larger diameter and better quality than is currently commercially available to the mat industry in 2018.
4. *The ASTM testing protocol is the same as FPL used - ASTM D143.* USFS bulletin 1780, published in 1960, and which researched variability in USA northern oak samples (and other species), *shows that the variability in our real-world samples is similar to the variability of FPL clear samples.* The coefficient of variability on our wood (non-clear samples) is almost exactly same as coefficient of variability on clear FPL northern red oak.
5. The FPL sample size and World Forest Group sample sizes were very similar.

	WFG real world samples			
Test	Average	Standard Deviation	Coefficient of Variation	Number of samples
Bending (Mpa)	51.77	11.37	21.97%	273
Shear (Mpa)	17.27	3.2	18.69%	250
Allowable compression perpendicular	25.81	8.02	31.10%	505
Specific gravity green gr/cm3	0.76	0.12	15.25%	1280
Modulus of elasticity (Mpa)	7,414	2,362	32.14%	273
Parallel compression (Mpa)	26.12	3.74	14.41%	252

Table 1 - Independent University testing data on real-world timbers

Independent Structural Engineers

Two independent structural engineers reviewed the testing and the data.

Engineer One concluded that, "From a structural engineering point of view, and considering the available information, I would estimate that your 8-inch eucalyptus mats should be roughly equivalent to an 11-inch or 12-inch SRO mat."[xi]

Engineer Two analyzed the mat capacity and the demand from a Caterpillar D11T resting solely on its grousers for bending, shear and compression. Capacity using American Wood Council's National Design Specifications 2015 exceeded the calculated demand by a factor of two to three.[xii] His conclusion was, "The 8" x 48" x 18' Southern Red Oak timber mat appears to be sufficiently designed for loading of a D11T Bulldozer even on the worst soil conditions. However, SRO has much less reserve capacity than that of the Eucalyptus mats. Additionally, there will be heavier construction vehicles for which the 8" x 48" x 18' Southern Red Oak mats will fail, but Eucalyptus mats will still be able to carry the load. Additionally, the side hardness of Eucalyptus is 1.5x that of Southern Red Oak, which means that the Eucalyptus mats will be much less prone to deformation, leading to a longer mat life."

A Houston-based structural engineer provided a letter with strength numbers for users to calculate loads themselves. *Letter available upon request.*

Reliable Supply Chain

World Forest Group manufactures its Eucalyptus mats in Brazil. The timbers are milled from logs harvested from well-managed forests. We then perform quality control inspections on all incoming timbers and then manufacture the mats in our own production facility near the port. Mats are shipped and arrive in Houston and other ports weekly. We are the importer of record and have an import permit with the US Department of Agriculture. We usually have mats in Houston for immediate delivery.

Figure 8 - Mats ready for shipment.

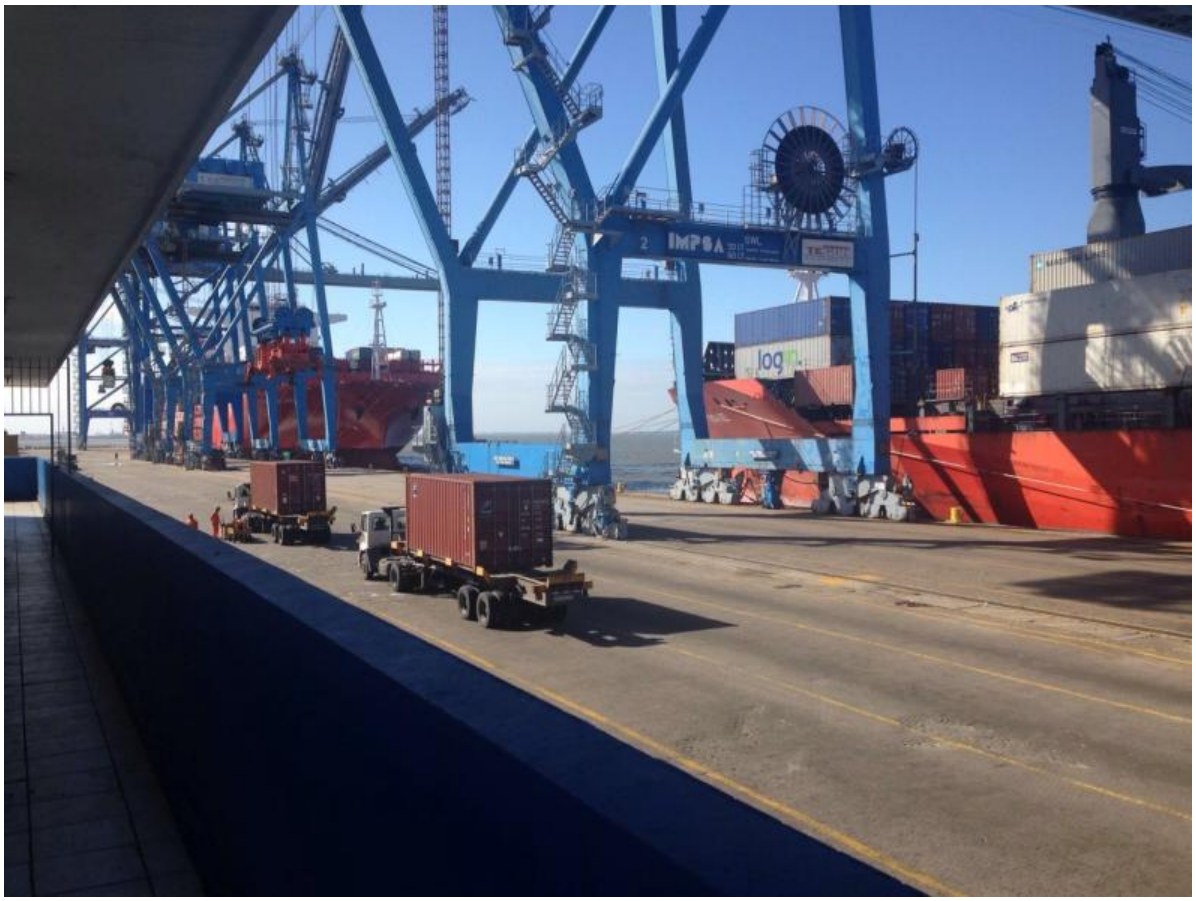

Figure 9 – Mats on way to loading. Port is new and highly reliable. World's largest ocean carriers service this port.

CONCLUSION

You are going to spend a lot of money on mats and you need *a better timber mat, one that is stronger, standardized and safer*.

This report explored why Eucalyptus mats outperform the standard alternatives and the whys and hows of strength characteristics and testing.

Eucalyptus is stronger with more uniform characteristics and can provide superior value in comparison to domestic hardwoods. In comparison to typical southern red oak mats, Eucalyptus provides substantially more strength for the same thickness.

Southern Red Oak mats are stronger than mixed hardwood mats; Eucalyptus mats are therefore a better value than mixed hardwood mats.

A user of World Forest Group Eucalyptus mats gets A Better Timber Mat with all the advantages of greater *strength, standardization and safety*.

REFERENCE MATERIAL

Janka Hardness

In this test a standardized steel ball is pressed into wood until the ball has entered 50% of its thickness. Hardness is an important measure of how gouged the mat surface will get over repeated use.

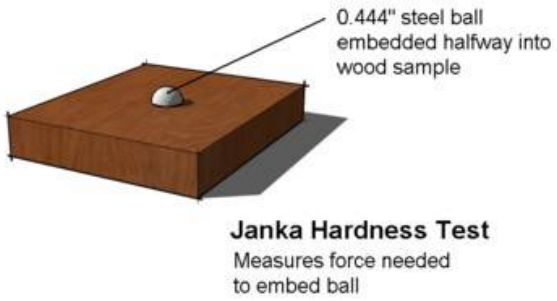

Figure 10 - Janka hardness methodology[xiii]

Maximum Crushing Strength

The crushing strength is the maximum load that can be applied to a unit area before it reaches its failure state. The maximum load it can resist depends only on the area to which the load is applied. For instance, when a tire transmits the weight of a vehicle to a slab, the wood will be crushed when the weight of the vehicle divided by the area of the tire in contact with the slab is equal to the maximum crushing strength. The beam would not break in half, but the top fiber would be crushed under the weight.

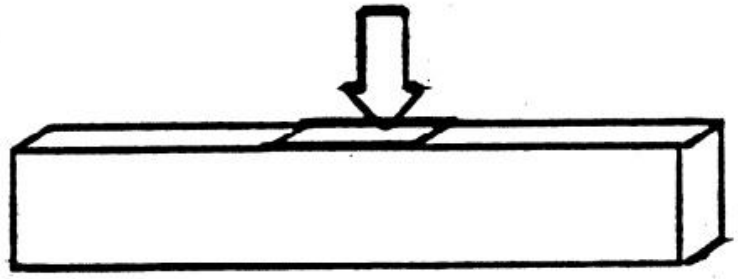

Figure 11 - Maximum crushing strength. (Also known as compression parallel to the grain)

Bending Strength

Bending strength measures maximum stress right before failure. As mats typically lie flat on the ground the measurement can be useful more in relation between species than in predicting failure. One place where thicker is better is in long bridge spans as the load will be suspended from two points rather than supported by the ground. The square of the thickness of wood is inversely proportional to the force applied to the wood. So, if wood thickness goes up by 50%, the force on the mat drops to only 44% of original force. (1 / $1.5^{\wedge 2}$ = 44%). As indicated in the following tables Eucalyptus has significantly higher stress capacity than most wood mats.

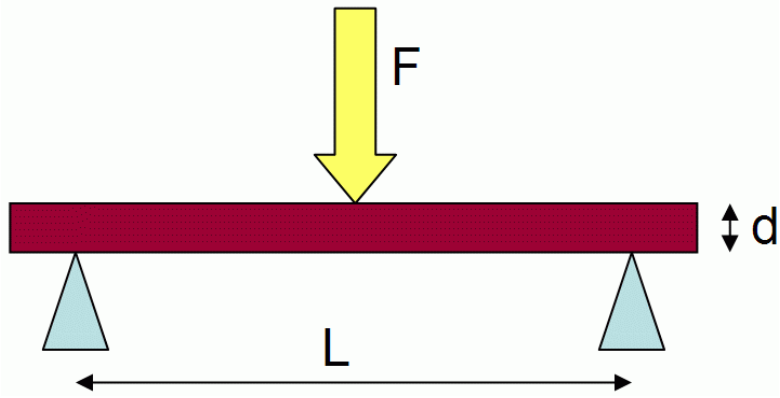

Figure 12 - Modulus of rupture (bending strength) test.[xiv]

		Modulus of rupture		Maximum Crushing Strength		Modulus of Elasticity		Janka Hardness
Common name	**Scientific Name**	**Mpa**	**lbf/in^2**	**Mpa**	**lbf/in^2**	**GPa**	**lbf/in2**	N
Eucalyptus grandis	*Eucalyptus grandis*	107.9	15,640	55.3	8,020	14.2	2,052,000	5,600
Southern red oak	*Quercus falcata*	83.0	12,040	42.0	6090	10.2	1,480,000	4,720
Douglas fir	*Pseudotsuga menziesii*	86.2	12,500	47.9	6,950	12.2	1,765,000	2,760
Eucalyptus grandis is stronger than Southern Red Oak		30%	30%	32%	32%	39%	39%	19%
Eucalyptus grandis is stronger than Doug Fir		25%	25%	15%	15%	16%	16%	103%

Table 2 - Eucalyptus compared to USA species[xv] (higher is better). lbf/in^2 = PSI. Eucalyptus is stronger than domestic woods.[xvi],[xvii] % indicates Eucalyptus strength divided by domestic wood strength.

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COMPANY

Since 1995 we've been a family owned company completely focused on forest based industrial and sustainable solutions and products. Our expertise is in production of industrial strength forest products (e.g. mats / timbers / railroad ties, etc.) and sustainable forest management.

We love the timber mat business because we can serve our customers' needs with a superior product which is stronger, standardized, safer, and which is environmentally advantageous and sustainable. We fully expect that we'll be making even a better timber mat in five, ten, and fifteen years from now.

Our key operating partners have worked together for 20+ years. Our two main family owners have worked together since 1983.

Our company is organized around the Golden Rule: We try very hard to treat our customers, employees, and vendors exactly how we would want to be treated.

FOR MORE INFORMATION

For more information on our mats please contact:

Jeffrey Atkin. +1-800-866-0795 x1. QUOTES@WORLD-FOREST.COM

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ENDNOTES

[i] *Changes in planted forests and future global implications*. 2015. Forest Ecology and Management. Tim Payn et al

[ii] Rosillo-Calle, F., V.Bajay, S., Rothman, H. *Industrial Uses of Biomass Energy: The Example of Brazil*. Taylor and Francis. 2000.

[iii] Look for Jarrah, the closest species in FPL, and very close in working characteristics to *E. grandis*.

[iv] Covered in the Reference Section.

[v] Standard measurements are performed at 12% moisture content (MC). No new mat will be at 12% MC as it takes years for big timbers to dry. An older and drier eucalyptus mat will outperform SRO and a green eucalyptus mat generally meets or exceeds the 12% MC strength measurements for SRO. There are two important implications.

1. All wood mats still have a lot of excess maximum crushing strength capacity even when green.
2. As mats dry out, they actually become more resistant to stress. For a species like Eucalyptus, which is very durable, an older mat may actually retain a significant amount of value, increasing its resale amount.

[vi] Data from http://www.wood-database.com/rose-gum/ and

Forest Products Laboratory. *Wood handbook - Wood as an engineering material*. Gen. Tech. Rep. FPL-GTR-113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 2010. See Chapter 5. Mechanical Properties of Wood.

[vii] Ibid.

[viii] For example, see:

Technical Note A-1. Forest Products Laboratory. 1919.

Scheffer, TC, Englerth, GH, Duncan, CG. *Decay Resistance of Seven Native Oaks*. Journal of Agricultural Research, Washington, DC. Vol 78, No 5-6. (1949).

[ix] Highley, TL. *Comparative Durability of Untreated Wood in Use Above Ground*. International Biodeterioration & Biodegradation (1995)

[x] Nelson, N.D., and Heather,W.A. Wood Color, Basic Density, and Decay Resistance in Heartwood of Fast-Grown Eucalyptus grandis Hill ex Maiden. Holzforschung, 26: 54–60. 1972.

[xi] Ronald Schmidt-Malavassi, Structural Engineer. Letter. November 28, 2016.

[xii] Details available upon request.

[xiii] By Nasa-verve at English Wikipedia, CC BY 3.0, https://commons.wikimedia.org/w/index.php?curid=24700863

[xiv] Courtesy of Wikipedia. https://en.wikipedia.org/wiki/Flexural_strength

[xv] Forest Products Laboratory. *Wood handbook - Wood as an engineering material*. Gen. Tech. Rep. FPL-GTR-113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 1999. See Chapter 4. Mechanical Properties of Wood.

[xvi] Wood handbook - Wood as an engineering material. Chapter 4.

[xvii] http://www.wood-database.com/lyptus/