RTA TieReport #8A

Tie Usage Index for Matching Wood Performance and Operating Conditions

The matching of wood species to specific railroad operating and environmental conditions allows for better use of different wood species and expanded availability of timber sources for use as wood crossties. Currently, several North American railroads use a very limited form of species segregation, to match wood performance and operating and environmental conditions. In order to build on this limited and subjective application, the Railway Tie Association sponsored a program to develop an objective Tie Usage Index that can be used to assist railroads in defining usage environments and matching the usage environment (both environmental and mechanical) with wood type and performance (e.g., species). This in turn provided a basis for defining species as a function of service environment and geographical location.

The Tie Usage Index is based on a set of specific numerical criteria ("indices") that can be used to define where different timber species can be installed. The Tie Usage Index includes the following specific behaviors and effects:

- Susceptibility to environmental decay, such as defined by a decay hazard index
- Susceptibility to mechanical damage such as defined by curvature and annual traffic density (annual MGT) and grade.

The resulting Tie Usage Index is a combination of these parameters and allows for the development of performance thresholds and the linking of these thresholds to specific wood species, preliminary values of which were presented in earlier RTA reports [1,2].

Development of Tie Usage Index

In order to address the two broad categories of crosstie degradation noted above, environmental decay and mechanical damage, the Tie Usage Index (TUI) was divided into two parts, with one part corresponding to the environmentally related degradation (the Environmental Decay Index) and the second part corresponding to the mechanically related degradation (Mechanical Damage Index). These two indices then combined to provide a single Tie Usage Index.

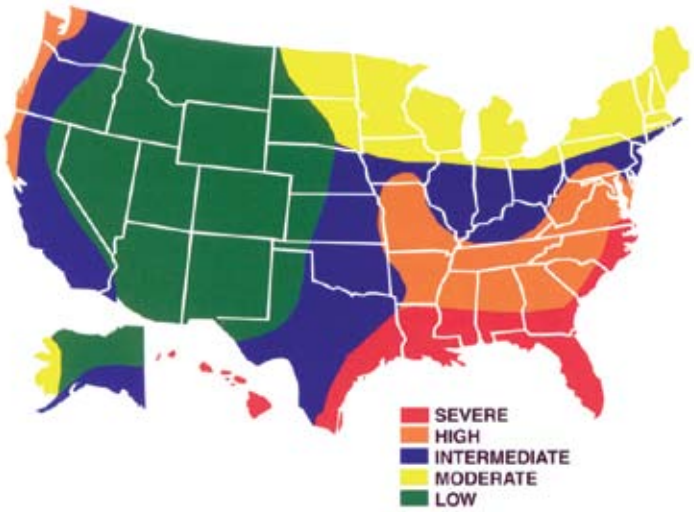


Figure 1: *Deterioration Zones of U.S.*

Tie Report #8A: Tie Usage Index for Matching Wood Performance and Operating Conditions (continued)

Environmental Decay Index
The environmental decay index was developed based on several studies, including a decay risk analysis for timber crossties by geographic region based on the U.S. Department of Agriculture [3] and the wood decay map developed by the Rural Electrification Administration for utility poles and incorporated into the American Wood Preservers' Association (AWPA) standards for Preservative Treatment of Poles (C-4) [4]. This latter map, which is presented in Figure 1, has five zones. Based on the referenced studies, a five-level wood tie Environmental Decay Index was developed as presented in Figure 2.

Mechanical Damage Index
For the case of mechanical damage or deterioration, significant research has been performed over the years on the relationship between wood tie life and key traffic and operating parameters. References 1 through 2 cite several studies that define key parameters that affect mechanical degradation of timber crossties. Recent research sponsored by the Railway Tie Association [5,6] has led to the development of engineering models for the analysis of tie life as a function of several of these key parameters. Among these key operating parameters that strongly influence the mechanical degradation of wood ties are:

- Annual traffic density (annual tonnage or MGT)
- Curvature
- Grade

Building upon the tie life damage effects used as a basis for the RTA equations, a series of mechanical damage indices was developed for each of the three parameters noted above and then combined to give an overall Mechanical Damage Index.

The specific equations used are presented in References 1 and 2. The corresponding Index values are presented in Figures 3, 4, and 5 for these three mechanical damage parameters.

To obtain the combined Mechanical Damage Index (MDI) the three individual mechanical indices are combined as follows: **MDI = CI * DI * GI/2867**

Where:
CI = Curvature Index
DI = Density Index
GI = Grade Index

Thus for the following case:

Curvature	= 1 degree;	CI	= 58 (see Figure 3)
Density	= 25 MGT;	DI	= 36 (see Figure 4)
Grade	= 1%;	GI	= 65 (see Figure 5)

The resulting Mechanical Damage Index (MDI) = 58*36*65/2867 = 47

Figure 6 presents a graph of the Mechanical Damage Index (MDI) as a function of curvature and traffic density (with grade = 0%).

Tie Usage Index
The Tie Usage Index (TUI) is then obtained by averaging the Environmental Decay Index (EDI) and the Mechanical Damage Index (MDI). Thus, applying this to the above example: for Zone 2; EDI = 48, MDI = 47 and the Tie Usage Index (TUI) = 47.

Tie Report #8A: Tie Usage Index for Matching Wood Performance and Operating Conditions (continued)

Figure 2: *Decay Index*

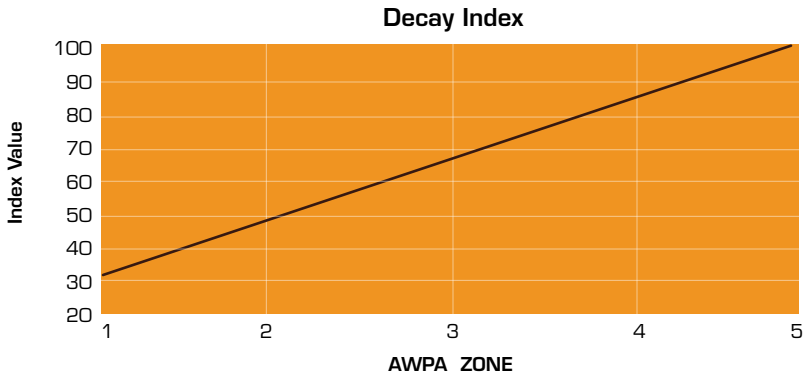


Figure 3: *Curvature Index*

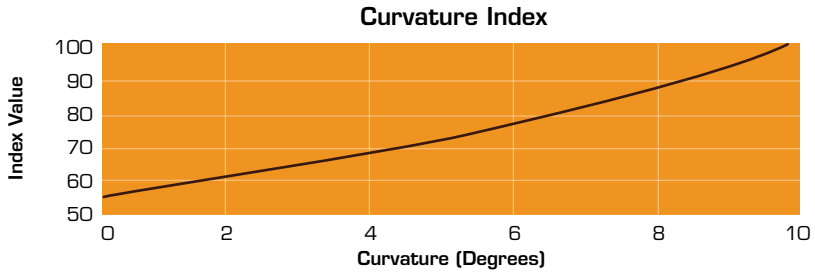


Figure 4: *Density Index*

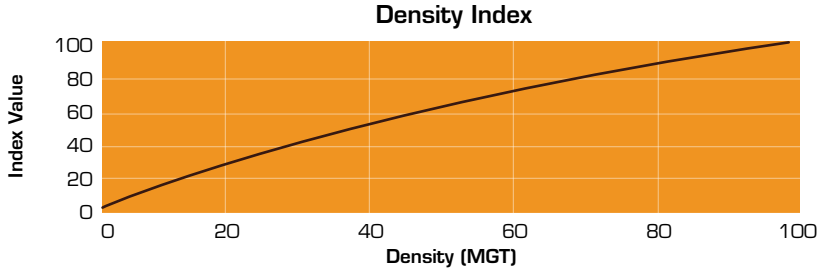


Figure 5: *Grade Index*

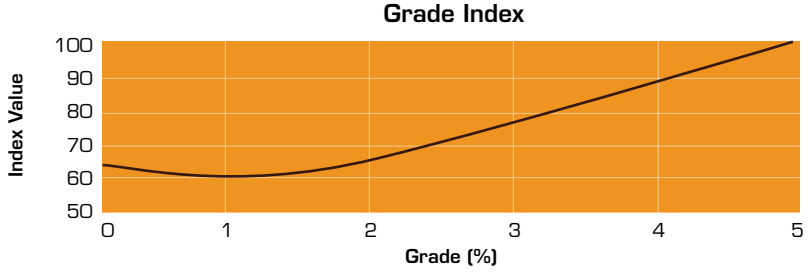
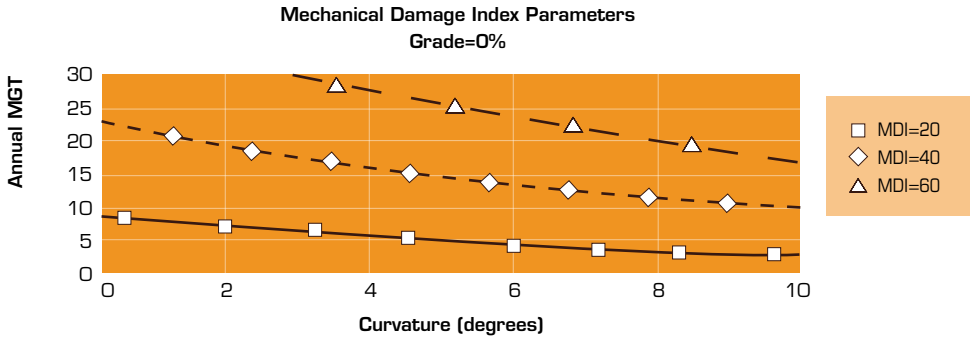


Figure 6: *Mechanical Damage Index as Function of Grade and Curvature*



APPLICATION OF TIE USAGE INDEX TO WOOD SPECIES

The Tie Usage Index is used to develop a relationship between those factors that influence tie performance, and thus life, and the different species of wood available for use as crossties. Starting with a comprehensive listing of all of the wood species that are available for use as crossties [7], the over 100 available species were grouped into "equivalent" categories based on ability to perform under both mechanical and environmental conditions. A total of 22 such equivalent categories were defined and are presented in Appendix A together with a list of all of the species corresponding to these 22 categories. (It should be noted that of these 22 categories, 6 are "E" or "Environmental" categories, which include those timber species where treatment or environmental/geographic use (e.g., locale) is a consideration.)

The full set of 22 timber categories were then rated, based on their expected level of mechanical performance, with the E categories rated mechanically but designated as a category with environmental considerations. Table A presents these timber category ratings, with the "best" performing timber categories at the top. Thus, wood species performance is expected to increase as the user moves vertically up the listing (with "best' on top).

Using the ratings presented in Table A, it is then possible to relate timber species to level of service, as defined by the Tie Usage Indices. A preliminary relationship is presented in Table B, which can be considered a preliminary Wood Species Usage Guide. This table relates wood species to railway use as a function of the two main deterioration categories defined above: environmental decay (as defined by the Environmental Decay Index) and mechanical damage (as defined by the Mechanical Damage Index). In this table, the railroad usage environment is divided into three levels of mechanical damage and three levels of environmental decay hazard as follows:

Mechanical Damage as based on the Mechanical Damage Index (MDI):

- Light MDI < 20
- Moderate 20< MDI < 40
- Severe MDI > 40

Note: The MDI values represent a combination of curvature, annual traffic density (tonnage) and grade. This combination is illustrated in Figure 7 for MDI values of 20, 40 and 60.

Environmental Decay Hazard as based on the Environmental Decay Index (EDI):

- Light EDI < 50 (Zones 1 and 2 in Figure 2)
- Moderate 50< EDI < 80 (Zone 3 in Figure 2)
- Severe MDI > 80 (Zones 4 and 5 in Figure 2)

Tie Report #8A: Tie Usage Index for Matching Wood Performance and Operating Conditions (continued)

For each of these nine usage areas, a listing of suitable timber species is defined. This is done by defining the lowest ranking timber category that is acceptable for use in that area. Thus, all of the timber categories located above the named category in Table B (to include the named category itself) is considered to be suitable for use in that category. Any timber category that is located below the named category is considered to be not suitable for use in that category. Furthermore, in the case of the Severe Environmental decay areas, any "E" category is likewise considered to be less than optimum, even if located above the named category.

Thus, for the case of the severe mechanical-light environmental usage area (upper right box in Table B), the following timber categories are considered suitable for use: Red Oak, White Oak, Northern Mixed Hardwoods (NMI) – I, Southern Mixed Hardwoods (SMI) – I and Northern Mixed Hardwoods (NMI) – H (see Appendix A in Tie Report #8B, which follows, for the specific wood species that make up this category).

However, for the case of the severe mechanical-severe environmental usage area (lower right box in Table B), White Oak would be excluded based on potential treatment concerns about this timber species. Similarly, for a light mechanical-light environmental usage area, all species in category WS III(E) and higher (from the category rating chart) are considered suitable for use. Thus Table B indicates the potential suitability of species for various applications ranging from light to severe mechanical wear and light to severe sensitivity to decay/environmental factors.

Table A: Category Rating
Red Oak
White Oak (E)
NMH-H
NMH – I
SMH-H
SMH – I
NMH – II
NMH – II (E)
Douglas Fir – Coastal
Douglas Fir – Intermountain (E)
SMH – II
SMH – II (E)
SYP – Dense
NMH – III
SMH – III
NMH – III (E)
ES – I
WS I
ES II
WS II
SYP – Standard
WS III (E)

E = Treatment issues or where environment-of-use (locale as it applies to climate) is a consideration

Best

[1] There exists a difference of opinion regarding the suitability of White Oak in severe environmental decay areas. As such, it has been excluded from the table for that application. However, some railroads continue to report satisfactory performance of White Oak even in the more environmentally rigorous areas of the country.

Tie Report #8A: Tie Usage Index for Matching Wood Performance and Operating Conditions (continued)

Table B: Species Usage Guide

Environment (EDI)	Mechanical (MDI) Light	20	Moderate	40	Severe
Light	WS III (E)		SMH III		SMH-H
50					
Moderate	WS I		SMH III		SMH-H
80					
Severe	SMH III*		NMH III*		SMH-H*

* Excluding all "E" classes

This chart indicates suitability of species for various applications ranging from light to severe mechanical wear and light to severe sensitivity to decay/environmental factors. For example, if you have a light operating (mechanical) index of use and a light environment for decay (dry/arid) or "environment" index then all species in category WS III (E) and higher (from the category rating chart) are suitable for use. Conversely, if you have a severe application for both mechanical and environ indexes of use then it is suggested that only species NMH-H (excluding E classes) and higher are suitable.

REFERENCES

1. Zarembski, A.M., Gauntt, J.C., "Development of a Tie Usage Index for Matching Wood Performance and Operating Conditions," American Railway Engineering Maintenance Association Annual Technical Conference, September 2002.

2. Zarembski, A. M., "Development of a Preliminary Tie Usage Index," Report Submitted to the Railway Tie Association, July 2001.

3. Russell, Allen, "Tie Decay-Underrated Factor," Railway Track and Structures, August 1986.

4. American Wood Preservers Association, Standards 2000, C-4 – Poles-Preservative Treatment by Pressure Processes.

5. ZETA-TECH Associates, Inc., "SelecTie II- Economic Benefit Analysis of Alternate Cross-Tie/ Fastener Configurations," Report to the Railway Tie Association, 1997.

6. ZETA-TECH Associates, Inc., "TieLife- Determination of Wood Tie Life and Future Cross-Tie Requirements," Report to the Railway Tie Association, June 1998.

7. Webb, G. V. and Webb, D. A., "Tie Guide: Handbook for Commercial Timbers Used by the Cross-Tie Industry," Railway Tie Association, Fayetteville, GA.