SECTION XII

Ties and Fasteners

Proper matching of tie/fastener systems to different operating environments must be based on the adequacy of the system to withstand the specific load environment. Furthermore, a better understanding of the nature of and rate of tie and fastener failure can lead to a more effective maintenance program aimed at maintaining an appropriate and adequate level of tie and fastener strength.

Rail Fastener Performance: What About Strength?

The recent trend towards Increasing axle load and train weight has led to questions regarding the adequacy of traditional fastener systems, specifically the cut spike. More directly, there are requirements for effective fastener systems suited to different track (and tie) configuration and operating conditions.

These *performance* criteria have been the subject of numerous analyses, investigations, and tests. Two recent papers have attempted to consolidate varied research activities into specific performance characteristics for wood' and concrete2 tie track.

Three basic categories:

Fastener performance characteristics can be divided into three basic categories:

1. Track Strength Properties (in cluding related fastener strength).
2. Operations and Maintenance Requirements.
3. Cost/Benefit Issues.

This *Tracking R&D will* address the first of these issues, Track (and Fastener) Strength, leaving the remaining two for subsequent coverage.

Consideration of Track Strength can be divided into four classifications. Each represents a basic mode of performance of track under traffic loading. These areas are:

a) *Longitudinal Restraint* - the ability of the track to withstand longitudinally applied loads, that is, loads in the direction of the track. Such loads include mechanical loading from train braking and acceleration, and thermal loading from changes in ambient and rail temperatures. For fastening systems, the requirement for longitudinal restraint translates into preventing the rails from moving with respect to the ties.

Among the specific longitudinal performance requirements is *the* capability of the fastening system to limit the size of the rail gap, in the event of a rail pull-apart. Table I presents a set of relationships between maximum allowable rail break or "gap" and fastener longitudinal restraint, for a temperature change of 75-degrees F.

A second fastener performance requirement is related to the force necessary to "plow" the tie in the ballast. Specifically, the fastener does not need significantly greater longitudinal holding power than this force, at which point the tie is already moving.

TABLE 1

MINIMUM FASTENER RESTRAINT FOR DIFFERENT RAIL BREAK "GAPS" DUE TO MAXIMUM TEMPERATURE CHANGE of 75°F FOR 132 RE RAIL

RAIL BREAK "GAP" (INCHES)	FASTENER RESTRAINT PER UNIT LENGTH OF RAIL REQUIRED TO LIMIT THE RAIL BREAK GAP (lbs./inch)	LENGTH OF RAIL ON EACH SIDE OF GAP WHICH MUST BE ANCHORED TO LIMIT THE GAP (ft.)	FASTENER SPACING (inches)	FASTENER RESTRAINT PER FASTENER ASSEMBLY REQUIRED TO LIMIT THE GAP (lbs.)
0.5	184	86	24	4416
0.75	122	129	24	2928
1.0	92	172	24	2208
1.5	61	258	24	1464
2.0	46	344	24	1104

Table 1 - Rail Break Gaps

b) Gage Widening/Rail Rollover - the ability of the track, and specifically the fastener system to maintain gage, that is, to keep the rails 56 1/2 inches apart at the gage points. Gage widening, in turn, is a combination of three factors: rail wear, translation, and rotation. 'Me latter two are most directly affected by the fastening system. Under conditions of high lateral load and high L/V ratios (lateral to vertical wheel loads), it is critical that the fasteners limit the rotation of the rail, to prevent dynamic gage widening, and the possibility of a wheel dropping in between the rails.

c) *Lateral Shifting Track Buckling* - the ability of the track to withstand lateral loading without the lateral movement of the track as a whole, as opposed to gage widening where only the rail moves laterally. In this mode, the performance of the fastening system is secondary to those of the tic and ballast systems. However, the fasteners do act to strengthen the track "frame" in the lateral direction, and to reduce the lateral movement along curves as temperature changes. It is also a phenomenon related to characteristics of longitudinal restraint.

d) *Vertical Loading* - the ability of the track structure to withstand vertical loadings, both static and dynamic. The fastener system transmits vertical loads, applied at the railhead to the cross-tie. The tie in turn distributes the load into the ballast and ultimately the subgrade. In the presence of dynamic loading, such as particularly high impacts from wheel flats or rail surface defects, the fastener system must also help distribute, and in the case of concrete ties, attenuate these. This requirement for attenuation is related to the need for the fastener system to introduce resiliency into the concrete tie structure. Usually, this resiliency is associated with the pad portion of the system.

In the case of elastic fasteners, the performance of the fastener during rail uplift under traffic must also be taken into account. Here, the fastener system must support the weight of the tie and rail section without excessive deformation. (Next month in *Tracking R&D*, 'The Intangible Aspects of Fastener Performance.')

1. Zarembski, A. M, "Performance Characteristics for Wood Tie Fasteners", Bulletin of the AREA. Bulletin 697, October 1984.
2. Zarembski, A- M., -Performance Characteristics for Concrete T ie Fasteners", Concrete Tic Systems for the 1980's, Proceedings of the Prestressed Concrete Tic Workshop, November 1983.

Rail Fastener Performance: The Intangibles

Last month, the performance requirements of track fastening systems, for both wood and concrete ties, were discussed in terms *of track and fastener strength.*

However, research studies' have noted that there exist two additional categories of fastener requirements which have to be addressed to properly and completely define the performance of such systems. These are *operations and maintenance requirements,* and *cost/benefits* criteria. These categories represent the "intangible" requirements of the fastener system. That is, they are often difficult to quantify but still represent important practical and economic considerations that make for ease *of* fastener use and effectiveness.

TABLE 1
NET ECONOMIC SAVINGS ($)*
WOOD TIE TRACK

Annual Tonnage	Curvature: 3 Degrees		6 Degrees	
	Lubricated	Unlubricated	Lubricated	Unlubricated
20 MGT	−13,457	− 5,067	− 5,067	30,013
30 MGT	− 6,021	7,456	6,958	60,500
40 MGT	1,280	18,252	18,250	88,989
50 MGT	7,957	30,900	29,517	118,026

**Net economic savings (life cycle) of track with elastic fasteners against track with cut spikes for one mile of track.*

Operations and maintenance

Operations and maintenance requirements can be as important as the track strength considerations, because they address real issues of concern for maintenance personnel who have ultimate responsibility in using rail fastening components in the field. Among the intangible considerations are: fastener life, maintainability, and, where needed, electrical isolation.

Fastener life refers to the passage of time or tonnage at which the fastener or its individual components must be replaced. If the fastener's performance drops below appropriately defined levels, such as those defined last month for track strength, or if a component degrades physically, then "failure" of the fastener occurs. Since fasteners are frequently removed and reinstalled, fastener life includes reassembly and reuse of components without loss of performance.

Besides having economic impact, service life also involves physical practicalities. Consequently, it may not be practical or economical for each of the fastener components to have the same service life. Nonetheless, a commonly used standard for fastener life is one which equals the life of rail in tangent track. Under heavy tonnage operations, this can be 500 MGT of cumulative traffic, or 25 years at 20 MGT per year. Under 100-ton car loading, this translates into over 15 million axleloading cycles.

Maintainability, as is presented in References I and_ 2, refers to those characteristics *of* a fastener which provide for ease of use in the field. It includes such intangibles as ease *of* installation and removal, with a minimum of specialized tools and with minimum ongoing adjustment for the fastener system. Among the other maintenance characteristics are: resistance to catastrophic failure, such as under derailments, ease of visual inspection of key fastener components, and a capability for mechanized installation in conjunction with large maintenance operations.

Electrical isolation, the third requirement, covers fasteners used in concrete or steel tie track in signal territories. Specifically, it calls for the electrical insulation of the rail from the rest of track to minimize the loss of signal circuit under all operating and weather conditions. Resistance values of 20,000 ohms and higher have been

Overall cost

The final category of fastener characteristics is one that addresses the overall cost of the track system. It is a matter of particular importance to private freight railroads. These companies operate in an economic environment which calls continuously for the minimization of expense and the maximization of benefit. Any criterion, then, developed for both tangible and intangible performance characteristics must be evaluated in light of total system costs. Further, these must be life cycle costs taken within the railway operating environment as against simple first costs.

Many studies have attempted to address the life cycle costs and benefits of fastener and fastener/tie systems within wood, concrete, or steel tie track. To illustrate the importance of this type of analysis in defining fastener system criteria, Table I presents the results of one economic analysis for wood tie systems.[3] It can be seen that under certain operating conditions, one type of fastening system offers life-cycle savings, while under another set of conditions, an alternate fastener system offers savings instead. Thus, after technical and other intangible requirements have been met, the net economic costs of a system must be addressed.

References:

1. Zarembski A. M. -Peribrmance Characteristics for wow Tie Fasteners", Bulletin of the AREA, Bulletin 697, October 1984.
2. Zarembski, A. M., -P;erfbmuu= Characteristics for Concrete Tie Fasteners". Concrete Tie System for the 1980s, Proceedings of the Prestressed Concrete Tie Workshop, November 1983.
3. Pandrol Inc., Economic cost-benefit analysis of fastener systems, 1983.

Missing Fasteners vs. Gage Strength

Maintaining the proper track gage under vehicle loading is a critical function of the tie-fastener system. This ability, referred to as the lateral strength, gage restraint strength, or simply gage strength of the track, has been the subject of an earlier Tracking R&D (see RT&S, August 1986). While the majority of research and test activity in this area has addressed wood tie track with cut spike fasteners, it has also extended to wood ties and concrete ties with elastic fastening systems.

Concrete tie track

Some recent research focused on the safety aspects of the gage strength of the track, and in particular regard to the effect of missing and non-functioning fasteners on concrete tie track. This activity dealt specifically with the assessment of safety for the track on the Northeast Corridor.'

For NEC concrete tie track, a series of tests were carried out to examine gage strength when one or more elastic fasteners were missing from one rail. At first, lateral and vertical load combinations, with an L/V ratio of up to 1.33, were applied to the track with no elastic fasteners missing.' The corresponding lateral deflection of the railhead at the point of loading was then measured. The same test was repeated with missing elastic fasteners involving the removal of a series of adjacent elastic clip pairs (both clips) from one rail. Test sequencing covered 3, 11, then 17 missing clip-pairs.

Investigators removed the clips symmetrically about the point of loading, and obtained the resulting load deflection behavior shown in Figure 1. It can be seen in the figure that even with 17 missing fasteners, the maximum loading of 20,000 lbs. resulted in a railhead fastening deflection of less than one inch, because of the lateral support to rail provided by the shoulders in the Northeast Corridor concrete tie.

Wood vs. concrete

This behavior in lateral strength was also matched to comparable test results taken on wood tie track with cut spike fastening. The results, also presented in Figure 1, indicate that the lateral strength of the wood tie track

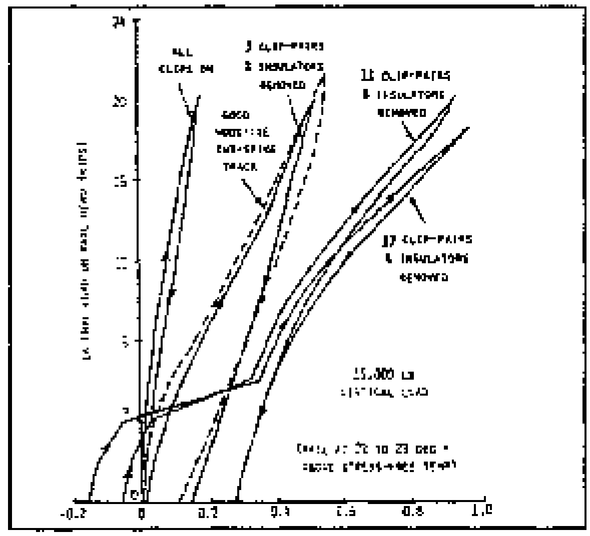

Figure 1 - Rail Head Lateral Displacement (in.)

compares to the lateral strength exhibited by the concrete tie track with three missing fasteners.

Likewise, other data on the lateral gage strength of wood tie track revealed the same characteristic loss in lateral* strength with an increasing

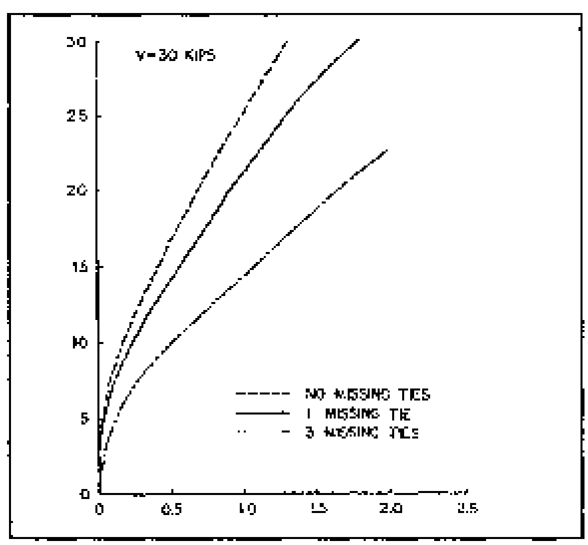

Figure 2 - Rail Head Lateral Deflection

number of missing fasteners. Figure 2 illustrates this. It shows lateral rail restraint of wood tie-cut spike systems under applied lateral and vertical loadings.[2] This data is based on a combination of field validation tests and analytical modeling.

As in the concrete tie case, increasing the number of missing fasteners (with missing ties as well) resulted, with wood, in a direct decrease in lateral gage restraint. However, it should be noted that while the general behavior of the wood tie and concrete tie system presented here are similar, the results are actually based on different loading combinations. Therefore, a direct comparison between wood and concrete tie performance is not appropriate. Also, it can be observed that even with one fastener and tie missing, a lateral rail head deflection of well over one inch can be achieved under suitable load combinations. This agrees with other, independently derived data.[3]

It is obvious that this type of information on the gage-holding ability of various tie and fastener systems can be of a real value to railroad maintenance officers in the development of suitable track maintenance standards, and in the assessment of track conditions.

References:

1. Ahlbeck, D. R., et al, -Development of Safety Criteria for Evaluating Concrete Tie Track in the Northeast Corridor Volume Z Track Safety Evaluation,- Federal Railroad Administration Report FRAMIX-86M2, law 1986.

2. Jeong. D. and Coitman, W Analysis of Lateral Rail Restraint, Fbderal Railroad Administration Report FRA/ORD-83/15, Sept. 1983.

3. Zarrmbski, A. M. and Choros, J., "Laboratory Investigation of Track Gage Widening." Association of American Railroads Report R-395, September 1979.

Examining Wood Tie Failure

Though conventional wood tie systems have been in use since 1831[1], research into tie failure is still an ongoing process.

The factors that affect the rates of wood tie failure encompass mechanisms such as mechanical and biological degradation, and weathering. Table 1[1] lists some of these mechanisms - factors that in turn combine to cause the deterioration resulting in the removal and replacement of the ties. The relative percentage of failure from each *of* the mechanisms noted can vary with traffic density and location.

One AREA study[2] indicated that, in general, 43 to 44 percent *of* ties are removed because of a combination of decay and deterioration leading to crushing in the tie plate area. An additional 18 to 20 percent are removed for having been plate cut, 16 to 18 percent from splitting, and 14 to 16 percent from spike killing. The remaining are removed for a broad range of additional reasons. However, mechanical failure related in turn to the stress and use factors, as defined in Table 1, tend to dominate the failure mechanisms- particularly in hardwood ties.'

I. Weathering Factors:
   A. Temperature (elevated, cyclic = depressed).
   B. Water.
   C. Temperature-moisture interactions (i.e. freeze-thaw).
II. Biological Factors (primarily fungi).
III. Stress Factors:
   A. Abrasion and compression due to ballast.
   B. Impact compression due to vertical rail loads
   C. Impact bending due to vertical rail loads.
   D. Spike loading due to lateral rail loads.
IV. Incompatibility Factors:
   A. Chemical degradation due to presence of rusting metal and high concentrations of acidic salts.
   B. Physical degradation due to particulate matter under tie plate during loading.
V. Use Factors:
   A. Quality and frequency of maintenance (i.e. spike removal, adzing, type of ballast).
   B. Track geometry (i.e. curves, ties per mile).
   C. Accidents (derailment, dragging equipment, spills).

Table 1 - Degradation factors affecting service life of crossties.

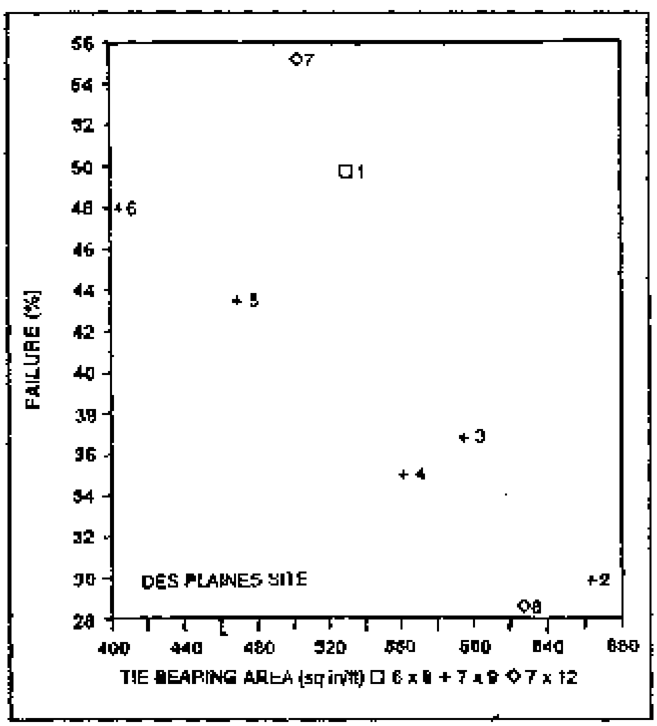

Figure / - Failure rate vs. tie bearing area

Long-term testing difficult

Because of the relatively long life of hardwood crossties, from 20 to 30 years for average mainline life,' it is difficult to maintain a significant tie testing program to failure. One test, however, has been taking place since 1967.[1] The test site is on the Chicago & North Western Railroad near Des Plaines, Illinois. *The* test was set up to evaluate the effect on tie life of key tie design factors, namely: tie length, varying from 8 feet to 10 feet, tie cross section from 6 inches by 8 inches to 7 inches by 12 inches, and tie spacing from 19 ½ inches to 29 1/4 inches. This test track currently experiences about 30 MGT of traffic annually. It was evaluated recently for tie failure, and the percentage of failed ties have been examined in relation to the dimensional parameters noted previously.[3] There were several interesting observations:

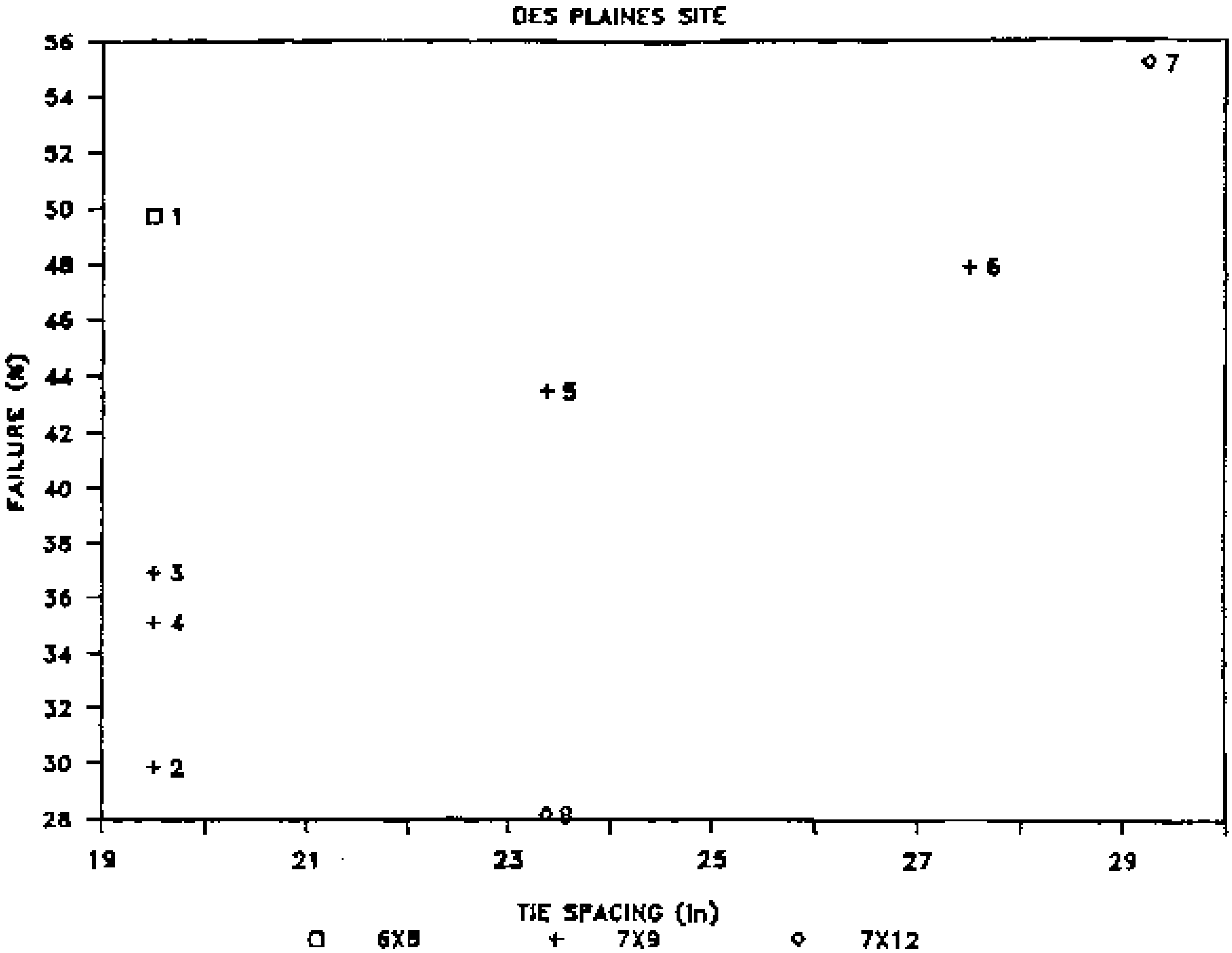

Figure 2 - Failure rate vs. tie spacing

Dowel-lam okay, too!

Overall, it was found that the best performing ties tended to be those with "standard" 7-inch by 9-inch cross sections and 191/2-inch spacing, as well as a section of track with dowel-laminated 7-inch by 12-inch ties at 23 3/8-inch spacing. As for the effect of tie length on failure rate along the test section, no significant difference was found between the 81/2-foot and 9-foot ties. There was, however, some better performance from the 10-foot ties.

Examination of the influence of tie cross section revealed a distinct improvement in performance with increasing cross section. Thus, the 7-inch by 9-inch ties performed better than the 6-inch by 8-inch, while the 7-inch by 12-inch served better than both.

Increasing tie width and length enlarges, in turn, the bearing area of the tie. Figure I shows that the rate of tie failure decreases in direct relation to the increase in the bearing area.

Finally, with examination of the effect of tie spacing, there was found a direct correlation between increased spacing and an increased percentage of failed ties. Ibis trend held for 7-inch by 9-inch and 7-inch by 12-inch cross sections, and is illustrated by Figure 2.

No variation between fact and theory has arisen from the information gleaned thus far from the Des Plaines site. Namely, that under mainline conditions, where mechanical degradation modes dominate tie life, those parameters which serve to reduce the level of stress on the tie serve also to improve its performance. However, it must be noted that other factors, such as the relative cost of the larger ties or closer tie spacing have not been addressed in the study noted. As a consequence, it still remains for the railroad maintenance officer to relate this type of information to the specific conditions of traffic and cost on his or her railroad.

References:

1. Chow, P., Lewis, S. L., and Reinschmidt, A. J.: "Effects of Natural and Accelerated Aging on Oak Crossties"; Proceeding, American Wood Preserves Association, 1987.

2. American Railway Engineering Association: Report of Committee 3, Tie and Wood Preservation; Bulletin 66 1, Jan. 1977.

3. Davis, D. D., and Shafarenko, V.: "Tie Condition at Des Plaines; A Progress Report"; Bulletin of the American Railway Engineering Association, Bulletin 713, Dec. 1987.

Extending The Life of Wood Crossties

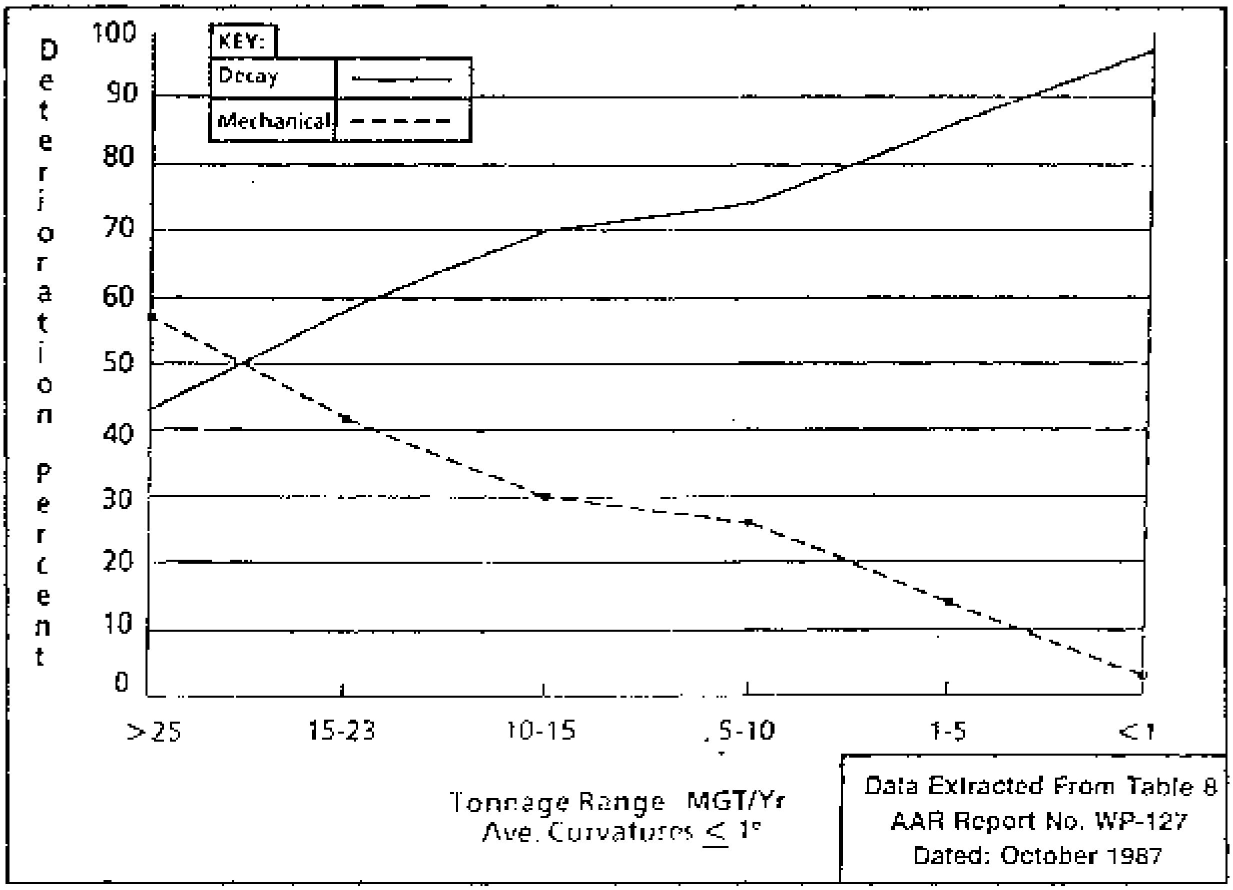

Figure 1 - Causes of tie failure

As railroads strive to improve the overall cost-effectiveness of their various maintenance activities, methods for extending the life of key (and expensive) track comportents are continuously being studied and tried. The conventional wood crosstie is one such component that is under-going investigation.

Several studies of the factors that affect tie service life have shown that wood-tie failure can be associated with mechanical degradation, decay (either biological or environmental/weathering related) or "use" (RT&S May 1988, p. 12). One AREA study (1) indicated that decay and wood deterioration were responsible for over 40% of all ties removed. Another recent report (2) quoted AAR data indicating that at annual traffic densities of less than 15 MGT, 70% of the ties failed due to decay

Furthermore, this study stated that on lighter-density lines, decay/weathering is the major mode of failure, accounting for a significant majority of tie failures on light-tonnage tangent track. As tonnage and curvature increased, however, the mechanical modes of wood-tie failure correspondingly increased. These trends are presented in Figure 1 (2). Note that even at moderate-density trackage (10 to 20 MGT per year), tie failures associated with decay made up more than 50% of all the failures. On light-density lines (less than 5 MGT per year), this percentage is significantly higher.

Noting that over 18 million ties were installed in 1986 (3), if 40% of these ties are replaced due to decay, tilts represents over seven million ties per year.

No. Ties Treated (Mill.)	Ties Treated Effectively (Mill.)	Potential Savings From Extended Tie Life (Life Extension in Years) ($ in Millions)				
		1 Year	2 Years	3 Years	4 Years	5 Years
1.64	1.64	$3.9	$7.5	$10.8	$13.9	$16.8
1.64	1.23	$2.9	$5.6	$8.1	$10.4	$12.6
1.64	0.82	$1.9	$3.7	$5.4	$7.0	$8.4

Figure 2 - Potential savings from in-track tie-treating program

Economic benefits noted

These data suggest that techniques for the extension of the life of the tie, by controlling or reducing the potential for decay, could have significant benefits. This is further supported by the savings shown in Figure 2, which presents a cost-benefit analysis carried out by a major Class I railroad (2). This analysis examined the present worth of an extension in wood-tie life using an in-place tie treatment. As can be seen in this table, even if the treatment is only 50% effective (bottom row), a tie-life extension of two years would be worth approximately $2.20 per treated tie while an extension of five years would be worth over $5 per treated tie. (Note that these savings are based on the average tie life and associated costs of the Class I railroad noted in Reference 2. These savings will change as a function of the actual costs and life of the tie in track).

Extending the life of the wood tie also affects the overall economics of alternate tie materials. This general trend is illustrated in Figure 3, which presents the results of an economic benefit analysis comparing wood vs. concrete ties for a specific base case with a fixed set of assumptions and conditions (4). Note that as the tie life increases, the economics of an alternate tie material (shown in Fig. 3 as the return on investment or ROI for the alternate, concrete tie) changes.

Wood tie treatment

Noting the potential for savings suggested by these types of analyses, several different in-place wood-tie treatments have been developed. These treatments are all aimed at extending the life of ties already installed and in place. In that manner, those ties which are located in track where decay is the dominant failure mechanism (such as light-to-moderate tangent track) can be selectively treated. In addition, by treating the ties, in place, the overall treatment costs can be kept to a minimum, since the need for tie removal and handling is eliminated. These in-place techniques utilize several different types of preservatives based on creosote, sodium fluoride (2) and borate (5). While several of these techniques are currently undergoing testing, preliminary analyses indicate good penetration by the preservative(s) and a potential for extension of the tie's service life (2,5).

These techniques, together with other approaches, such as the use of premium components for the extension of the tie's service life, are all being examined as a means of extending the overall in-service life of this key track component. as well as reducing life-cycle costs. This, in turn, follows an overall trend of introducing new components and maintenance practices to reduce the overall cost of track maintenance.

References

(1) American Railway Engineering Association: Report of Committee 3, Tie and Wood Preservation, Volume 78, Bulletin 66 1, January 1977.

(2) McCarthy. W. T., Use of Under Plate Treatment in Place for Ties, Bulletin of die American Railway Engineering Association, Volume 90, Bulletin 72 1. May 1989.

(3) Association of American Railroads. Railroad Facts, 1987 Edition, September 1987.

(4) Zarembski, A. M. and Masih, J. T. A., "On the Development of a Computer Model for the Economic Analysis of Alternate Tie/Fastener Configurations.- Bulletin of the American Railway Engineering Association, Volume 90, Bulletin 72 1, May 1989.

(5) Beauford W and Beal-Preston J., "Preservative Treatment of Wooden Sleepers, “Railway Technology International”, Sterling Publications Ltd., London, 1988.

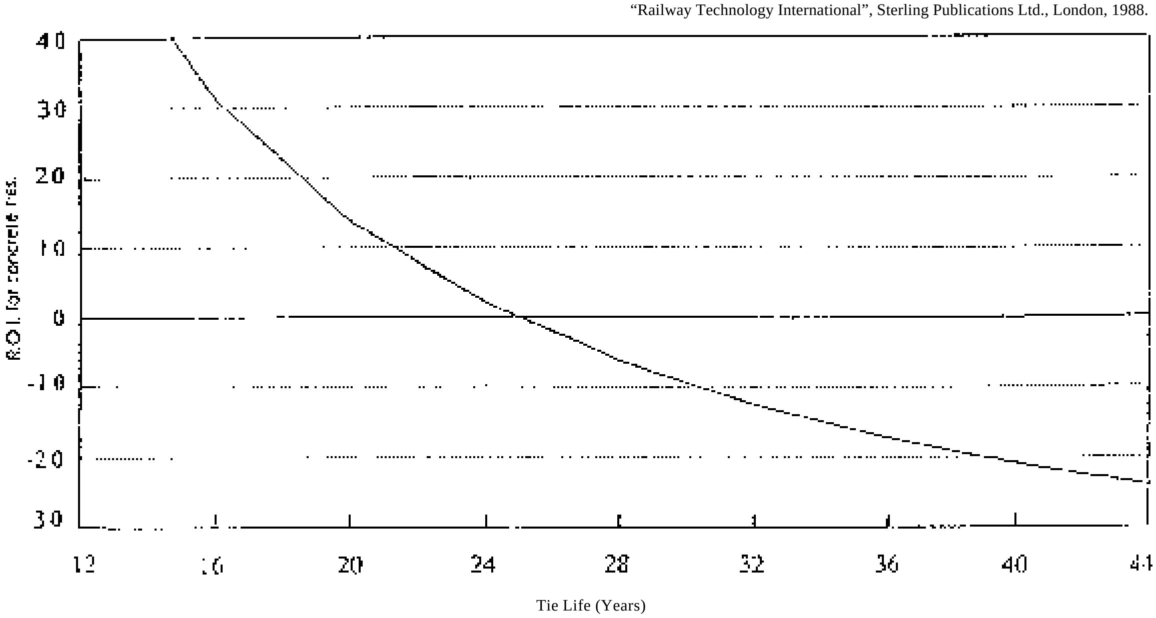

Figure 3 - Economic benefit analysis. wood vs. concrete ties (based on assumptions indicated).

Wood Tie Life
Part I
Average Tie Life

In a conventional mile of railway track, there are approximately 3,250 crossties, spaced, on the average, 191/2 inches apart. Although each of these ties experiences approximately the same level of loading and the same range of environmental conditions, differences in wood, treatment and support will result in a difference in the life of these ties. Even if all of the ties are installed at the same time, they will not all fail at once. Rather, they will fail in accordance with a statistical distribution about a "mean" or "average' value. This average value can be used as a guide to determine the "life" of the tie in track.

The average life is a function of several factors, including track and traffic characteristics and environmental conditions. Over the years, there have been attempts to define, in broad terms, the average life of ties as a basic function of the traffic density of the track. This is necessary, at a minimum, in order to allow for the differences in failure modes of the ties, and in particular the differences between mechanical failure modes at higher-traffic densities and environmental failure modes at lower-traffic densities (See RT&S, May 1988, p. 12).

Using data acquired between 1934 and 1957, early researchers developed the relationship between average tie life and traffic density presented in Figure 1 (1). This showed that under light-traffic loadings, an average tie life of 50 years was achieved (yards and sidings had an average tie life of 60 years). Under high-traffic densities, however, this life dropped to less than half of these figures (1).

Subsequent analysis (See Figure 2) of tie-life data taken during 1978 shows a very similar trend, with low-density tracks having an average tie life of over 40 years, and high-density tracks having an average life of just over 20 years (2). Once again, there appears to be a difference in the tie-failure mechanism associated with high- and low density types of track.

Environmental effects

More recent data on a moderately-high-density track show a similar average tie life. In this case, detailed analyses of several sites on a 20 MGT mainline in the northeastern United States showed a distribution of tie failures corresponding to an average tie life of between 25 and 30 years (3). This figure appears to be consistent with the average tie life obtained for that tonnage level in Figures I and 2.

The preceding data allow for the development of a relationship between average tie life and annual traffic density. However, the effect of other parameters on average tie life is not as well defined. These other parameters include curvature, axle load, ballast condition, as well as

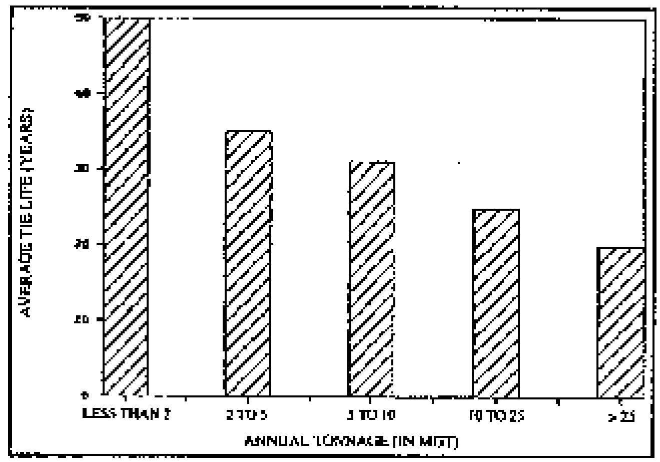

Figure 1 -Average fie life (data from 1934 to 1957)[1]

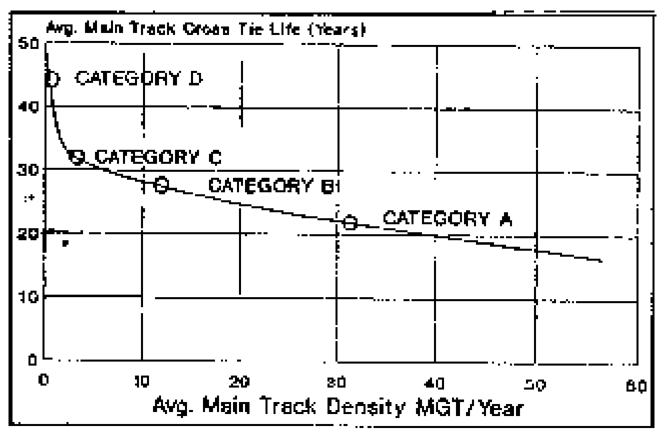

Figure 2 - Tie life versus tonnage, from 1978 industry statistics[2]

a range of' track and traffic parameters, which affect the load distribution on the crosstie. In addition, the variation in environment has been found to play a strong role in tie life, particularly on the moderate- and light-density lines where the primary modes of tie failure are environmentally related.

This environmental effect was recently illustrated by examining the average tie life in different geographical arid climatic regions of the United States. The U.S. was divided into three distinct zones, based on "decay hazard" (Figure 3). The aver-age fie life in the Eastern region was found to be 46 years; the Southern region, 30 years; the Western region, 51 years (4). Such a broad categorization of climatic conditions can result in differences in average tie lives of a factor of 1.5 or greater. This suggests that environmental factors have a significant effect on the average life of ties in track.

Considering these effects, it is possible to estimate the average tie life as a function of at least several key factors. However, the average tie life does not give the actual distribution of tie failures in track. Rather, it defines the point about which these failures are distributed. The distribution of tie failures about this average value will be presented in Part II.

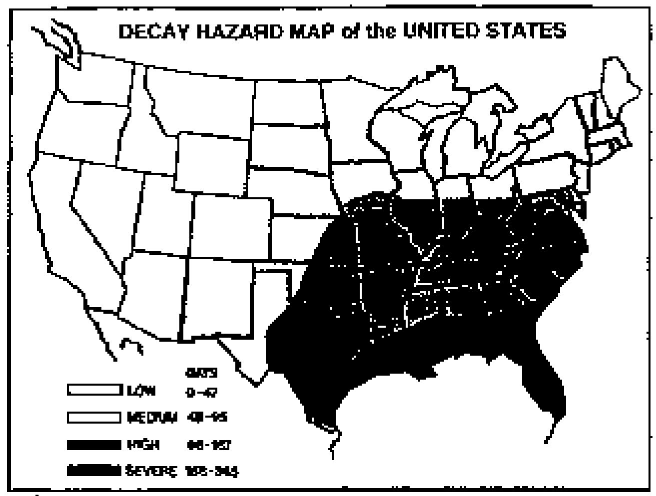

Figure 3 - En

References

(1) Code. C. J., -Crossties: What is the Average Life?" Railway Track & Structures, December 1962.

(2) Mcliveen, E R.. Roney, M. D., Lake, R. W. and Raymond, G. P., "The Road Cost Maintenance Model, " Canadian Institute of Guided Ground Transport Report 80-16. March 198 1.

(3) Davis. D. D. and Chow, P., "Tie Condition Inspection: A Case Study of the Failure Rate, Modes, and Clustering, - Bulletin of the American Railway Engineering Association, Bulletin 723. Volume 90. December 1989.

(4) Russell, Allen, -Tie Decay-Underrated Factor.- Railway Track & Structures, August 1986.

Wood Tie Life: Part II Distribution of Failed Ties

Last month's Tracking R&D looked at the "average" life of wood crossties in track as a function of several key parameters. It noted that wood crossties do not all fail at the same time, even when they are installed together. Rather, small differences between individual ties can result in distinctly different individual tie lives, even when all the ties are subjected to the same loading and climatic conditions.

Differences in individual tie failures can be attributed to the fact that wood is not a homogeneous material. There are differences in species types, as well as variations in the wood properties within a single species. Variations in the amount of preservative absorbed during treatment, differences in local support conditions (and, hence, stress distribution) and other local variations can result in differences in the amount of time it takes a tie to fail.

On an individual basis, these variations in tie condition make it almost impossible to predict the life of a single tie. However, studies of large numbers of ties have shown that the failure of large groups of ties takes the form of a statistical distribution of "failed" ties (1). Figure I shows a "normalized" distribution curve for failed ties as a function of a tie's average life (which must be determined independently). As can be seen from this curve, the distribution of tie failures occurs around the "average" tie life (shown at 100% average life) in a less than symmetrical manner. The curve, distributed around the 94% average-tie-life point, indicates that 50% of the ties will have failed after a period corresponding to 94% of the average tie life has passed.

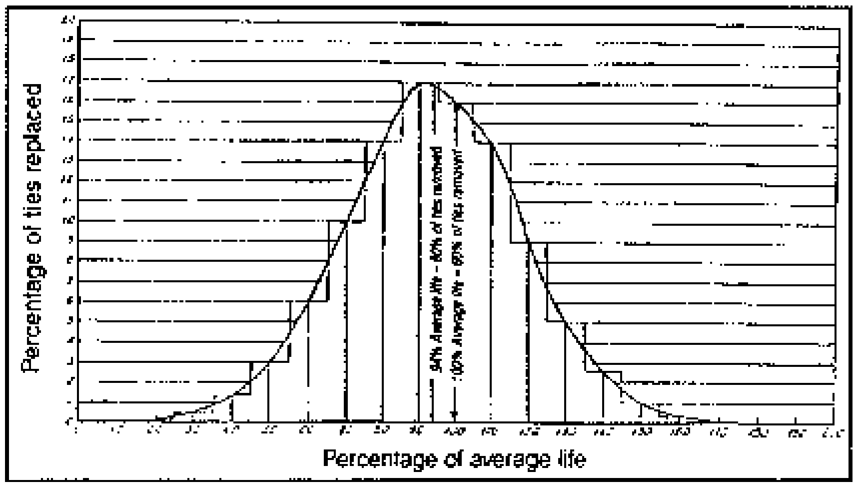

Figure 1 – Frequency curve showing successive percentage of tie replacement for 10 percent intervals of average life'

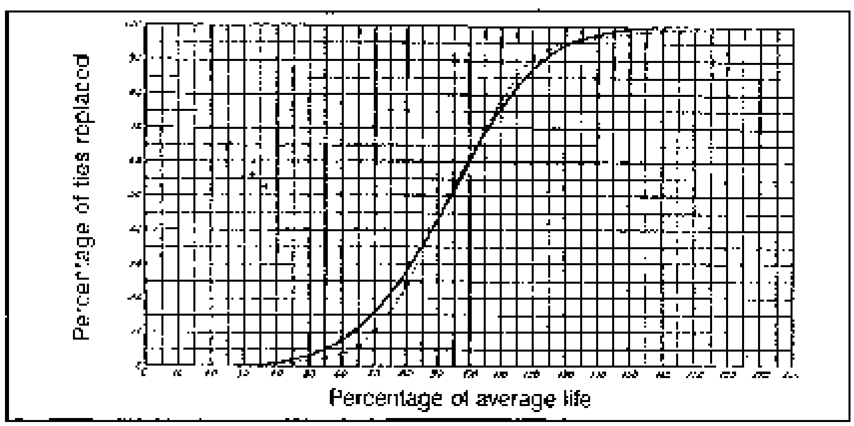

Figure 2 - Curve of total replacements (broken line), 1918 studies; curve of total replacements (solid line). all studies'

Figure 2 presents this curve in a slightly different format with the vertical axis showing the cumulative percentage of replaced ties. (Failed ties are defined as ties that have been replaced by the railway.) This curve allows for the determination of the percentage of ties that will have failed, as a function of their "average" life (1). Although this data was developed based on new or out-of-face tie installations, it can also be used for the analysis of track subject to periodic tie gang cycles (2,3). This information allows for the analysis (and prediction) of the annual rate of tie failures for track that has been maintained using conventional North American tie maintenance practices.

Recent research

These failure distribution curves have since been validated by more recent railroad data (3,4). An analysis of an all-new construction in which new ties were installed at the same time and subjected to mainline traffic densities of approximately 20 MGT per year is presented in Figure 3. Since the average fie life was not known, the data was plotted against distribution curves calculated for several average tie lives. As can be seen in Figure 3, the actual failure distribution appears to follow the 25-year-average-life distribution curve quite well.

Noting these results, it appears that the distribution of failing ties can be predicted by using such a combination of statistical tie failure distribution curves and an externally obtained (either calculated or estimated) average tie life.

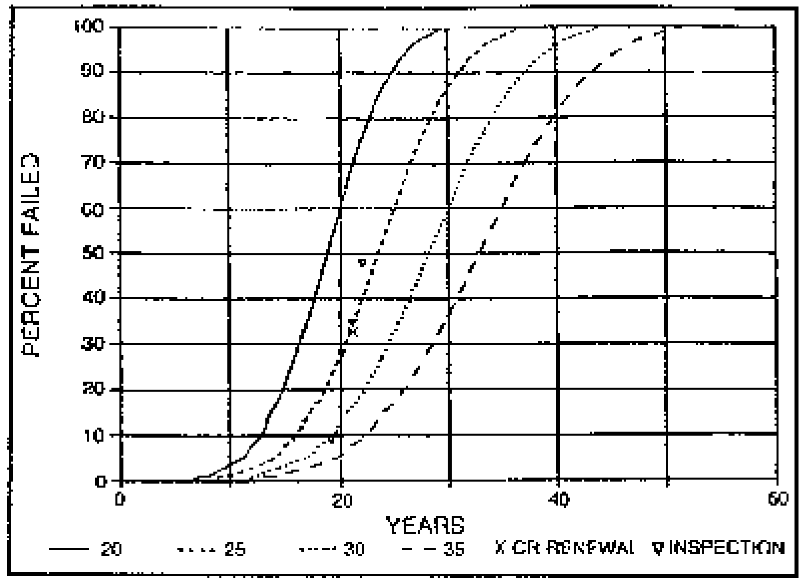

Figure 3 - Forest products curve for various average life values: Cumulative failures versus years in track, at mile 266'

References

(1) MacLean, J. D, -Percentage Renewals and Average Life of Railway Ties," U.S. Department of Agriculture, Forest Products Laboratory, Madison, Wis., November 1957. Reviewed and Reaffirmed 1965. (2) Abbott, R. A., "Track Structure and Methods for Predicting Tie Life:' Crossties, January 1982.

(3) Wells, T. R, "fie Failure Rate Analysis and Prediction Techniques," Association of American Railroads Report R-5 15, October 1982.

(4) Davis, D. D. and Chow. P., "Tie Condition Inspection: A Case Study of the Failure Rate, Modes, and Clustering, "Bulletin of the American Railway Engineering Association, Bulletin 723, Volume 90, December 1989.

Strength Properties of Wood Crossties

A major function of the crosstie is to support the vertical and lateral loads transmitted to the tie through the rails. The ability of crossties to support these loads is defined as the strength of the ties.

One recent research effort attempted to quantify several key strength-related properties of wood crossties, and to relate these properties to the condition of ties in track. Ibis activity, which was carried out as part of the Association of American Railroads' ongoing track maintenance research program, tested four groups of ties selected from a railroad test site (1). These four groups were defined, based on visual evaluation of their condition, as good, marginal, bad and unusual. (These ties were approximately 20 years old and were subjected to approximately 20 MGT of mainline traffic per year on a northeastern U.S. railroad.) A group of new ties was similarly tested in order to obtain reference values.

In order to quantify the strength of the ties, in a manner representative of their performance in track, a series of bending, surface hardness and other tests were carried out. The tie bending tests, which were performed to simulate a severe loading condition, showed a reduction in both maximum static load and corresponding bending modulus of elasticity.

Tie bending tests

Figure I presents the results of the maximum static bending tests (simulating a center-bound tie). As can be seen from these results, the good, marginal and bad ties experienced a loss of approximately one-third of their new bending strength (as defined by this test), while the unusual ties (which were the most severely-failed group) lost more than half of the new-tie bending strength.

Similar results were obtained for the bending modulus of elasticity tests presented in Figure 2. In this case, the bending modulus of the good, marginal and bad ties are all approximately 50% of the new ties. (The lack of variation in these three categories exhibited in both sets of tests is probably due to the subjective nature of the visual inspection.) For the unusual (failed) ties, the bending modulus was approximately one-third of the new ties (or a loss of two-thirds of the new modulus values).

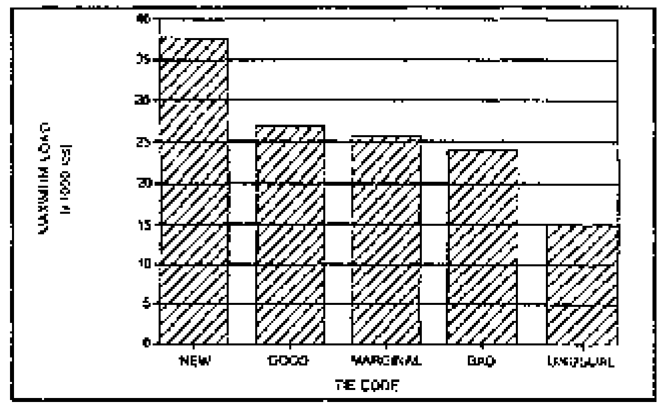

Figure 1 - Maximum static bending load for 20-year-old ties (1).

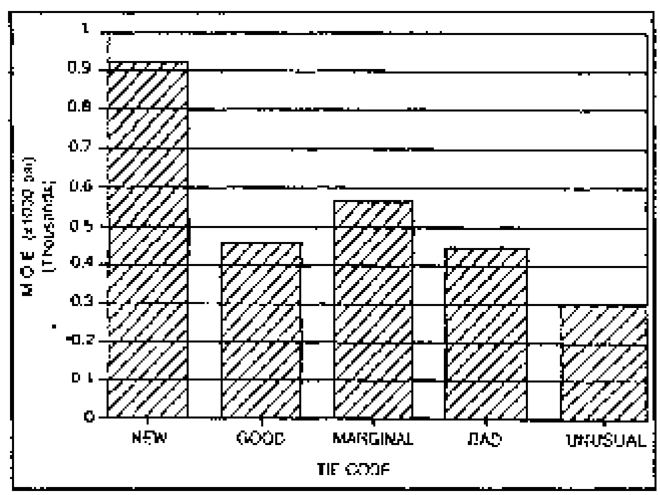

Figure 2 - Bending modulus of elasticity values for 20-year-old ties (2).

This variation in bending modulus was significantly greater than that encountered due to differences in species. This is clearly illustrated in Figure 3, which shows the bending modulus of elasticity (for clear wood samples as opposed to the whole tic values shown in Figure 2) for several different wood species (2). Although the greatest variation in modulus among the species was a factor of two (between cedar and maple), among the most commonly used hardwoods, this variation was of the order of 33%, significantly less than

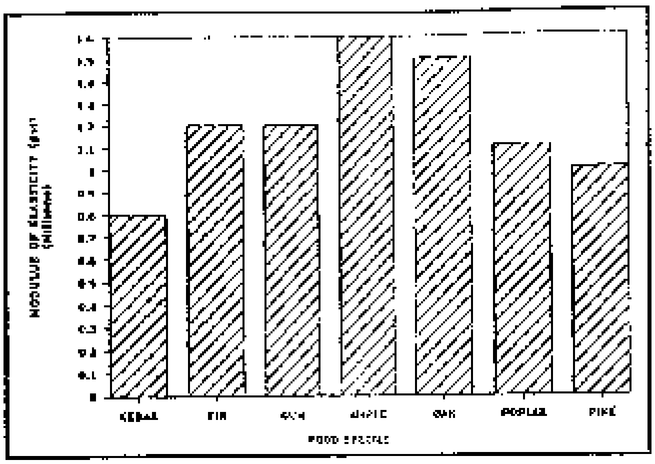

Figure 3 - Modulus of elasticity in bending for clear-wood samples (2).

that measured due to deterioration in the field (2,3).

A second class of tests was carried out to determine the deterioration in surface properties of the ties. These tests, which examined the surface hardness and the compressive modulus of the ties, at the center and at the railseat (under the tie plate), showed a similar loss of properties, particularly in the railseat area (2). This is illustrated in Figure 4, where the loss of tie hardness under the tie plate is approximately 50% for good and marginal ties, 60% for bad ties and 75% for unusual ties. The degradation in the center of the tie, away from the area of load application, is significantly less. (Comparable behavior was observed for the compressive modulus tests.)

The remaining tests showed a similar set of behavior, with the overall reduction in strength of the 20-year-old ties being approximately 30% to 50% of the new-tie values (1). Thus, it appears that the actual strength properties of the ties are reduced under actual service conditions. Noting the lack of consistency in the visual assessment of these ties, however, it appears that there remains a need for more objective field-measurement techniques for assessing the actual in-track condition of wood crossties.

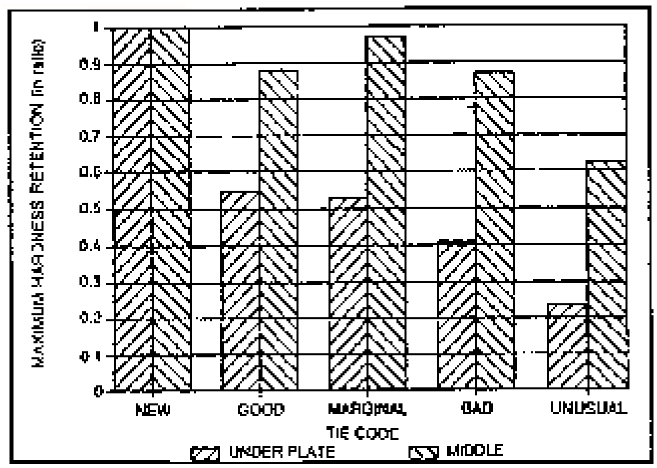

Figure 4 - Maximum hardness retention for 20-year-old ties (1).

References

(1) Davis, D. D. and Chow, P., -Tie Condition Inspection: A Case Study of the Failure Rate, Modes, and Clustering:' Bulletin of the American Railway Engineering Association, Bulletin 723, Volume 90, December 1989.

(2) Carmichael, C.. "Kent's Mechanical Engineer's Handbook, Twelfth Edition," John Wiley & Sons, 1950.

(3) Forest Products Laboratory, "Wood Handbook: "U. S. Department of Agriculture.