RTA TieReport #3

Modern Cross-Tie Inspection and Planning Tools

In order to effectively and efficiently maintain the railroad's track structure, railroad maintenance officers must have accurate knowledge of the exact condition of the track and its key components. However, while inspection tools used for measurement of rail and track geometry condition have been around for many years, inspection tools for cross-ties are only now becoming available to supplement and complement the traditional tie inspector's "calibrated eye." This is in spite of the fact that cross-ties represent the second largest cost area, accounting for between 20% and 40% of railroad track maintenance costs.

The traditional method of cross-tie inspection makes use of tie inspectors who walk the track, visually inspecting the condition of the ties, and in some cases supplementing the visual inspection by "kicking" the ties and/or fasteners and observing any movement. Bad ties are "counted" using simple mechanical counters which keep track of the number of bad ties in each mile, a number that is written down and ultimately introduced into the railroad database. Since the tie inspectors can range from experienced, full-time tie inspectors to local inspectors, roadmasters or supervisors who generate tie counts upon request, the ability of the tie inspectors to accurately and consistently identify bad ties has always been in question. The ability to categorize ties into more than two simple categories (good vs. bad) simply did not exist.

In recent years, however, several new systems for monitoring and recording tie condition have come into widespread use. In addition to providing detailed and accurate information about tie condition, they also collect a sufficient level of data as to allow for accurate planning of tie maintenance and replacement activities.

TieInspect®

One such new-generation tie inspection system is the *TieInspect®*[1] cross-tie inspection system that has been actively used by railways to accurately "map" the track's tie condition and plan replacement activities based on this condition mapping [1, 2, 3]. TieInspect is a hand-held (computerized) data collection and analysis system that allows the tie inspector to record the condition of each tie individually, thus providing a complete database of current tie condition and allowing for analysis of these collected data. While still based on the tie inspector's visual observations, the ability to categorize tie condition into 4 or 5 categories, and to accurately map the condition of all of the ties, individually, provides the railroad with a powerful tool to accurately determine which ties have to be replaced and when.

[1] *TieInspect and its associated software products TieReplace, TieMark, TiePrioritize, etc. are products of ZETA-TECH Associates, Inc.*

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Figure 1: TieInspect Tie Inspection System

TieInspect consists of a palmtop computer (PDA) and an ergonomically designed handgrip input device (Figure 1) designed to accommodate the tie inspector's traditional inspection technique while giving him the flexibility to record a whole range of important additional information. Thus, the unit records tie condition data for every tie, together with information about location, curvature, tie type, tie material, events, notes, etc.

Because it can categorize tie condition into four or five categories, railway users have been able to develop standardized tie rating systems, such as the system shown in Figure 2, which is currently used by BNSF to inspect and plan tie replacements on over 6,000 miles of track annually [2,3]. Using the TieInspect units and working in two-person teams, BNSF field inspectors average 40 miles of track inspected per team per week.

Figure 2: BNSF Tie Condition Rating System

The collected TieInspect data are downloaded to a data base which can be resident on a stand-alone Windows-based computer or a computer network, for analysis, display, and storage. The data can then be viewed in both a summary and detailed format, such as the mile by mile summary distribution and counts of good, marginal, and bad ties (shown in Figure 3). The bar chart on the top of Figure 3 shows the summary data for each mile in that segment, to include tie count and percentage of ties in each condition category. For each individual milepost, a detailed graphical representation of the tie inspection data or tie condition map is presented for each inspection.

	TIE CLASS			
CONDITION	1 FRA Defective BLACK	2 BNSF Defective RED	3 Moderate YELLOW	4 Good GREEN
Broken	Broken through - separated	Broken through – Not separated	Not broken through	No Breaks
Split or Otherwise Impaired	To the extent the crossties will allow ballast to work through, or will not hold spikes or rail fasteners	Will not hold spikes or rail fasteners. *Loose spikes in curves greater than 2 degrees.*	Tie holds spikes, some splits deep enough to allow water into tie. *Tie can be plugged and respiked if in tangent or curves 2 degrees and less.*	Slight weather splits but integrity not compromised
Deteriorated	So that the tie plate or base of rail can move laterally more than ½ inch relative to the crosstie	So that the tie plate or base of rail can move laterally more than ¼ inch but less than ½ inch relative to the crosstie	Less than ¼ inch of lateral plate or rail movement	No plate movement or cut and no sign of deterioration
Plate Cut	More than 40% of the ties' thickness	More than 1 inch but less than 40% of the ties' thickness	Greater than ¼ inch, up to 1 inch in depth	¼ inch plate cut or less.
Wheel Cut		More than 2 inches deep within 12 inches of the base of the load-bearing area, not broken through the tie.	½ inch to 2 inches deep not broken through the tie	½ inch or less with no structural damage to tie
Rotted or Hollow		Substantial amount of wood decayed or missing. Hollow under plate area.	Some rot over tie and on ends. Not hollow under plate area.	None
Expected Remaining Life			Less than 20 years	20 years or greater

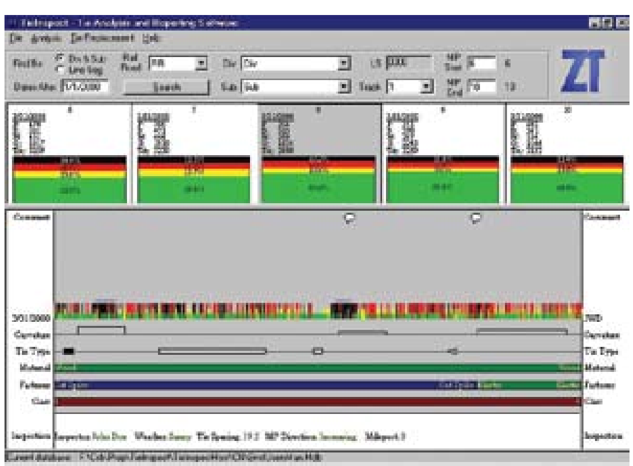


Figure 3: TieInspect Tie Condition Data Display

There data are then used in the analysis of the tie condition and planning of the tie maintenance activities, as described later in this note.

Track Strength Measurement

A second approach to measuring tie condition is based on the measurement of the lateral or gage holding strength of the track, and in particular of the tie and fastener system. This approach, which is based on research and development activities by the AAR and VTSC in the late 1970s and 1980s, makes use of a gage spreading force to apply lateral (and restraining vertical) loads to each rail and simultaneously measure the lateral movement of the two rails, i.e., the gage widening under load of the track. Extensive research has shown that the resistance to this lateral movement or deflection under load is directly related to the condition of the ties and fasteners and represents the gage strength of the track. By monitoring this lateral or gage strength, from a continuously moving track strength testing vehicle, it is possible to identify weak spots in the track due to poor or inadequate tie and/or fastener condition. It is also possible to identify clusters of bad ties that need to be replaced, based on inadequate gage strength, thus forming the basis for a tie replacement program [4].

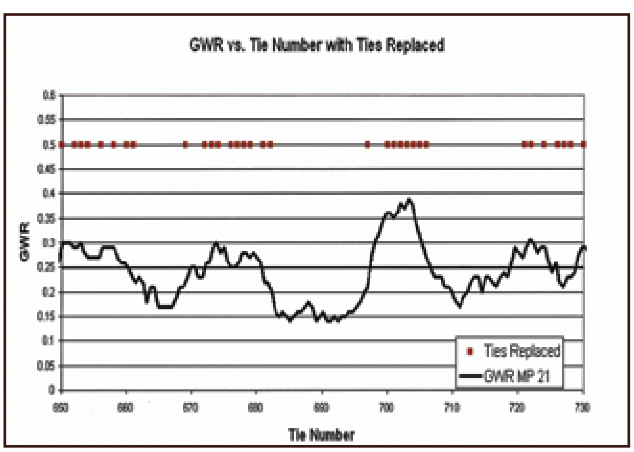
One commercially available track strength system is shown in Figure 4A. This Gage Restraint Measurement System[2] (GRMS), which is mounted under a rail bound inspection vehicle, uses split-axle technology coupled with an instrumented wheel set to apply and measure vertical and lateral loads on the railhead. A second system consists of a hi-rail based inspection vehicle using a split axle type of loading system as shown in Figure 4B.

Figure 4A: *GRMS Inspection Vehicle*

Figure 4B: *TrackStar Hi-Rail Inspection Vehicle*[3]

These systems can conduct continuous track strength testing, which tests speeds of 30+ mph. Using real time measurement of the track deflection under load, various track strength indices are calculated to include Loaded Gage, Projected Loaded Gage (PLG), and Gage Widening Ratio (GWR), which in turn are used to identify ties with inadequate lateral gage strength that must be replaced (see Figure 5) [5].

Figure 5: *Track Strength Output Report and Identified Ties to be Replaced*



[2] GRMS is a product of ENSCO Inc.
[3] TrackStar is a product of Holland Company.

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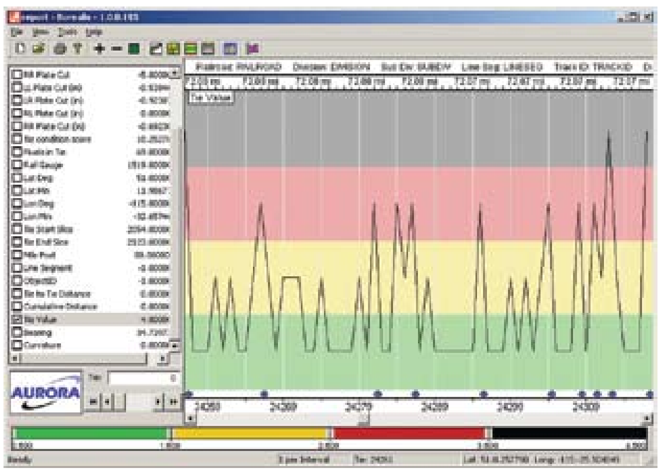
Automated Machine Visual Tie Inspection

A third approach that has recently been introduced to automatically inspect ties in track makes use of machine vision technology and associated image processing techniques. While several generalized machine vision systems for track inspection have been tried, the new Aurora[4] tie inspection system has developed a level of technology necessary to inspect tie condition. Using this technology, data are gathered at speeds of up to 30 miles per hour and then analyzed, off line, based on visual tie condition criterian to include location, length and width of splits, depth of plate cutting, spike uplift, etc. Both two-level tie condition (good vs. bad) and four-level tie condition (Figure 6) reports can be generated and presented in a report format.

Figure 6: Aurora Four Level Tie Condition



Tie Maintenance Management and Planning

As noted earlier, the availability of tie condition data allows for a more effective tie maintenance management and planning activity than that allowed by the traditional "bad tie per mile" count. This ranges from a relatively simple exception reporting approach to more sophisticated tie replacement logic approach as well as prioritization of tie replacement activities and scheduling of tie maintenance gangs.

The exception report approach is currently used with track strength data such as illustrated in Figure 5 for Gage Widening Ratio (GWR). By defining a strength threshold level, the number of locations (and ties) that exceed that threshold can be identified and counted. Figure 6 extends this approach to four levels, again providing a count of ties in each condition category.

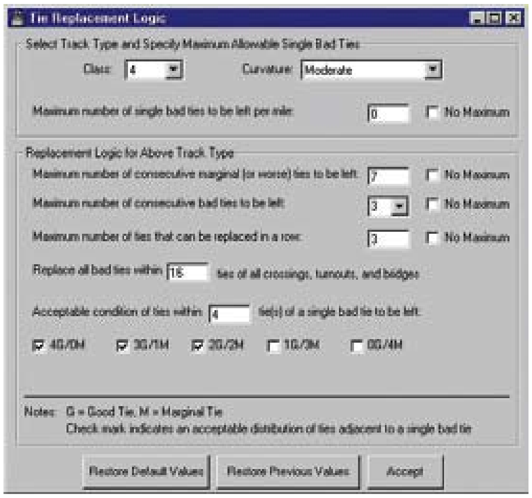
A more sophisticated approach to identification of ties to be replaced, based on the severity of service and the condition of the ties adjacent to the tie in question, is built into the TieReplace logic of the TieInspect system. This represents a tie replacement decision process based on key track and operating factors such as:

- Condition of tie
- Number of adjacent good and/or marginal ties
- Curvature
- Class of track (speed)
- Proximity to crossings, turnouts and bridges

It also allows for single bad ties to remain in track, where appropriate. Figure 7 illustrates the replacement logic approach. The TieReplace logic determines the specific individual ties that are to be replaced each mile based on the inspected condition of the ties as recorded in the database. The result is a complete data file of replacement ties for each mile of track inspected and analyzed and represents the required tie replacement program for the inspected track. This tie replacement file can then be loaded back into the hand-held computer units and used to identify the ties to be replaced.

[4] *Aurora is a product of Georgetown Rail Equipment Company*

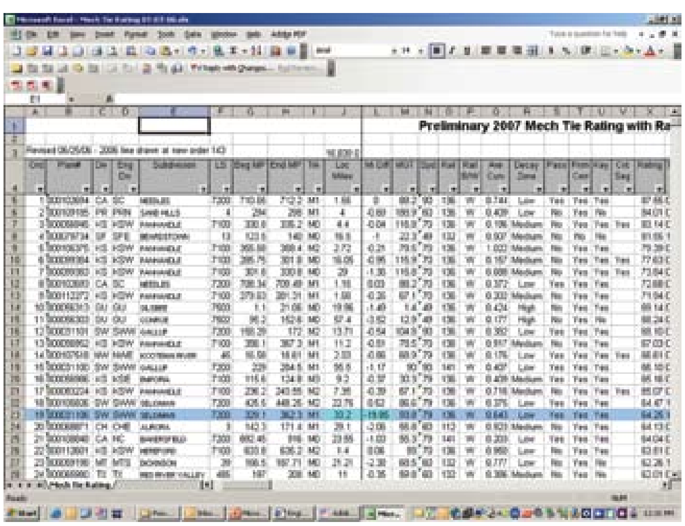
Figure 7: TieReplace Replacement Logic



Prioritization

Accurate and complete tie condition information, such as provided by a detailed tie condition map, can be used to effectively set tie replacement budgets and prioritize tie replacement activities. One example of a prioritization approach, currently used by BNSF, calculates a Prioritization Index[5] for tie segments that forms the basis for which tie gangs can be authorized [7]. In addition to the total number of bad ties per mile in the segment, this Prioritization Index (also referred to as a Condition Index) incorporates other information that is relevant to defining the priority of a tie program to include Clustering, Annual Tonnage (MGT), Climate, traffic, time since last inspection, track quality, etc. The result is a Priority Rating for each proposed tie replacement segment, as illustrated in Figure 8, which can then be used as an objective basis to set tie programs using defined cut-off limits.

Figure 8: BNSF Tie Prioritization and Budgeting Report Using Prioritization Index [7]



[5] *Developed and implemented by ZETA-TECH Associates, Inc.*

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Gang Planning

In addition to providing immediate information for next year's program, accurate tie condition data also allow for the analysis of long-term (future) tie requirements on both a local and large scale level [5,6]. Using tie condition data in conjunction with tie degradation models allows for the calculation of a rate of tie degradation and a forecast of required tie gang cycle dates.

In all cases, availability of accurate tie condition data allows for more accurate tie replacement decision making, to include replacement of sufficient but not excessive ties, effective prioritization of locations where tie replacement is required, better tie budgeting, and more effective tie gang scheduling.

REFERENCES

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2. Zarembski, A.M., Parker, L.A., Palese, J.W., "Use of Comprehensive Tie Condition Data in Cross-Tie Maintenance Planning and Management on the BNSF", American Railway Engineering Maintenance Association Annual Technical Conference, September 2002.

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