# RTA TieReport #6

## *Performance Requirements for Wood Crosstie Fasteners: Part I, Track Strength*

The performance requirements for a freight railway elastic fastener system can be divided into two broad categories [1, 2, 3]:

- Track strength requirements
- Track performance requirements

The track strength requirements relate directly to the ability of the fastener/tie system to adequately and effectively perform its functions under the defined traffic and environmental loading conditions. This is the "strength", or load-carrying capacity, of the system, and includes the full range of track loadings: longitudinal; lateral (both gage widening and lateral track); and vertical.

The track performance requirements refer to those factors (often non-quantifiable) that relate to the ability of the system to accommodate itself to railroad practices and operations. These include system life requirements, maintenance considerations, economic and operating considerations.

This Tie Report will focus on the first category, the track strength requirements. In general, it is necessary to first define the load environment under which the fastening system must perform. Based on this load environment, the actual "strength" requirements can then be defined. As used here, the fastener "strength" or load-carrying capacity refers to the fastener's ability to carry the vehicle and environmental loading without "excessive" deflection or deformation.

There are three basic areas of fastener strength performance, corresponding to the three principal loading directions [1]. These are:

**A. Longitudinal Strength**
The resistance of the fastener system to longitudinal loading, both mechanical and environmental (thermal).

**B. Lateral Strength**
The resistance of the fastener system to lateral loading. From the fastener perspective, this consists primarily of gage widening resistance, the resistance of the fastener system to static or dynamic gage widening.

**C. Vertical Strength**
The resistance of the fastener system to vertical loading. This is to include the ability of the fastener to attenuate dynamic impact loading and to resist uplift forces.

For each of these strength areas, a performance requirement, defined as an ability of the fastener system to resist external loading, can be specified, either in the form of maximum allowable load or as a maximum allowable deflection for a given level of loading.

It should be noted that the strength characteristics of the fastener systems under long-term traffic loading will degrade after time and/or traffic. Thus, any final performance specification must take this degradation behavior either by defining a single set of performance values that the system must always exceed or alternately by defining both a "new" strength value and an "old" strength value, reflecting the requirements in both states. Note: any such "old" value" must be based on the life of the fastener/tie system, which is of the order of 20,000,000 to 40,000,000 loading cycles, (where each cycle represents a single passing axle).

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**A. Longitudinal Strength**

Longitudinal fastener strength is the ability of the fastener system to provide longitudinal restraint to the rail and prevent rail movement or creepage under all loading conditions. As noted previously, longitudinal loading can be due to train action, such as train or engine braking and/or acceleration, and to environmental action, specifically the variation in temperature, both rail and ambient.

The function of the fastener is to provide longitudinal restraint to prevent any movement of the rail with respect to the ties. Under mechanical loading, this is simply the case of each fastener picking up a portion of the load, up to its maximum capacity, until the entire longitudinal load is restrained. In the case of thermal loading, the distribution of longitudinal consists of two distinct loading zones, the two end zones or "breathing" zones in which longitudinal movement of the rail takes place and the center "constrained" zone in which no longitudinal movement occurs. Therefore, the fastener longitudinal restraint is most critical in these end or "breathing" zones. These zones are at the ends of the Continuously Welded Rail (CWR) strings or at each side of a rail gap, such as occurs during a rail pull-apart or break. Good longitudinal restraint strength is required to prevent development of an excessive rail end opening or "gap" at any discontinuity in the CWR or in the event of a pull-apart or rail break where the break or gap must be controlled to avoid an excessive gap in the rail.

AREMA specifies 2400 lbs. (2.4 Kips) fastener restraint for passing of the fastener longitudinal restraint test and 2500+ lbs. (2.5+ Kips) in its rail fastening system performance table, which is included in Table 1 below [4]. For wood ties at 19.5-inch spacing, this corresponds to a longitudinal restraint of the order of 1500 lb./ft. Most elastic fastener systems meet or exceed these limits.

In the case of wood tie/cut spike/rail anchor system, rail anchors have longitudinal restraint values (new) of the order of 5000+ lbs. (AREMA requires a minimum of 5000 lbs.). This, when placed in a conventional box anchor, every other tie configuration, corresponds to a longitudinal strength of 1500 lbs./ft., corresponding to the elastic fastener values.

**B. Lateral Gage Strength**

As noted earlier, lateral gage strength refers to the ability of the fastener system to limit the amount of gage widening, both static and dynamic. This is an important parameter, since a key fastener function is to maintain track gage under loading, i.e., to prevent dynamic gage widening. Gage widening is defined to be any increase in the standard gage of the track structure.

**Gage widening is associated with three distinct mechanisms as follows:**

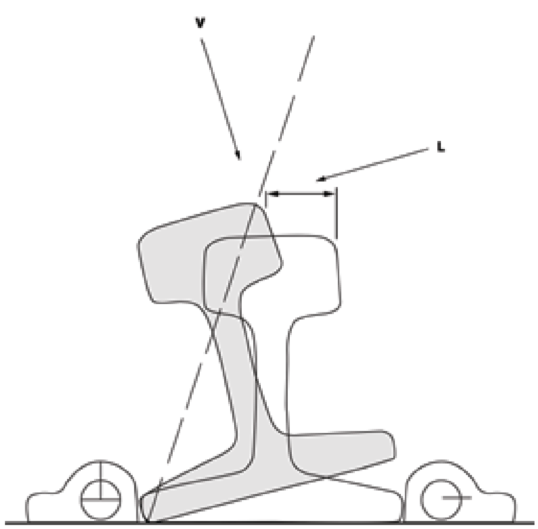
A. **Rail wear**; abrasive wear on the railhead, particularly the gage face of the high rail. Rail wear is outside the scope of the fastener system, although it is slightly affected by fastener stiffness.

B. **Rail translation**; rigid body movement of the rail, without any rotation, i.e., lateral movement of the base of the rail.

C. **Rail rotation**; rotation of the rail about its longitudinal axis, i.e., overturning (Figure 1).

From the point of view of track strength, modes B and C are of concern.

*Figure 1: Rail Rotation Under Lateral and Vertical Loading*



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Fastener strength is generally defined in terms of deflection under loading, under defined lateral and vertical wheel/rail loading, in which case the combined deflection (B + C) is considered [3].

Table 1 presents several parameters that relate directly to the lateral gage strength of the fastener/tie system. Note that these are a function of the wood type as well as the fastener, since they represent the strength characteristics of the combined wood tie/fastener system. These include:

- Lateral rail restraint, defined by AREMA [4] to be a measure of the load necessary to move (B) or rotate (C) the rail section perpendicular to the running axis of the rail.
- Fatigue L/V test, defined by AREMA [4] to be a repeated load test conducted on the fastening system to determine its resistance to rail movement under repeated load. This test looks at the long-term performance and degradation of the tie/fastener system.

Tests comparing the gage widening strength (deflection under load) have shown that the lateral gage strength of new hardwood ties with elastic fasteners are comparable to (and in some cases greater than) the strength of concrete ties with the same elastic fasteners [5].

### *Table 1: Properties of Rail Fastener Systems for Wood Ties*

| | Oak | Northern Mixed Hardwoods | Southern Mixed Hardwoods | Southern Yellow Pine | Softwood | Douglas Fir |
|---|---|---|---|---|---|---|
| Longitudinal Rail Restraint (kips) | 2.5+ | 2.5+ | 2.5+ | 2.5+ | 2.5+ | 2.5+ |
| Lateral Rail Restraint (kips) | 18-30 | 18-30 | 18.3+ | 18.3+ | 18.3+ | 18.3+ |
| Fatigue L/V Tests | 0.5-4.0 | 0.5-4.1 | 0.5-4.2 | 1.2 | 1.2 | 1.2 |
| Spike/Screw Pullout Test (lbs) | 5,000-6,600+ | 5,000-6,600+ | 5,000-6,600+ | 3,000-5,000 | 3,000-5,000 | 3,000-5,000 |
| Impacts on Fastening System (lbs/in$^2$) | 1,000-4,000 | 1,000-4,000 | 1,000-4,000 | 1,000-4,000 | 1,000-4,000 | 1,000-4,000 |

**C. Vertical Strength**

Vertical strength refers to the ability of the tie/fastener system to respond to loading in the vertical plane. [It includes the ability of the fastening system to withstand and attenuate high levels of dynamic loading and for wood tie track, to resist pull-out of the fasteners during uplift of the track (as a railroad wheel passes by).

Traditional analyses of vertical dynamic effects (i.e., speed effects) calculate speed factors of the order of 1.6 times the static wheel loads at speeds of 60 mph (based on the AREMA speed effect formula [4]). Defects on the rail surface (corrugations, engine burns, battered welds), rail joints, or imperfections in the wheel tread, i.e., flats or out-of-round wheels, can magnify the vertical loads by factors of 2 to 4 [6], though recent measurements using wheel impact detectors have found factors of 5 and higher (Figure 2 [6]).

Table 1 presents several parameters that relate directly to the vertical strength of the fastener/tie system. Note, as in the case of the lateral strength, these parameters are a function of the wood type as well as the fastener, since they represent the strength characteristics of the combined wood tie/fastener system. These include:

- Spike/Screw Pullout Test defined by AREMA [4] to be the force required to remove the fastener (screw or spike) from the tie. A measure of the vertical strength of the fastening system.
- Impact on Fastening System. Defined by AREMA [4] to be the ability of the rail seat pad (or wood tie) to attenuate the effect of wheel and rail impact loads on ties.

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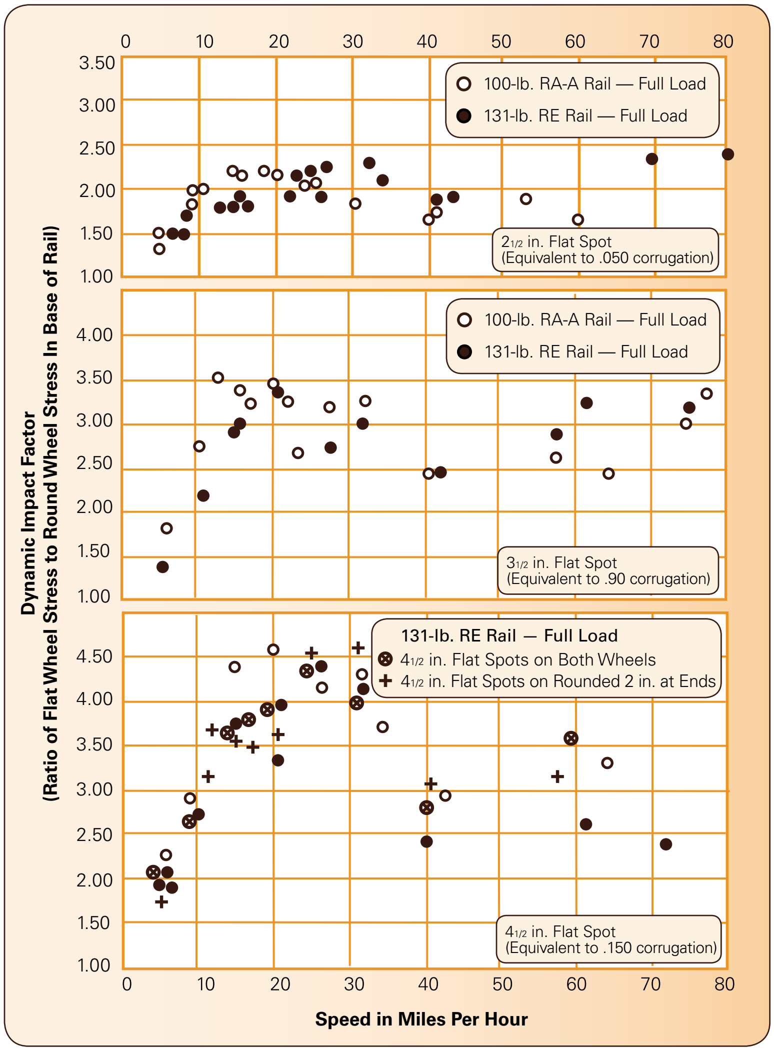
### Figure 2: *Dynamic Impact Factor Associated Wheel Flats [6]*




**Note: Many of the key properties of the fasteners will vary with wood type. In order to allow for the potential use of a broad range of wood types, the wood tie properties have been divided into six (6) categories of wood as presented in Table 1[4]. The fastener properties presented in Table 1 are consistent with those presented in the Manual for Railway Engineering of the American Railway Engineering and Maintenance of way Association (AREMA) [4].*

## REFERENCES


1. Zarembski, A. M., "Performance Characteristics for Wood Tie Fasteners," Bulletin of the American Railway Engineering Association, Bulletin 697, Volume 85, October 1984, pp. 341-369.

2. Railway Tie Association, "Wood Tie-Fastener Performance Specifications for Transit and Rail Passenger Operations," November 1991.

3. Zarembski, A. M., "Wood Tie Fastener Performance Requirements: The User's Points of View," Symposium on Elastic Track Fasteners, American Railway Engineering Association, Omaha, NE, June 1992.

4. American Railway Engineering and Maintenance of way Association (AREMA), Manual for Railway Engineering, 2007, Chapter 30, Section 30-A-11.

5. Choros, J., "Laboratory Tests of Three Alternate Track Structures," AAR Report R-614, September 1985.

6. AAR Joint Committee on Relation Between Track and Equipment, "Effect of Flat Wheels on Track and Equipment," AAR Report MR113, May 1951.