Track Structure Sensitivities

A proper understanding of the many factors that influence the distribution of stresses in the railroad track structure is necessary in order to properly balance the many engineering parameters that go into the design of the track structure. If the sensitivities of the track structure, and its key components — the rail, ties, ballast, and subgrade — are properly defined and understood, the most effective means for strengthening the track structure can be determined.

Over the years, many theoretical, analytical, and experimental studies of the behavior of the track structure have been carried out. In the course of these studies, theoretical bases for the behavior of the track structure have been developed, such as the beam on elastic foundation theory explained by Talbot and Kerr (1, 2). Earlier Tracking R&D articles have dealt with this theory (*RT&S*, May 1989, p. 10 and June 1989, p. 12). A recent study performed a comprehensive sensitivity analysis (based on a theoretical foundation), relating each of the key track components to the track parameters that directly influence their behavior and loading (3). It is these sensitivities that are of particular interest to track engineers and maintenance personnel.

Rail bending moment

For example, Figure 1 presents the sensitivities of the rail's bending moment (and the bending stress in the rail) to eight different track design parameters ranging from the rail weight to the modulus (E) of the subgrade (3). "These sensitivities are with respect to a defined set of reference values, as noted in the Figure.") As can be seen in this Figure, the rail weight and track support conditions (as represented by the ballast modulus (E), the ballast depth and the subgrade modulus provide the greatest effect on the bending response of the rail (and, thus, the bending stresses induced in the rail). This is also

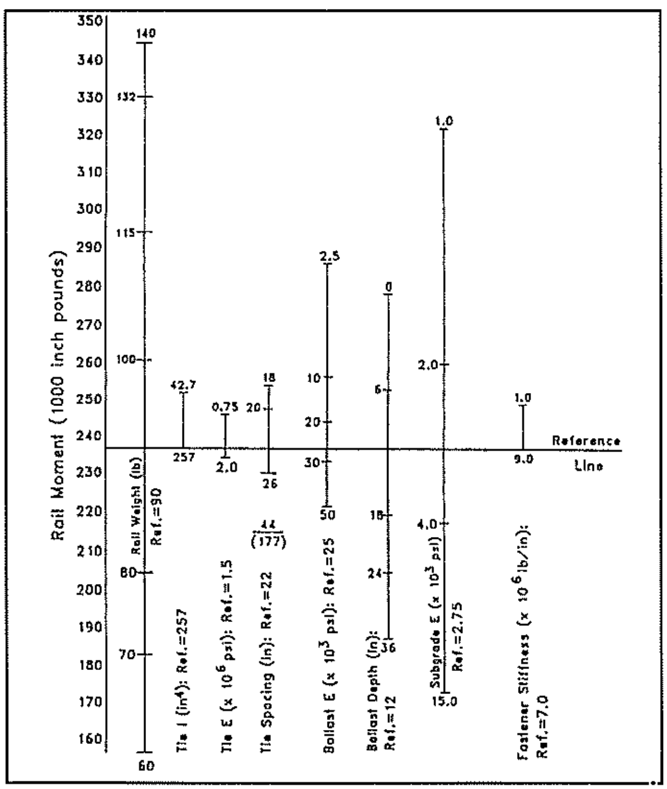

Figure 1 — Effect of inputs on rail moment (3).

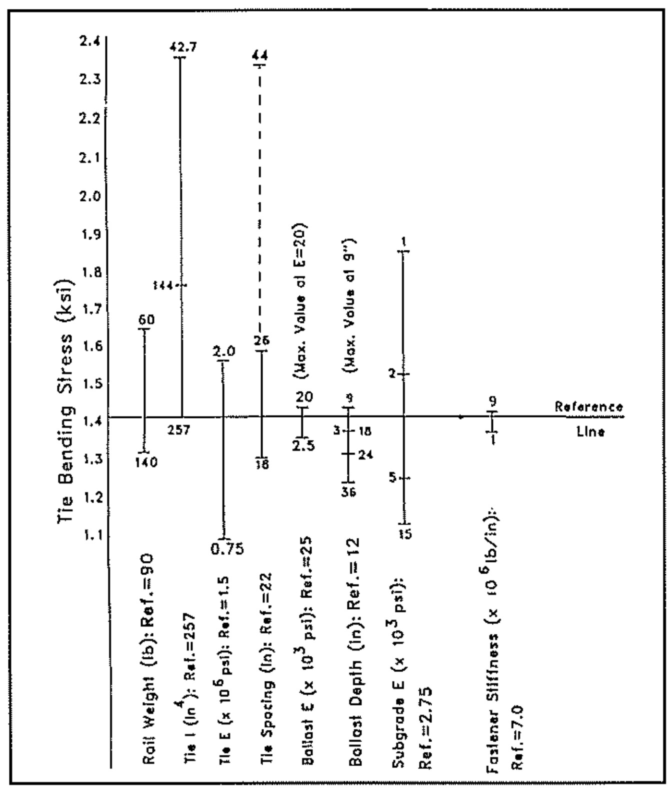

Figure 2 — Effect of inputs on tie bending stress (3).

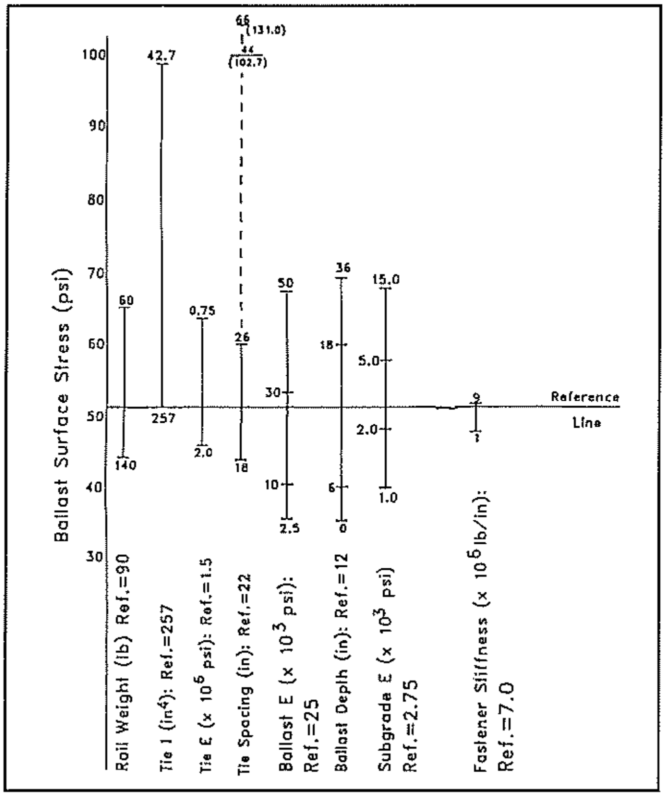

Figure 3 — Effect of inputs on ballast surface stress (3).

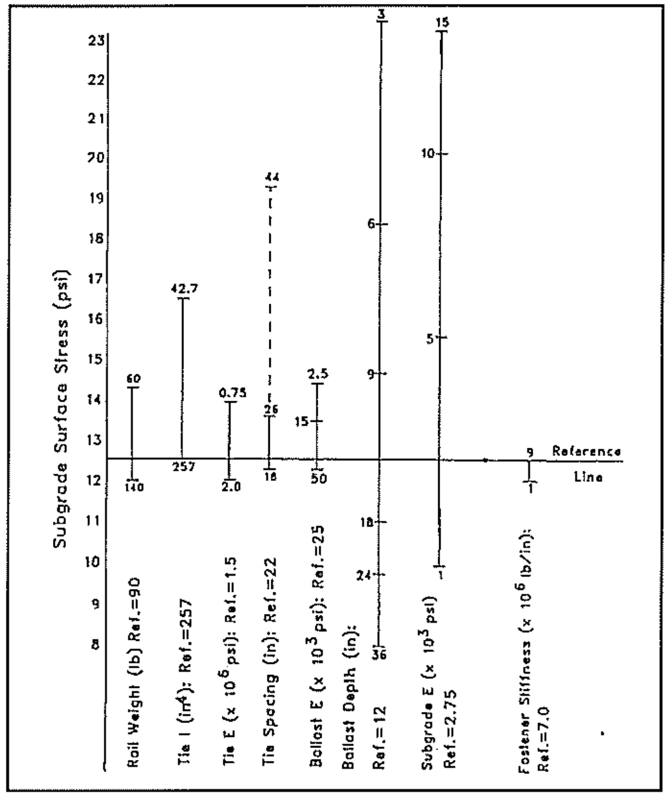

Figure 4 — Effect of inputs on subgrade surface stress (3).

in agreement with the behavior predicted by beam on elastic foundation theory, which showed a strong sensitivity between rail bending moment and two key track parameters: The bending stiffness of the rail (I), which is directly related to its weight, and the track modulus (k or u), which is directly related to the ballast and subgrade conditions (2). Conversely, this Figure shows that several track parameters, such as tie stiffness and modulus, and fastener stiffness have a relatively small effect on the rail's bending moment, thus indicating that changing these parameters will have no real effect on the bending stresses induced into the rail.

Figure 2 presents a similar sensitivity relationship for the cross-tie. In this case, it can be observed that the bending stresses in the crosstie are strongly influenced by the tie's moment of inertia (I) as well as by the subgrades support condition (as defined by its modulus E). Also influencing the tie's bending stresses, though to a smaller extent, are the rail weight, the tie material's modulus, tie spacing and the ballast depth. Fastener stiffness and ballast modulus are shown to have a relatively small effect on tie bending (3).

Figures 3 and 4 present similar sensitivities for the ballast surface stress (stress at the top of the ballast layer) and the subgrade surface stress (stress at the top of the subgrade). In the case of the former, the ballast surface stresses can be seen in Figure 3 to be very sensitive to (and strongly affected by) the tie's moment of inertia (I) and the tie's support condition (ballast and subgrade characteristics). Also influencing the ballast surface stress, though to a smaller extent, are rail weight, tie modulus and tie spacing (3). Figure 5 illustrates the latter sensitivity, i.e. the effect of tie spacing on ballast surface stress, in a more conventional format.

Figure 4 (3) presents the sensitivity of the subgrade surface stress to the same set of track parameters. This latter case is of particular interest, since the more traditional beam on elastic foundation analyses do not differentiate between stresses within the ballast/subballast layer. As can be seen in this figure, the subgrade surface stress is most strongly influenced by the depth of the ballast layer and the properties of the subgrade itself.[3] This indicates that in an area in which the subgrade is overstressed, increasing the depth of the ballast above that subgrade is an effective method for reducing that subgrade surface stress. While changing rail size, tie properties and/or spacing, the relative effect of these changes are significantly less than that of changing the depth of the ballast layer (or changing the subgrade material itself, a difficult job).

It is through these types of engineering sensitivities, that theoretical track relationships can be used to guide railway engineers in their efforts to effectively strengthen the track structure. It should again be noted that these results are based on a theoretical model of the track structure, and as such are limited by the model(s) used to develop these relationships. They represent a tool, however, that can be used by railway engineers to correct problems within the track structure.

References:

1. Talbot, A. N. et al., "Report of the Special Committee on Stresses in Railroad Track", Bulletin of the American Railway Engineering Association, 1918-1940.
2. Kerr, A. D., "On the Stress Analysis of Rails and Ties", Bulletin of the American Railway Engineering Association, Bulletin 659, Volume 78, September 1976.
3. Plotkin, D. E., Wagers, S. K., and Prose, G., "A Railroad Track Structural Analysis Method for Work Planning: Development and Example Application", US Army Corps of Engineers CERL Technical Report M-91/07, October 1990.