Vertical Wheel Loads: The Distribution on Cross-Ties

The primary function of the track structure is to support the loads of the vehicles moving over the track, and to distribute the loads through the track structure in a safe and efficient manner. To that end, the track structure is designed as a series of elements, each of which "spreads" the vehicle loads so as to permit the next element (or series of elements) to support the load effectively.

This concept is illustrated in Figure 1, which shows that a single wheel load, P, is distributed by the track structure from the railhead to the crossties, into and through the ballast layer, and into the subgrade. The actual manner in which the load is distributed, and the "shape" of the load distribution, is determined by the design of the track structure itself. By analyzing the track structure as a "beam on an elastic foundation" (see *RT&S,* May 1989, p. 10 and June 1989, p. 12), it is possible to calculate the distribution of the load through the track structure and through each of its individual elements (1, 2).

The distribution of loading can be clearly seen in the case of the transfer of a single wheel load from the rail to the crossties. As Figure 1 indicates, the rail acts as a beam resting on an elastic foundation (composed of the ties, ballast, subballast and subgrade). The rail "beam" distributes the load of an individual wheel over several crossties — the one directly beneath the wheel (tie No. 0) and several ties on either side of it (ties Nos. 1, 2, 3, etc.). The actual number of ties that carry a share of the wheel load, and the actual percentage of the wheel load carried by each tie, is a function of the strength of the beam (which in turn is a function of its section, or size) and the stiffness of the track support (the track modulus). Such a distribution is illustrated in Figure 2, which shows that one wheel load is distributed over more than seven ties in the case of a conventional track structure (heavy rail, stan-

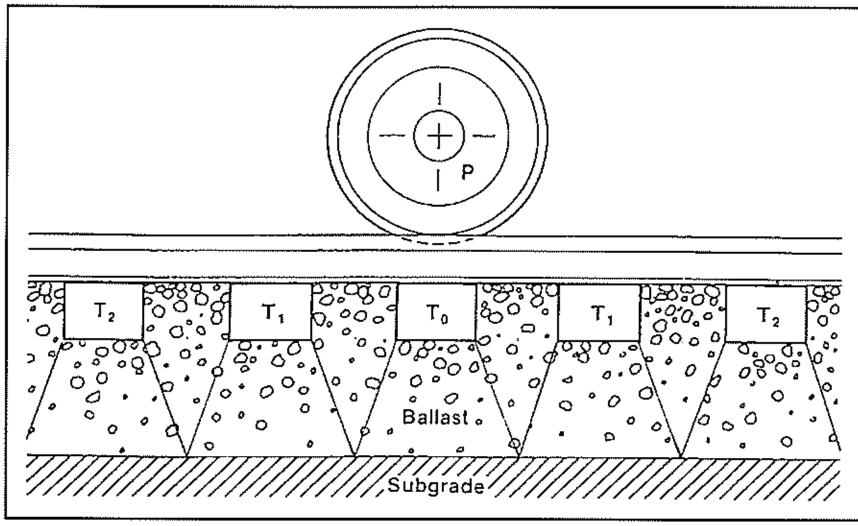

Figure 1 — Distribution of vertical wheel loads to the track structure.

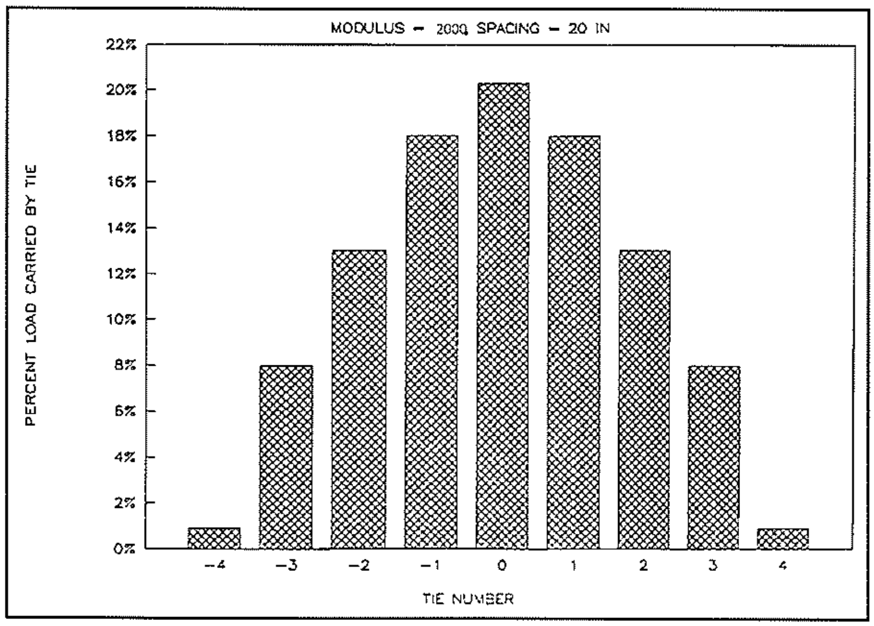

Figure 2 — Distribution of vertical wheel loads.

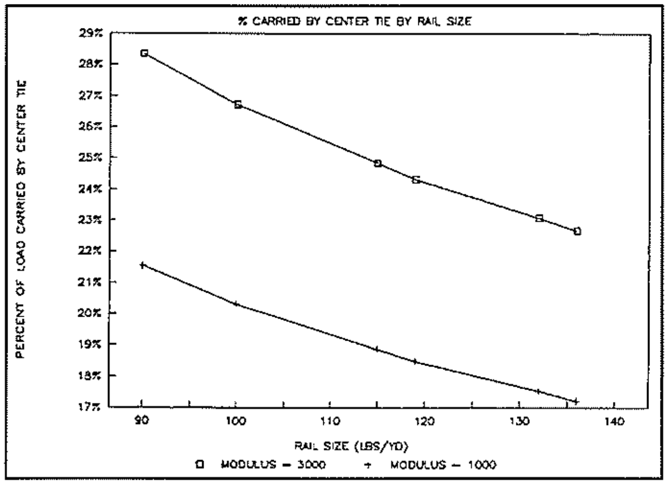

Figure 3 — Effect of tie spacing on load distribution.

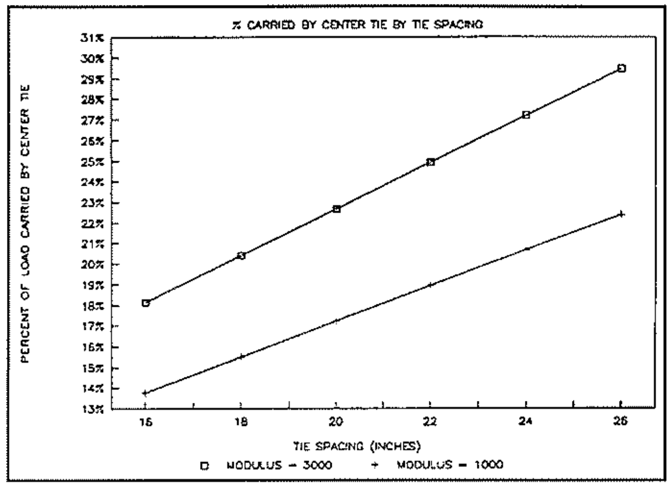

Figure 4 — Effect of rail size on load distribution.

dard tie spacing, wood ties) on a good track foundation (with a modulus of 3,000 lbs/in./in.). It should be noted that while the center tie does carry the largest single percentage of the vertical wheel load, it does not necessarily carry the bulk of the load. While the exact percentage will vary as a function of the track design and conditions, the center tie generally carries between 15% and 40% of the applied wheel load. In the case of good track with a heavy rail section (illustrated in Figure 2), the center tie carries approximately 20% of the wheel load, while each of the adjacent ties (one on either side) carries an additional 18%. Thus, the three ties directly under the wheel carry a total of almost 60% of the wheel load. However, even a tie 80 inches away from the wheel (tie number 4) carries a small amount of the wheel load. (Shortly beyond that point begins the "uplift" wave effect, where a negative or uplift force is applied to the ties (1, 2).)

The effect of changing track design parameters, such as rail section and tie spacing, on the distribution of loads is illustrated in Figures 3 and 4. Figure 3 shows the effect of changing rail section (which corresponds to rail size and rail stiffness) on the percentage of the wheel load carried by the center tie. As would be expected, increasing the size of the rail from 90 pounds to 136 pounds results in a decrease in the percentage of the wheel load carried by the center tie. This is due to the stiffer rail (the rail with the larger moment of inertia) "spreading" the load, thus reducing the percentage carried by the center tie, and increasing the number of ties which are affected by this wheel. This effect holds true even when the modulus (stiffness) of the track is changed, as is shown in Figure 3, for track modulus values of 3,000 lbs/in./in. (good track) and 1,000 lbs/in./in. (soft track).

Changing the tie spacing also results in a change in the distribution of the wheel load to the crossties. As can be seen in Figure 4, increasing the tie spacing causes the center tie to carry an increased percentage of the wheel load. This, in fact, is what happens in track in the area of a "failed" tie. In such a case, the adjacent ties are forced to support an increased share of the vertical (as well as the lateral) load, which increases the magnitude of the load applied to the ties.

A proper understanding of the behavior of the track structure, in supporting and distributing wheel/rail forces, can help maintenance personnel better understand the effects of their design or maintenance decisions, and allow them to effectively design and maintain their track.

References

(1) Talbot et al., "Report of the Special Committee on Stresses in the Railroad Track," Bulletin of the American Railway Engineering Association, 1918-1940.

(2) Hay, W. W., *Railroad Engineering, Second Edition*, John Wiley & Sons, New York, 1982.