

Distribution of Vertical Wheel Loads: Ballast and Subgrade

In last month's Tracking R&D, the distribution of vehicle (wheel) loading from the rail to the cross-ties was discussed. It was noted that the track structure is designed as series of elements, each of which "spreads" the vehicle loads so as to permit the next element, or series of elements, to effectively support the load.

Figure 1 presents this distribution conceptually, showing the transfer of loading into the ties, from the ties through the ballast and into the subgrade. As can be seen from this figure, a single wheel load, P , is distributed over several cross-ties and into the ballast with a large "footprint." The ballast layer spreads the load over a wide area so as to reduce the actual bearing pressure transmitted to the subgrade. Spreading the load is a key function of the track structure. It allows for the distribution of the large wheel/rail forces through the ballast and subballast, and reduces the corresponding loads (pressures) to a level compatible with that of the subgrade.

Reducing the unit pressure

By increasing the depth of the ballast, the area over which these forces are distributed (the base of the "pyramid") increases (1). This, in turn, reduces the unit pressure at the bottom of the ballast layer. Thus, by properly matching the depth of the ballast to the bearing strength of the subgrade, it is possible to optimize the "design" of the track structure to allow the wheel load to be distributed to a level of bearing pressure compatible with the actual strength of the subgrade.

This behavior is illustrated in Figure 2, which shows the subgrade pressure as a percentage of the tie-bearing pressure (i.e. the load transmitted to the ballast directly underneath the tie) and as a function of the depth of the ballast and subballast layer. As can be seen in this figure, the subgrade pressure (in percent or psi) decreases directly with the ballast depth. This effect significantly

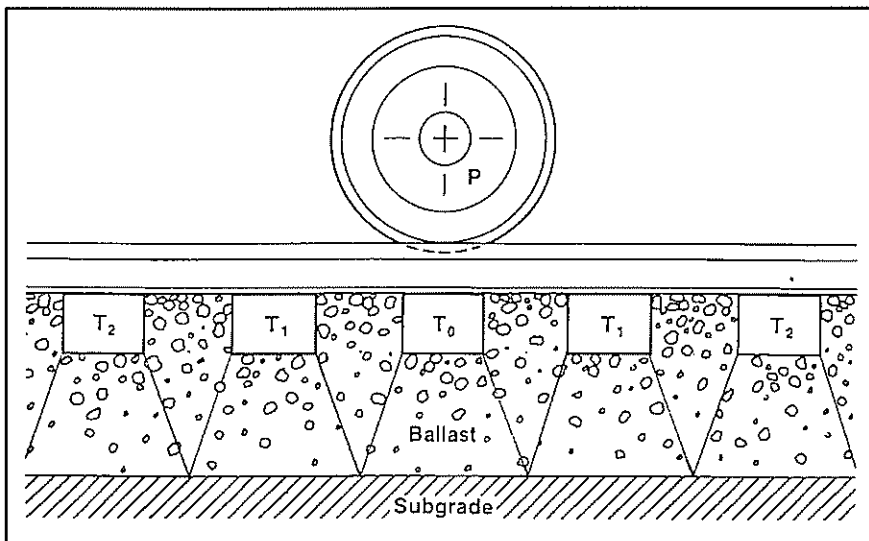


Figure 1 — Distribution of vertical wheel loads to the subgrade

reduces the subgrade pressure from more than 75% of the tie-bearing pressure at a ballast depth of 12 inches to approximately 25% at a depth of 30 inches of ballast and subballast.

This analysis was based on the empirical (test-derived) relationship developed by A. N. Talbot (2, 3) which states that subgrade pressure decreases non-linearly with ballast depth. While other relationships between vertical pressure and ballast depth have been developed by various researchers (4), they all show this inverse relationship between pressure and ballast depth, which indicates that the vertical pressure decreases as the ballast depth increases.

Figure 3 shows the same behavior as a function of the load carried by the individual tie. As was noted in last month's Tracking R&D, the wheel load is carried by several ties. The actual percentage of the wheel load carried by each tie is a function of the rail section and the stiffness of the track support (track modulus). As can be seen in Figure 3, while the vertical pressure (in psi) varies as a function of the tie load, in all cases, increasing the depth of the ballast layer can significantly reduce the load transmitted to the subgrade.

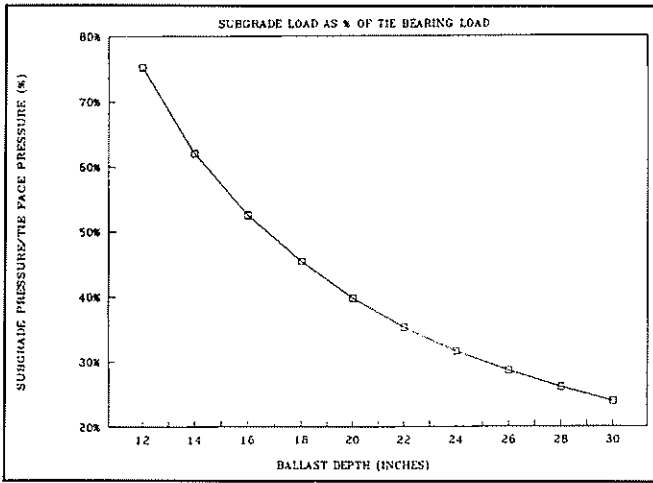


Figure 2 — Subgrade stress versus ballast depth.

By properly matching the depth of the ballast layer with the strength of the subgrade, as obtained through soil classifications and tests such as the California Bearing Ratio, it is possible to properly design the track structure (and specifically the ballast and subballast layer) to allow for a transfer of load at a level below that which will cause overloading and local failure of the subgrade materials.

A proper understanding of the behavior of the track structure in supporting and distributing the wheel/rail forces applied to the track can help maintenance personnel understand the effects of their design or maintenance

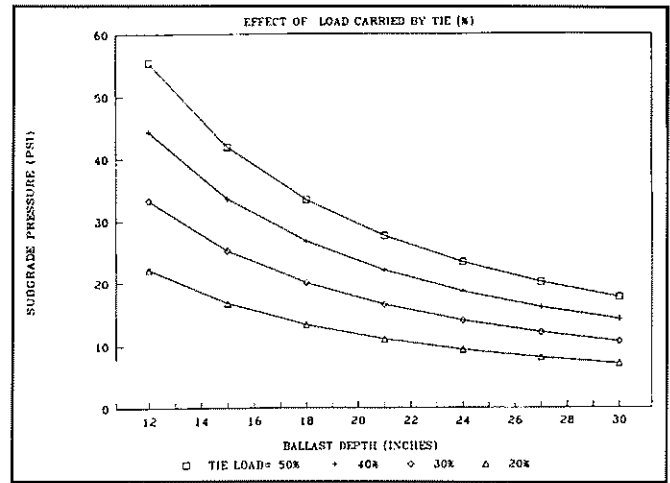


Figure 3 — Subgrade pressure versus ballast depth

decisions, and allow them to effectively design and maintain their track structure. This is particularly important in today's environment of increasing traffic densities.

References

- (1) Clarke, C. W., "Track Loading Fundamentals—3: Determination of Ballast Depth," *The Railway Gazette*, February 1957.
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- (3) Hay, W. W., *Railroad Engineering, Second Edition*, John Wiley & Sons, New York, 1982.
- (4) Doyle, N. F., "Railroad Track Design: A Review of Current Practices," Australian Government Publishing Service, Canberra, 1980.