Track Modulus Characteristics

As was discussed in the previous Tracking R&D (RT&S, May 1989), the track modulus is a representation of the stiffness of the track structure based on a physical model. It is related directly to the deflection of the track under load, such as under a passing freight car axle.[1,2]

However, this modulus or stiffness value varies, not only as a function of the track structure and its condition (*RT&S*, May 1989), but also as a function of the loading itself. This behavior stems from the fact that the track substructures — particularly the ballast and the subgrade — are non-linear materials; that is, their deformation under load behaves in a non-linear manner. Yet, beam-on-elastic-foundation theory assumes that this support condition is linear, i.e., the track substructure acts as a linear spring.

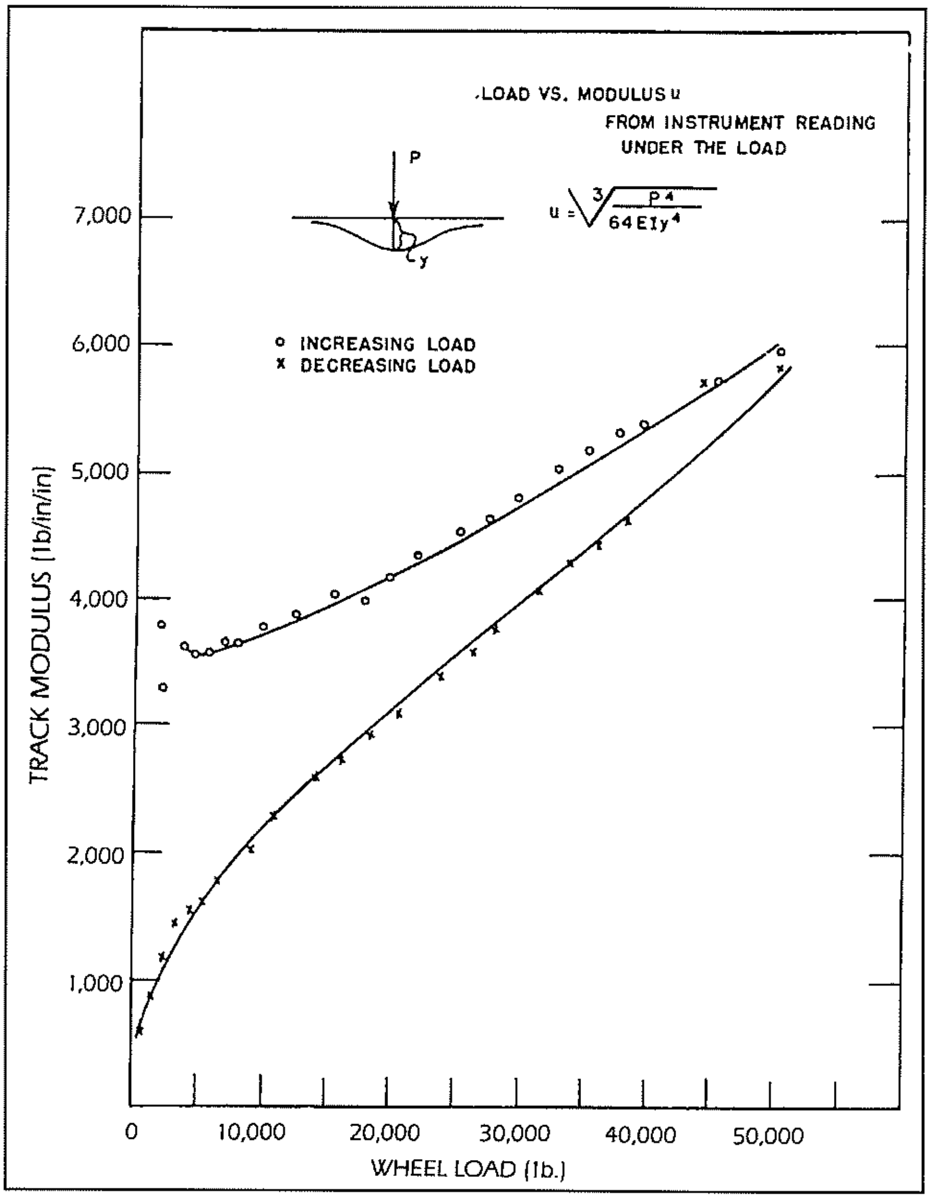

Figure 1 — Modulus vs. wheel load for the increasing and decreasing load sequence

The result of this difference between theory and "reality" is the relationship between modulus (as calculated from beam-on-elastic-foundation theory) and load, presented in Fig. 1.[3] These results were taken from a set of carefully controlled laboratory tests in which the load was increased and the corresponding deflection measured (and modulus calculated).

As can be seen in Fig. 1, the modulus value itself varies as a direct function of the load at which the deflection is taken. (Note: if the load-deflection behavior was truly linear, the same modulus value would be obtained irrespective of the applied load.) This variation is quite significant, ranging between 3,500 lb./in./in. and 6,000 lb./in./in. (on the loading cycle) for wheel loads between 5,000 lb. and 50,000 lb. For a load of 33,000 lb., corresponding to the static load of a 100-ton car, the modulus value was approximately 4,500 lb./in./in.

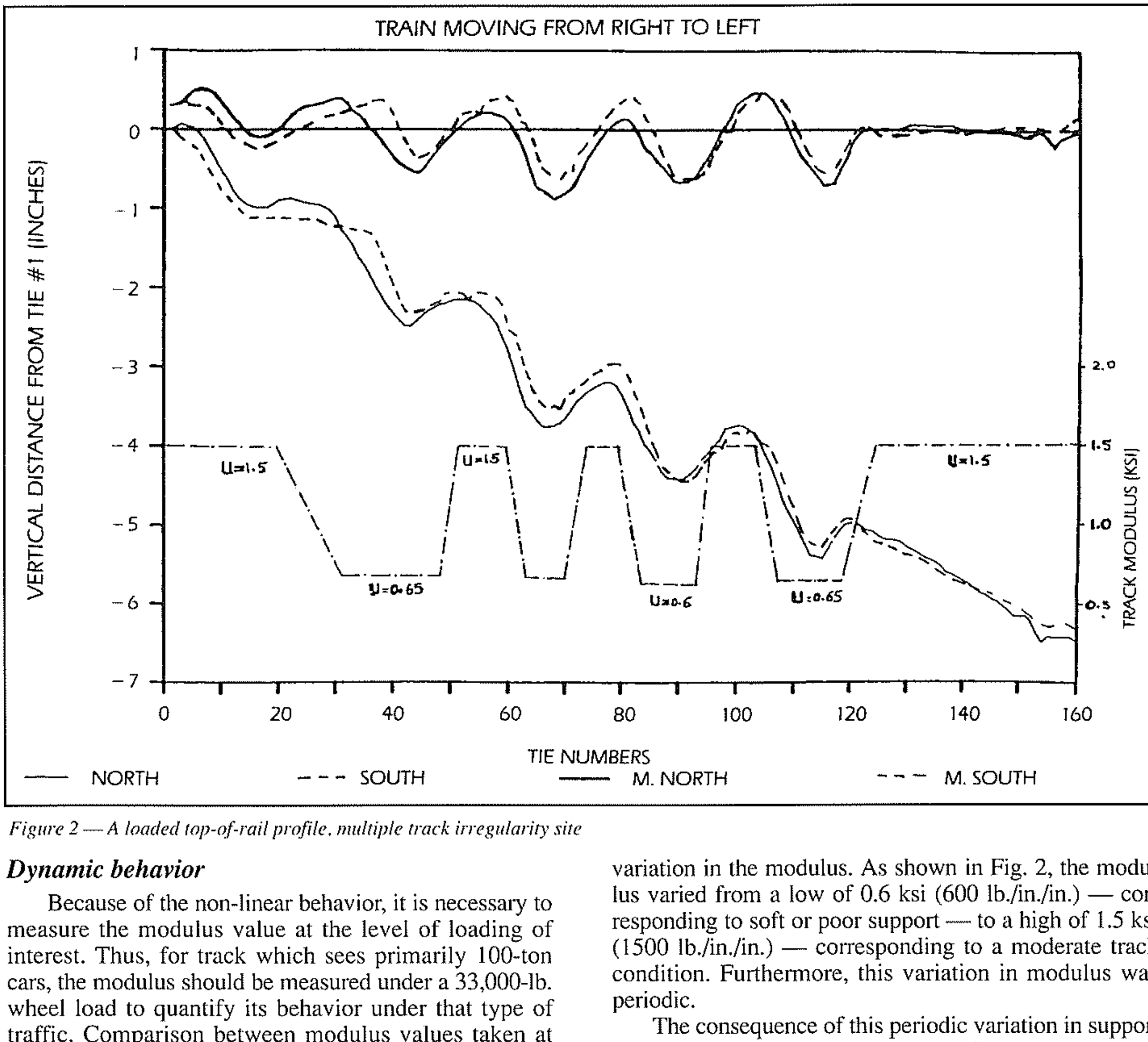

Figure 2 — A loaded top-of-rail profile, multiple track irregularity site

Dynamic behavior

Because of the non-linear behavior, it is necessary to measure the modulus value at the level of loading of interest. Thus, for track which sees primarily 100-ton cars, the modulus should be measured under a 33,000-lb. wheel load to quantify its behavior under that type of traffic. Comparison between modulus values taken at different levels of loading can be, as a result of this behavior, quite difficult and should be done with caution.

Another recently observed behavior associated with variation in track modulus along the track is the effect of varying track modulus on vehicle dynamic behavior. Specifically, that variations in modulus longitudinally along the track can excite a moving freight car vertically and initiate harmonic "bounce" in the moving vehicle.

This type of behavior, which has been demonstrated theoretically, was observed recently in an AAR test using an instrumented box car.[4] At several sites along the test route, the vehicle experienced vertical bolster loads in excess of 1.8 "g"s (1.8 times the static load). Most of these loads were attributed to either individual irregularities in the track, such as a deep engine burn, or to multiple irregularities in the track, such as variations in surface geometry due to low welds. However, at one test site a distinct variation in track support condition was observed.

Measurement of the track deflection and associated track modulus at this site showed a distinct pattern of variation in the modulus. As shown in Fig. 2, the modulus varied from a low of 0.6 ksi (600 lb./in./in.) — corresponding to soft or poor support — to a high of 1.5 ksi (1500 lb./in./in.) — corresponding to a moderate track condition. Furthermore, this variation in modulus was periodic.

The consequence of this periodic variation in support condition was that the track acted as if there were a series of vertical surface irregularities in the roadbed. This in turn resulted in vehicle bounce and the corresponding high vertical bolster load.

Thus, while track engineers have always been aware intuitively of some of the consequences of poor track condition, the ability to monitor the track support condition through the measurement of the track modulus represents another tool through which the track structure can be evaluated and maintained.

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.
3. Zarembski, A. M., and J. Choros, "On the Measurement and Calculation of Vertical Track Modulus," *Association of American Railroads Report R-392*, September 1979.
4. Reinschmidt, A. J., and S. Kalaycioglu, " Using an Instrumented Freight Car to Locate Vertical Track Irregularities Which Cause Excessive Vertical Loads," *AREA Committee 2 Symposium on Automated Track Measurement*, Chicago, IL, March 16-17, 1988.