Track Modulus vs. Track Structure

The traditional method of defining the vertical support condition of the railroad track structure has been the "track modulus." Track modulus, often referred to as the "modulus of elasticity of rail support," is a theoretical concept that is based on the assumption that the track structure acts as a continuously supported beam — the rail — resting on a uniform layer of springs. This layer of springs represents the remainder of the track structure: ties, ballast, sub-ballast and subgrade. The stiffness of this spring layer along the length of the track is the track modulus, and is usually represented in the literature by the letter "u" or "k".

Track modulus is directly related to the deflection of the track under load (see *RT&S*, June 1985). That is, the greater the track modulus, the stiffer the track structure and the smaller the deflection of the track under a given axle (or truck) load. Conversely, soft track — track with poor support that has a large deflection under load — has a low track modulus.

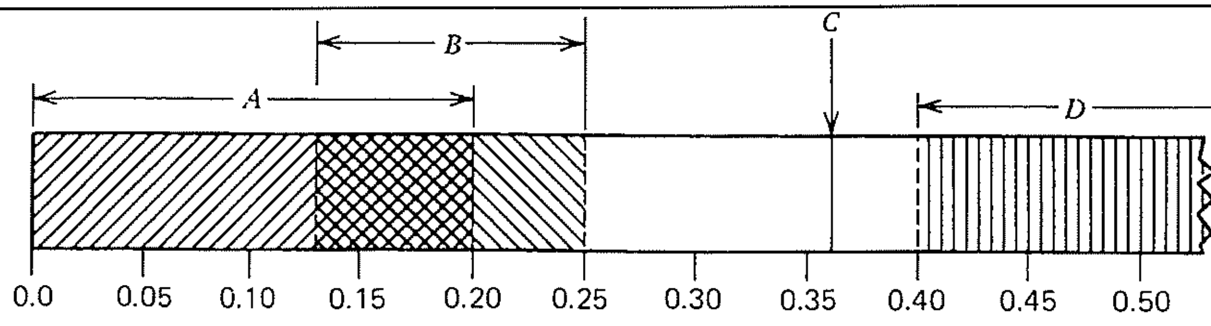
The most commonly used relationship between deflection and modulus calculates the modulus at a given location using the track deflection directly underneath the loading wheel, the applied wheel (or axle) load, and the stiffness of the rail section. This is based on the "beam on elastic foundation" theory, first introduced in the 19th century.

Studies over the years have related the track modulus to the type of track structure and its subsequent behavior

TABLE 1 VALUES OF *u*

Rail	Ties	Track and Ballast	*u*
1. 85 lb	7 in. × 9in. × 8 ft 6 in. spaced 22 in. c. to c.	6-in. fine cinder ballast, in poor condition on loam and clay subgrade	530
2. 85 lb	7 in. × 9 in. × 8 ft 6 in. spaced 22 in. c. to c.	6-in. cinder ballast, in fair condition on loam and clay subgrade	750
3. 85 lb	6 in. × 8 in. × 8 ft 0 in. spaced 22 in. c. to c.	6-in. limestone on loam and clay roadbed; good before tamping	970
4. 85 lb	6 in. × 8 in. × 8 ft 0 in. spaced 22 in. c. to c.	6-in. limestone on loam and clay roadbed; after tamping	1080
5. 85 lb	7 in. × 9 in. × 8 ft 0 in.	12-in. limestone on loam and clay roadbed; good before tamping	1065
6. 85 lb	7 in. × 9 in. × 8 ft 0 in.	12-in. limestone on loam and clay roadbed; after tamping	1090
7. 85 lb	7 in. × 9 in. × 8 ft 6 in. spaced 22 in. c. to c.	24-in. crushed limestone on loam and clay	1200
8. 130 lb RE	7 in. × 9 in. × 8 ft 6 in. spaced 22 in. c. to c.	24-in. gravel ballast plus 8 in. of heavy limestone on well compacted roadbed	2900-3000
9. 110 lb RE	7 in. × 9 in. × 8 ft 0 in. spaced 22 in. c. to c. GEO fastenings	Flint gravel ballast on wide, stable roadbed	2500, 2600, 3600 Average 2900
10. 110 lb RE	7 in. × 9 in. × 8 ft 0 in. spaced 22 in. c. to c. GEO fastenings	Limestone ballast on wide, stable roadbed	3700, 5500, 6200 Average 5100

*From the First and Sixth Progress Reports of the Special Committee on Stresses in Railroad Track.



Range	Track Behavior
A	Deflection range for track that will last indefinitely
B	Normal maximum desirable deflection for heavy track to give requisite combination of flexibility and stiffness
C	Limit of desirable deflection for track of light construction (≤100 lb)
D	Weak or poorly maintained track that will deteriorate quickly

Values of deflection are exclusive of any looseness or play between rail and plate or plate and tie and represent deflections under load.

Figure 1

in track. The extensive research of the Talbot Committee in the 1920s and 1930s[1,2] resulted in a commonly referred to table of track characteristics and associated modulus values. This table is shown here. Note that the modulus values range from a very poor track (u = 500 lb./in./in.) to a very good value of over 5000 lb./in./in. These in turn correspond to deflections of over $\frac{1}{2}$-in. for the poor track to less than $\frac{1}{10}$-in. for the stiff track. As can be seen in Fig. 1,[2,3] the former track is expected to deteriorate quickly while the latter track is expected to have a very low rate of degradation.

More recent research has examined the effect of newer track materials on track stiffness. These new materials include concrete cross-ties and elastic fasteners on both wood and concrete cross-ties. While it is clear that a poor ballast and/or subgrade section will have poor track support, and correspondingly a low modulus regardless of the track superstructure, the effect of the tie and fastener systems can be noticeable for moderate and good subgrades.

One recent set of carefully controlled laboratory tests — taken on a *good subgrade* — compared wood ties with cut spikes, wood ties with elastic fasteners, and concrete ties with elastic fasteners.[4] In all three cases, the track modulus was over 4000 lb./in./in., corresponding to a deflection of less than $\frac{1}{10}$-in. However, the effect of the elastic fasteners on wood and the combined concrete ties and elastic fasteners was to increase the vertical modulus by a further 67 percent and 100 percent respectively.[4] (Note: these tests represent one specific set of tests with a specific ballast and subgrade under a simulated truck loading of 33 tons per axle.) These results are presented in Fig. 2.

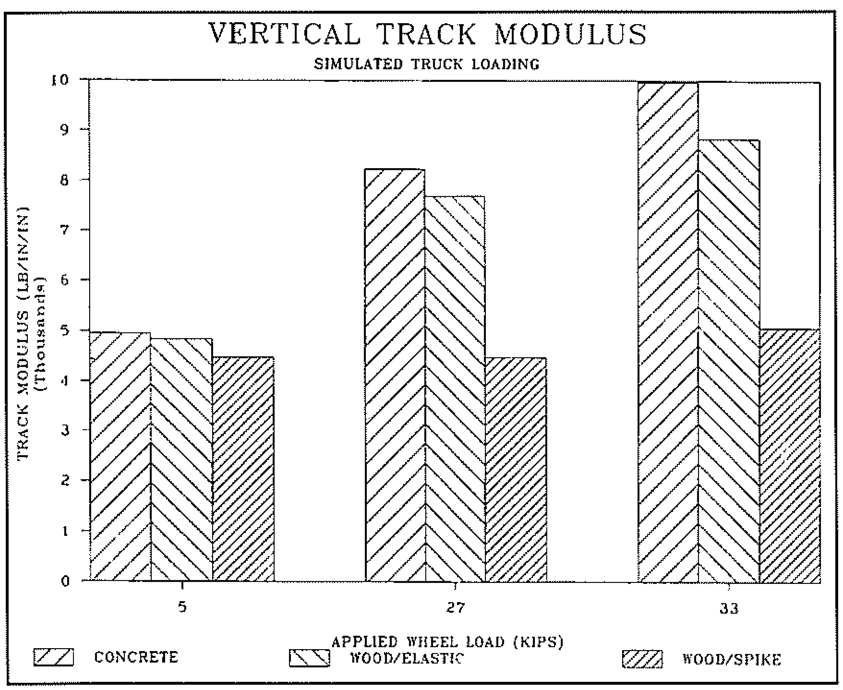


Figure 2 — Vertical Track Modulus

This type of behavior, which has been observed elsewhere as well, suggests that significant increases in track stiffness beyond those values first examined by Talbot are possible. In light of recent studies of the effect of track stiffness on wheel impacts and wheel rail dynamics (RT&S, May 1987), it is not clear that "good" track behavior will continue for these stiff track structures, and in particular the very stiff structures with modulus values exceeding 10,000 lb./in./in. This issue remains a subject for further research.

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. Lundgren, J. R., et al., "A Simulation Model of Ballast Support and the Modulus of Track Elasticity," *University of Illinois Civil Engineering Transportation Series No. 14*, Urbana, Illinois, 1970.
4. Choros, J., "Laboratory Tests on Three Alternative Track Structures, *Association of American Railroads Report R-614*, September 1985.