Effect of Track Stiffness on Vehicle Rolling Resistance

One of the benefits recently claimed for concrete tie track is its increased track stiffness or modulus This refers to the fact that for concrete tie track, the deflection under load, or stiffness,[1] is greater than for corresponding wood tie track. This behavior has been examined in the past[2] and has been the subject of recent additional tests by the Association of American Railroads.[3] Fig. 1 presents the results of this most recent set of tests carried out at the AAR's track laboratory. As can be seen in this figure, the modulus of concrete tie track is three to five times greater than for corresponding wood tie track, under the test conditions reported in Reference 3.

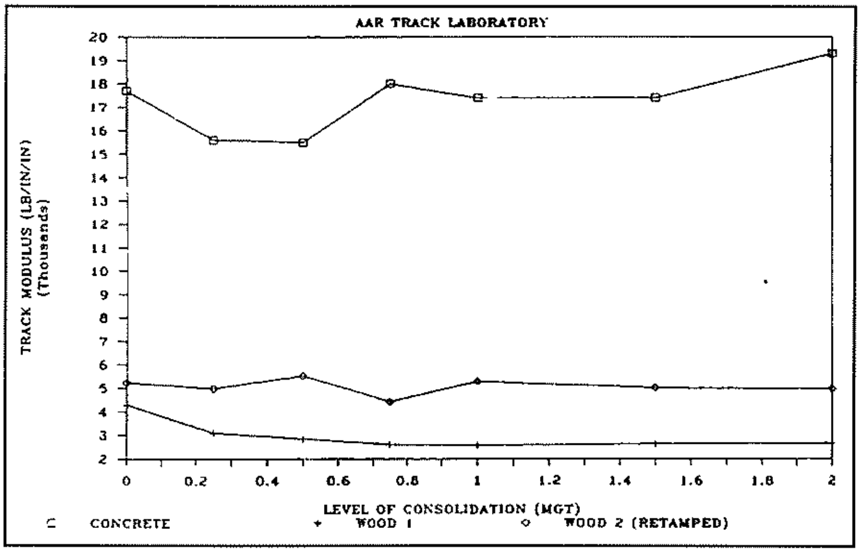

Figure 1 — Vertical Track Modulus Tests

Associated with this increase in track stiffness is a corresponding decrease in vehicle rolling resistance.[3] This specific rolling resistance behavior is associated with the deflection of the track under a passing wheel and the associated energy required to overcome this deflection.[4] Thus, in the case of stiffer track, i.e., track with a larger track modulus, the corresponding track deflection under load is less and the associated rolling resistance component due to that track deflection, is likewise smaller.

Tests at the AAR's track laboratory examined the effect of this increased track stiffness on the rolling resistance of the track laboratory's track vehicle. The results are presented in Fig. 2 for the first series of wood tie track tests and Fig. 3 for the corresponding concrete tie tests. Comparing these two sets of results indicates that the rolling resistance under concrete tie track was 0.5 to 1.5 lb./ton less than that under wood tie track. However, subsequent tie tests, in which the ties were retamped to increase their stiffness, did not produce the same significant differences between the rolling resistances of the wood and the concrete tie tracks.[3] Note that these tests were low speed tests, carried out in the range of 3 to 12 ft/sec. (2 to 8 mph). Behavior at higher operating speeds was not examined in these tests because of the operational limitations at the track laboratory.

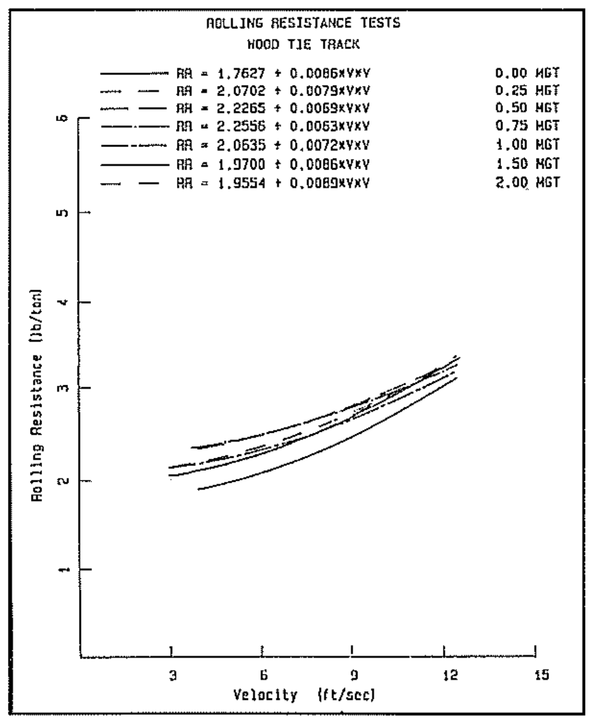

Figure 2 — First wood tie rolling resistance values

These results should be examined in light of earlier work (1937) by the American Railway Engineering Association on the effect of track deflection on train resistance.[4] These AREA studies resulted in the development of an equation for the track deflection component of the rolling resistance.[4] This equation was as follows:

$$R = \frac{0.0145 * P}{\sqrt{(I * u)}}$$

where:

R = rolling resistance due to track deflection (lb./ton)

P = average wheel load, in lb.

I= rail moment of inertia and

u = track modulus in lb./in/in

Using the values obtained by the AAR track laboratory tests[3] in this equation, allows for the calculation of the rolling resistance component due to track deflection. These results are presented in Fig. 4. It must be noted that the rolling resistance values for the wood and concrete tie track in Fig. 4 can not be directly compared with those values in Figs. 2 and 3, because they represent the track deflection component of rolling resistance, while Figs. 2 and 3 present the "total" rolling resistance values (to include wheel/rail friction, as well as other additional factors). However, the difference between the two sets of values, i.e. wood and concrete, can be directly compared, since all of the other factors are held constant in the two sets of tests. Thus, comparing the differences in rolling resistance values, the AREA formula derived differences are shown to be between 0.4 and 0.7 lb./ton (Fig. 4) compared to the differences of 0.5 to 1.5 noted previously for the initial test results (Figs. 2 and 3). These results appear to compare quite favorably, thus suggesting that the rolling resistance difference is in the order of 0.5 lb./ton.

Such a difference in rolling resistance would result in an increased train resistance of approximately 5000 lb. for a 10,000 ton unit train. While the actual fuel penalty associated with this increased resistance is a function of many factors, including speed, operating characteristics, locomotive efficiency, etc., it would be of the order of 1 gal. of additional fuel per mile for each additional 5000 lb. of rolling resistance. Thus, an increase in track stiffness appears to result in a decrease in track related rolling resistance, and associated power (and fuel) requirements .

References:

1. Zarembski, A. M., and J. Choros, "On the Measurement and Calculation of Vertical Track Modulus," Association of *American Railroads Report R-392*, September 1979.
2. Kish, A. et al, "Track Structures Performance Comparative Analysis of Specific Systems and Component Performance," *Federal Railroad Administration Report FRA/ORD-77/79*, September 1977.
3. Reinschmidt, A. J., and S. P. Singh, "Resistance Due to Vehicle Track Interaction," *Proceedings of the Railroad Energy Technology Conference II*, Atlanta GA, May 1986. Also published as AAR Report R-671, 1987.
4. Van Atta, R. E., et al, "Train Resistance as Affected by Weight of Rail," *Bulletin of the American Railway Engineering Association, Vol. 38*, 1937.

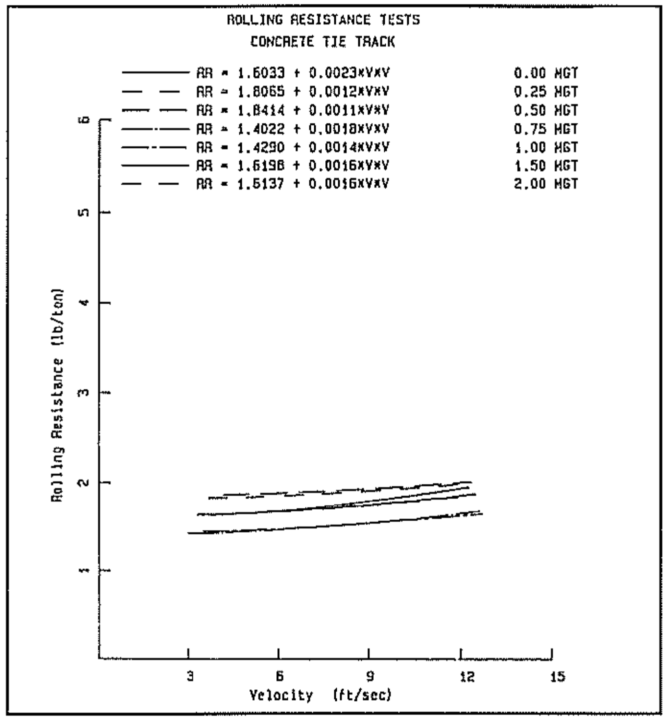

Figure 3 — Concrete tie rolling resistance values.

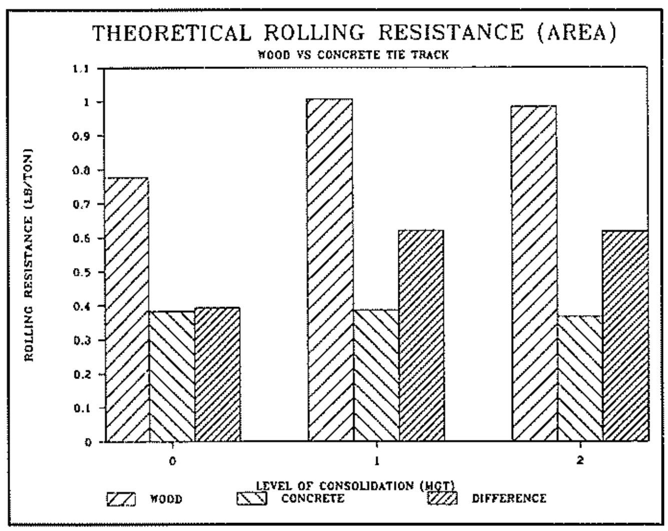

Figure 4