Introduction

GEORGE H. WAY

The question of crosstie function or purpose cannot be addressed in isolation; the function of railway track must first be discussed. Because track is a system that includes ties, rails, ballast, and fastenings, care must be taken to not focus solely on one element of that system without recognizing that each element affects the others and is, in turn, affected by them as well. In recent years track system design and analysis has become rather sophisticated. Computer models help analysts predict stress levels and performance and life expectancy of many track systems elements. Also, economic models help analysts choose least-cost alternatives of component renewals.

Currently there is better instrumentation to verify those models and tell the analyst what is actually occurring in track structure under load. But there is concern that too much specialization may detract from concentrating on the entire system. Analysts cannot afford to concentrate so hard on any one element of track that they lose sight of what is occurring in the rest of the system.

The function of railway track is to support and guide railway vehicles. Crossties play a significant role in that general function in conventional or crosstie track, but only because up to now, at least, crosstie track has proved to be generally the most economical track structure available to railway engineers. Yet it must be remembered that so-called conventional track is only one of several civil engineering structures capable of performing the function of guiding and supporting trains. So far it is the best for most purposes, but there are most likely exceptions.

Having established that, the issue of conventional or crosstie track can be addressed. But first, some history of crossties must be recalled. In the first burst of enthusiasm for building railways both in the United States and in Great Britain, where it all started some 150 years ago, railway track did not include crossties. The crosstie as an element of track structure was invented by an American in 1832. Earlier track builders confronted with the problem of distributing rail loads to the subgrade tended to use stone sleepers; that is, blocks of stone supporting a single rail. (The term sleeper still remains in use in Great Britain, even when they are really talking about crossties.)

Early in the 1830s Jonathan Knight was the engineer in charge of building the original parts of the first U.S. railroad, the Baltimore & Ohio's line westward from Baltimore to Point of Rocks by way of Ellicotts Mills. Chessie people have properly referred to that trackage over the years as the Old Main Line. Knight used no less than five types of track structure. Several of these included wooden stringers to which iron straps were attached to form a rail. Knight also copied the British practice of supporting these rails on stone blocks approximately 14 in.[2].

At about the same time Robert Stevens was in charge of track construction on the Camden and Amboy Railroad. Stevens is known as the inventor of the Tee rail. He is purported to have conceived of the Tee rail while whittling to pass the time on the long voyage to England to purchase the original Camden and Amboy locomotive. That locomotive was the John Bull; currently it resides in Washington, D.C., at the Smithsonian Museum.

Stevens purchased the locomotive without difficulty from Robert Stephenson, who had achieved his fame as the builder of the Rocket for the Liverpool & Manchester, the first passenger-carrying railway in the world. The rail, however, was another matter, but eventually Stevens was able to have some Tee rail rolled in Wales after he posted bond against potential damage to the mill machinery. The No. 36 iron rail was shipped from Cardiff and received in Philadelphia in May 1831.

Stevens, like others, including Knight, was fastening this rail to stone blocks as he pressed his track construction southward on the east bank of the Delaware River. However, whereas Knight placed his square stone blocks diagonally to the rail with their corners in contact, Stevens placed them normal to the rail and about 3 to 4 ft apart. By December 1832, the line was almost complete from South Amboy to Bordentown, New Jersey. The Camden and Amboy stone sleepers were made of granite quarried at Sing Sing, New York.

Stevens was anxious to complete track construction to Bordentown before winter halted construction. But delivery of the stone sleepers was slow. As a temporary expedient, he had nearby trees cut into logs, laid them crosswise to the track, and spiked the rail to them. This expedient not only worked, it worked better than the stone-sleepered track. It worked better because the newly innovated crossties served the functions of load distribution and gauge retention; at the same time these crossties were economical, and they also knit the track structure together so that both rails remained in a common plane.

The unintended genius of Steven's invention was additionally attractive because the wooden crossties permitted inexpensive fastening of rail to the supporting structure. It was soon found that crossties also facilitated rapid and convenient correction to irregularities of line and surface. This attribute was particularly welcome in view of the enormous difficulties being encountered in this regard with stone-sleepered track. Crosstie track was so successful that it quickly supplanted stone-sleepered track, which has never been tried or used again.

The history of crosstie invention has shown a good deal about crosstie functions. Crossties are expected to accept and transmit vertical and transverse rail loads without failure or excessive deflection or deformation, to hold rails in gauge, to hold tracks in line and surface in conjuction with grandular ballast to facilitate restoration of line and surface, and to do all these things at a reasonable first and replacement cost. Rest assured that Robert Stevens did not have a complete performance specification in hand when he cut down that first tree north of Bordentown, but as soon as he cut it to length and laid it in the track bed, the essential criteria for successful crossties were pretty much established. Although the strength, dimensions, and weight of individual crossties can vary within reasonable limits, the performance of a collection of ties for a given set of traffic conditions probably will not. It is interesting to note that, to date, no one has felt compelled to write a performance specification for a timber crosstie.

Track and crosstie development went on in a fairly straightforward fashion for almost 100 years. Iron rail gave way to bessemer steel, and bessemer steel gave way to open-hearth steel. When axle loads increased to the point that rails crushed wood fiber prematurely, tie plates were developed. Rail anchors were used to control longitudinal rail movement. A host of differing grandular materials were tried and used for ballast of different depths and section. Some worked and some did not.

In the early 1900s Arthur N. Talbot of the University of Illinois decided that a more scientific way to describe and analyze the response of track to the loads imposed on it was needed. The concept of track modulus was introduced by Talbot in 1918 after 4 years of study by the American Railway Engineering Association's (AREA) Special Committee on Stresses in Railroad Track, which he chaired. With that first report the importance of crosstie weight, dimensions, spacing, and ballast section in determining track stress and deformation under load began to be understood. Intuitively, engineers believed that less deformation was better than more, and strove for stiffer and stiffer track.

At about the time that some engineers agreed that maybe there was an upper limit to desirable stiffness (after all something usually breaks when there is too little cushion against impact), engineers became serious about energy costs and conservation policies to control them. At the Association of American Railroads' laboratory in Chicago, significant differences in energy consumption of a single vehicle crossing a short piece of track have been measured as the stiffness of that track is increased. Thus, although there probably is an optimum track modulus, it can be surmised now that it is higher than it once was and, like everything else, varies from situation to situation as a function of traffic, weather, and the price of oil.

The choice of material from which to fashion crossties or sleepers has occupied railway engineers since the time of Jonathan Knight and Robert Stevens, and it probably will as long as there are railroads. There are obviously many choices: solid sawn timber, prestressed concrete, reinforced-concrete blocks tied together by steel bars, plain steel, laminated timber, and reconstituted timber. And within each of these broad categories there is considerable variety. In the early days of AREA's Committee 3 (Ties and Wood Preservation), there were many long and serious debates between Jack Slocomb of the B & O Railroad and several other experienced foresters such as Ken Edscorn of MoPac and Lauress Collister of Santa Fe concerning the relative merits of red versus white oak and both versus hickory, beech, and hard maple. There are significant differences between these species in the amount of seasoning required, their treatability, flexure strength, and resistance to decay. There were equally learned discussions in that committee about how much of what kind of preservatives was most economical, and the relative merits of the several methods of treatment.

While these debates were occurring in Committee 3, the AREA Special Committee on Concrete Ties was equally preoccupied with questions of pretensioning versus posttensioning, size of prestressing wire, rusted versus indented wire, wire versus strand, air entrained versus plain concrete, and the relative merits of a host of different aggregates. This is no longer a simple world involving easy choices.

When railway engineers make decisions about what type of crossties they will use, they should and most often do make them on a basis of economics. As mentioned previously, engineers have become more sophisticated about such things.

Price alone is no longer the sole criterion. Discounted cash flow analysis applied to a string of expenditures over the life of the track structures being considered is at long last becoming a fairly standard practice. The problem, however, when dealing with long-lived assets is the number of factors to be included, what assumptions the engineers are prepared to make, and what values the engineers select when such assumptions are made. Even with current analytic tools, the enormous computational power available, and the proliferation of data, the decision-making procedures are far from precise or accurate. If Robert Stevens, Jonathan Knight, and Arthur Talbot could hear today's engineers, they are probably chuckling to one another about how complicated railroad engineering has become.

But even with sophisticated tools, decisions still must be based in large part on judgment, gut feel, and intuition. No longer can engineers use these kinds of inexact criteria to choose between 7 in. x 9 in. x 8 ft., 6 in. red oak seasoned for 9 months and treated with No. 7 per cubic foot of 60/40 creosote/coal tar and a 10 in. wide x 9 in. long No. 670 pretensioned concrete tie using 9 indented wires for prestress, exhibiting a 300 ft/lb flexure strength at the rail seat.

Unfortunately, engineers do have to call on the same kinds of inexact judgmental criteria to tell them what volume of traffic the track will carry 5 and 10 years from now, what the wheel loads will be, and what the inflation rate and cost of capital will be. These factors are fed into computers so that an objective decision, free of emotion and intuition, can be made about the decision to use either the red oak or prestressed-concrete tie.

Today engineers have to become much smarter before they can say that these decisions are made based solely on objectivity. Thus it is hoped that these papers on crossties will aid engineers in their work.