A Performance-Based Approach to the Development of a Recycled Plastic/Composite Crosstie

Thomas Nosker, Ph.D., Richard Renfree Ph.D., and Jennifer Lynch
Plastics & Composites Group, Rutgers University

Mark Lutz - Conrail, Altoona, PA
Barry Gillespie - Norfolk Southern
Kenneth E. Van Ness, Ph.D. - Washington and Lee University
Richard Lampo - U.S. Army Construction Engineering Research Laboratories

Introduction

In 1994, Rutgers University's Plastics and Composites Group, formerly the Center for Plastics Recycling Research was grant funded by the New Jersey Commission on Science and Technology to develop and test composite railroad ties made from recycled plastic. Since the inception of this project, the major participants have been Rutgers University, Earth Care Products, Inc. (US Plastic Lumber), Conrail, Norfolk Southern, and the US Army Corps of Engineers.

The base mixture of materials targeted for use in this application is predominantly high-density polyethylene from milk bottles, detergent bottles, and the like. Much of the 3.27 Kg (7 .2 billion pounds) of this material that is generated anual1y in the United States is land filled.[1] Government regulatory agencies recognize that land filling as the least favorable disposal strategy, and that the possibility exists that in the future there may be economic incentives for products constructed from recycled plastic.

Alternatives for the wooden crosstie are being considered because of the desire to increase tie service life and also due to changing economic and regulatory conditions, which may impact the railroad industry's ability to use creosoted wood in the future. Particularly in moist, humid surroundings, the activity of biological organisms limit tie life. Plastic crossties are not subject to the attack of these organisms. Other traditional modes of failure include "spike killing" and tie plate cutting. Both are due to the accumulated effect of heavy axle loads, as measured in MGT (millions of gross tons). Economically, as the hardwood market continues to become more global in nature, wood will be diverted to uses more profitable than crosstie manufacture. Also, it is apparent that over the past twenty-five years environmental regulations have become more stringent. It is in the railroad industry's interest to research crosstie materials that do not require a preservative. The research into plastic/composite crossties is timely because of the lag time required to prove engineering design criteria and economic benefits in revenue service.

It is projected that the full production cost of a plastic composite tie will be on the order of $75. Because this cost is greater than that of a wood creosoted crosstie, the plastic tie is not viewed as a one-for-one replacement for wood at this time. It is believed that the premium benefit of plastic crossties will be substantiated in specific applications such as tunnels, curves, switches, bridges, under grade crossings, paved areas, and other locations where tie service life is reduced due to poor drainage.

Research Objectives

The objectives and approach of the cooperative research were established as follows:

- Develop a specification that defines mechanical property targets and performance requirements based on the dimensions and physical and mechanical properties of a conventional wood crosstie.
- Fabricate prototype plastic/composite ties that conform to the details of the specification in item I.
- Conduct laboratory tests to confirm the properties of the plastic/composite tie.
- Install the plastic/composite ties in track and monitor their performance.

Railroad Tie Specification

The plastic/composite crosstie specification developed by the research group provided valuable guidance as to what the research targets would be in terms of product appearance and performance. The target tie was specified with dimensions of 17.8 X 22.9 X 259 cm or 7 X 9X 102 inches, and to have the appearance of a standard hardwood tie. The tie must not absorb water, diesel fuel, mineral oil and grease. The target tie must not be electrically conductive, and not highly susceptible to degradation or abrasion. The target tie must not allow an increase in its 143.5 cm or 56.5 inch gauge by more than 0.3175 cm (0.125 inches) under a lateral load of 10,900 Kg (24,000 Ibs.) and a static vertical load of 17,727 Kg (39,000 Ibs.). The target tie must be able to sustain a dynamic vertical load of 63,636 Kg (140,000 Ibs). Installation of the target ties should be easily facilitated with standard materials handling systems, utilizing standard premium fastening systems.

Physical Properties of Plastic/Composite Crossties Manufactured

When considering alternative crosstie materials, it is logical to use wood as a basis for comparison because of its widespread use and proven performance. However, wood was originally selected because of its natural abundance and easy machining, and its performance has been demonstrated empirically over time. It is important to note that optimum material properties for a crosstie have not been established, and deviations from those of wood do not necessarily imply that a material will not perform adequately.

The combination of physical properties of the composite railroad tie produced using optimized techniques exceeded the established targets. A previous paper reported on the mechanical property performance of the composite railroad ties last year[2], but a summary will be given here. A modified Railroad Industry Standard four-point flexural load experiment was performed on full-sized composite ties until failure. The test incorporated a sixty-inch support span and a six-inch load span. The ultimate strength and Young's modulus were calculated from the results of the flexural tests, and exceeded 27.59 MPa (4,000 psi.) and 2,068.97 MPa (300,000 psi), respectively. Permanent deformation under lateral loads and rail seat compression were both tested in the laboratory and found to sufficiently meet the performance criteria. Screw spike holding power in plastic composite ties is comparable to that of wood crossties, allowing a comfort level to installing these types of spikes in field trials. However, most railroads in the US utilize standard cut spikes. Testing at both the Norfolk Southern and the Corps of Engineers laboratories indicates that cut spike holding power in plastic/composite ties is about half that of wood crossties (roughly 3,000 pounds versus 8,000 pounds withdrawal force). Long term, standard cut spikes loosen considerably in wood,[3] to the point where they require no withdrawal force. What is not currently known, however, is how much spike-holding ability is required, and do the cut-spike holding ability in wood and plastic composite ties converge with time? Researchers are currently exploring techniques to increase the cut spike holding ability in the plastic composite ties and to find the answers to these questions.

Plastic/Composite Tie Installation

In October of 1995, ten plastic ties were installed at Rose Yard in Altoona. Pa. The ties are non-consecutive and are intermingled with twenty wood crossties. Periodically, each tie is examined visually and also has six dimensions evaluated (Figure 1). The values of the measured parameters have not changed since installation. To date, 23 million gross tons (MGT) have passed over this site at speeds not exceeding 15 miles per hour. The ties show no signs of weathering even though the winter of 1995-1996 was particularly severe in the northeast. The ties were covered by snow almost continually from mid-November to the beginning of March during that season.

In April of 1996, two consecutive ties were placed in a 5-degree curve in the FAST track at the American Association of Railroads (AAR) Transportation Technology Center in Pueblo, Co. The ties saw 130 MGT of traffic at a speed of 40 miles per hour up until May 1997. At that time, one of these ties was removed for laboratory testing, and 24 new composite ties were placed adjacent to the remaining original plastic composite tie. In 1997, another 100 MGT are planned. The ties are visually monitored and there has been no indication of tie plate cutting or other deterioration. The lack of tie plate cutting is very significant in these installations. The tie, which was removed from service in May 1997, was subjected to standard testing for sensitivity of this material to tie plate cutting (the rail seat abrasion test), which is comprised of cyclically loading a tie plate mounted to the tie with tens of thousands of pounds force at a predetermined angle for a million cycles. The AAR's testing machine broke at approximately 900,000 cycles, and there was no evidence of tie plate cutting. The project team is hoping to put this tie back in track.

In October of 1996, six ties were installed in mainline service at Milepost 220.41 on Conrail's Pittsburgh Line where track speed is 35 miles per hour. This section of track is in a 6 degree curve and typically the traffic level is 35 MGT annually. The ties lie in two sets of three consecutive ties with six wood ties between them. The track inspector monitors the appearance of the ties and the track gage. To date, there is no evidence of tie plate cutting, spike loosening, or any other sign of degradation.

Discussion/Future Direction

The time dependent mechanical properties of plastics and composites will have an effect on gage holding in curves due to creep and also when spikes will become loose from stress relaxation. Research continues to develop a predictive model that could be applied to these composite materials.[4] This model would help establish a quick, inexpensive technique to predict the long-term mechanical properties of plastic/composite crossties and therefore be able to estimate the service life of the tie.

Efforts continue to optimize the manufacturing process to reduce the cost of the ties. Costs associated with the feedstock can be minimized by centralized sourcing and tracking of materials, contracts to supply granulated materials, and better utilization of multi-modal transportation. Using automated materials handling from the loading dock to the extruder can reduce operating costs. An economy of scale can be derived from utilizing larger extrusion and molding systems with more automation.[5] U.S. Plastic Lumber is presently manufacturing crossties, crossing timbers, and turnouts under a patent agreement with Rutgers University. Manufacturing capacity for the rail tie is being expanded at the Trenton, TN facility.

For wood ties, the unit cost is higher for larger and longer pieces and also higher-grade pieces. An order with pieces of matching thickness and uniform surface characteristics also has a higher cost. Thus, timber switch ties and bridge ties have higher unit costs (per board foot) than do standard track ties. Further, the installation of these ties costs more than standard ties. It appears that the unit cost of plastic/composite ties is constant with respect to size. Short line and industrial railroads have a high proportion of turnouts and a high labor cost associated with switch tie replacement and therefore could benefit from the development of a plastic/composite switch tie.

The results of the physical testing and the performance of the plastic/composite ties in track have been promising and they indicate that continued evaluation is warranted. The installation of a larger number of consecutive ties and tie sets at switches is required to ensure that the plastic ties are bearing full in- service loads.

Acknowledgements

The writers would like to acknowledge the following personnel with their respective organizations that have contributed to this project. Conrail: Jim Beyerl, Kurt Gansauer, P. Michael Lovette, Sam Luke; US Army Construction Engineering Research Laboratories: Don Plotkin, American Association of Railroads: Cannen Trevizo.

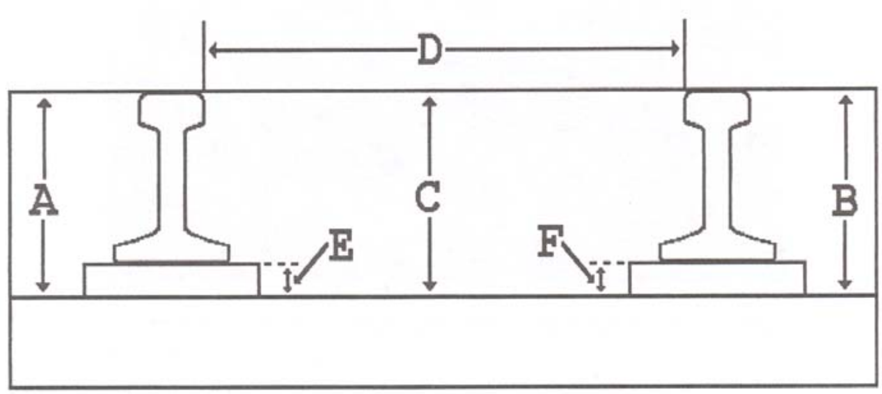

Figure 1

Figure 2- Recycled Plastic Railroad Ties Prior to Installation at AAR's FAST Track in Pueblo, CO.

Figure 3- Recycled Plastic Composite Ties Being Installed at AAR's FAST Track in Pueblo, CO.

[1] Modern Plastics, Vol. I, No.1, January 1997.
[2] Gillespie, B., Lutz, M., Nosker, I., Plotkin. D., "Development of a Recycled *Plastic* Composite Crosstie", American Railway Engineering Association Bulletin No. 760, May 1997, Volume 98.
[3] Zarembski, A. "Aging of Wood Ties and Associated Loss of Strength", Railway Track & Structures, August 1993, P.10.
[4] Nosker, T., Renfree, R., Sachan, R., Van Ness, K. E., " Pi-OOictive Techniques for Comingled Plastic Properties".
[5] Nosker, T., Ren:free, R., "Production Scale-Up for Recycled Polymer Composite Railroad (RR) Ties», New Jersey Commission on Science and Technology, July 1996.