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Laboratory Evaluation of Plastic Composite Crossties

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Summary

Under sponsorship of the Association of American Railroads' Strategic Research Initiatives Program, Transportation Technology Center, Inc. (TTCI) and the University of Illinois Urbana-Champaign (UIUC) have investigated performance issues with plastic composite crossties. This *Technology Digest* provides guidance on remedying current performance issues such as fastener hole cracking during installation and discussion of production issues such as internal voids.

Examination of failed plastic composite crosstie specimens was conducted at the laboratories of TTCI and UIUC. Crossties with spike hole cracking and internal void defects were sectioned and analyzed both chemically and physically.

Findings from this work include the following:

- Compared to concrete or solid-sawn wood crossties, plastic crossties have more variability in composition and performance. Plastic composite crossties are made from a combination of recycled materials. They may contain polyethylene, polystyrene, rubber, glass fibers, and inert fillers.
- The typically used extrusion method of production, although the only currently commercially feasible process, presents challenges for large cross-section shapes like crossties.
- Pure polyethylene will shrink about 15 percent in volume from melt temperature to full crystallization. Voids created in the center of the crosstie cross sections are likely with the current extrusion process, if not considered in the design. Strategic location of voids in crossties should be part of the design. There may be an optimal void composition in the rail seat area for fastener pull-out strength and cracking prevention.
- Plastic crossties must be predrilled for fasteners. Polyethylene is relatively incompressible compared to wood. Spiking a nonpredrilled crosstie will result in displacement of material, rather than compression. The displaced material is likely to extrude from the top and bottom of the crosstie and cause lateral bulging or cracking of the crosstie in the rail seat area.

The railroad industry is searching for ways to reduce the capital intensity and life-cycle costs of operations, while also improving the safety, reliability, and capacity of the system. Track components, such as crossties, can significantly affect operating performance. Improvements in performance of plastic composite crossties will provide the railroads with more alternatives to improve the technical, economic, and environmental performance of their operations.

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INTRODUCTION AND BACKGROUND

Plastic crossties offer several potential advantages to railroads for use in freight applications. They offer superior resistance to environmental degradation, especially in warm, moist climates, and they are good for the environment, being made of recycled materials and posing no railroad waste disposal issues.

Application of a product that uses post-consumer recycled plastics to a demanding service application like crossties has proven to be difficult. Issues of product consistency and ability to meet insufficiently defined track construction and service environments have prompted railroads to re-evaluate the efficacy of plastic crossties.

Crossties are a major capital and maintenance spending area for railroads. More than \$800 million is spent annually on wood crosstie replacements. Maintenance spending is an additional \$50 million per year.¹

Significant plastic crosstie performance issues include:

- Product quality and consistency
- Ability to withstand high dynamic loads
- Compatibility with currently used fastener systems and installation practices

Under the direction of the Association of American Railroads' Engineering Research Committee, TTCI was tasked with understanding and solving the performance issues with plastic crossties. TTCI was directed to address the above three specific areas of concern and develop recommended guidelines for performance of plastic ties.

ANATOMY OF A PLASTIC COMPOSITE CROSSTIE

Plastic composite crossties are made to resemble solid sawn wood crossties by their size, shape, and functionality. The similar size, shape, and weight allow railroads to handle, install, and maintain plastic crossties with the same methods and equipment used for wood crossties. Compatibility of plastic and wood crossties has led to some performance issues for plastic crossties. Because of the similarities in size and weight, plastic crossties are often handled like wood crossties.

Problems arise when the plastic ties do not have the resilience or deformation characteristics of wood. Spiking ties without a predrilled hole is acceptable for wood, but damages plastic crossties. With concrete crossties, the differences in material characteristics are recognized and accounted for in handling and installation practices.

Plastic composite crossties are composed of recycled plastics and fillers. Additional ingredients, such as glass fibers or rubber, may be added to enhance crosstie performance. These additives are used to increase the bending strength (fibers), improve impact resistance (rubber), or improve dimensional stability (inorganic fillers, rubber). They may also be added to reduce initial crosstie costs.

The general dimensions of plastic crossties are 7 by 9 inches by 8 1/2 or 9 feet. Like wood crossties, the cross-section is constant. Plastic crossties are typically extruded lengthwise through a mold. Figure 1 shows cross-section views of two typical plastic crossties. Note that there are voids present due to shrinkage during cooling after being extruded.

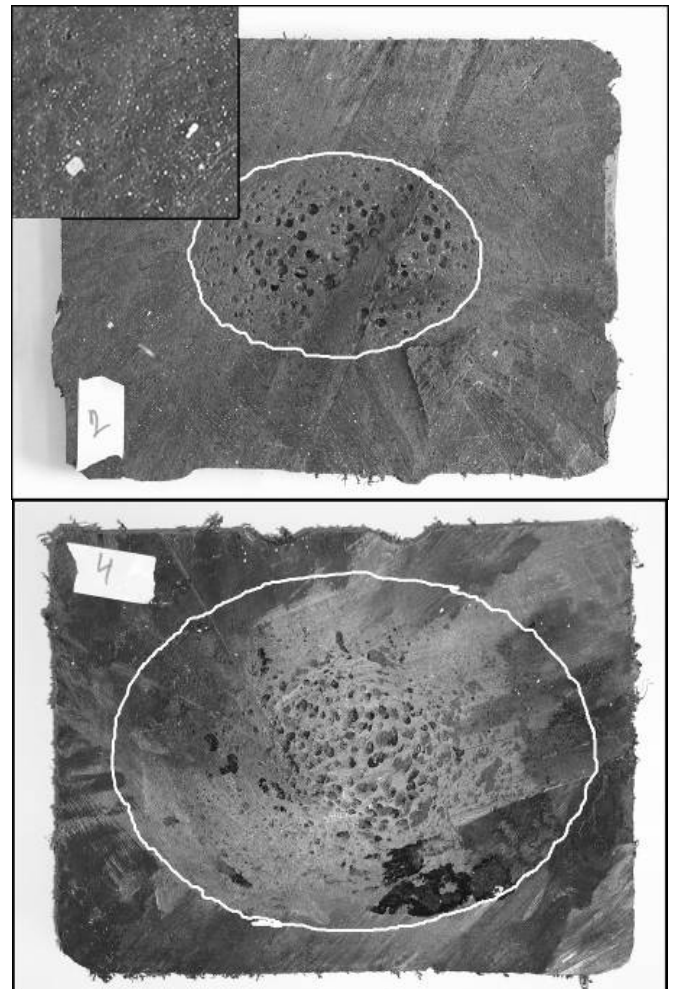


Figure 1. Typical Plastic Crosstie Cross Sections (range of small and large void central areas)

The top photograph in Figure 1 shows a crosstie with a limited amount of voids in the center of the cross section. This crosstie has solid material and no large voids in the area that would accept fasteners. It is a crosstie free of manufacturing defects.

The bottom photograph shows a crosstie with manufacturing defects. It has a much larger central void zone, extending into the fastener locations. The crosstie also shows major voids (lower right) that would weaken the holding strength of the fastener.

One of the crossties examined had a subsurface longitudinal crack that coincided with the boundary between the dense outer shell of the crosstie and the lower density, central void region. This area may be prone to tensile residual stresses and weakness under loading as compared to more dense material

closer to the crosstie surfaces. Figure 2 shows the internal cracking in a cross section. Recent work, sponsored by the Federal Railroad Administration, has shown that relatively small changes in crosstie density can be detected by non destructive means.²

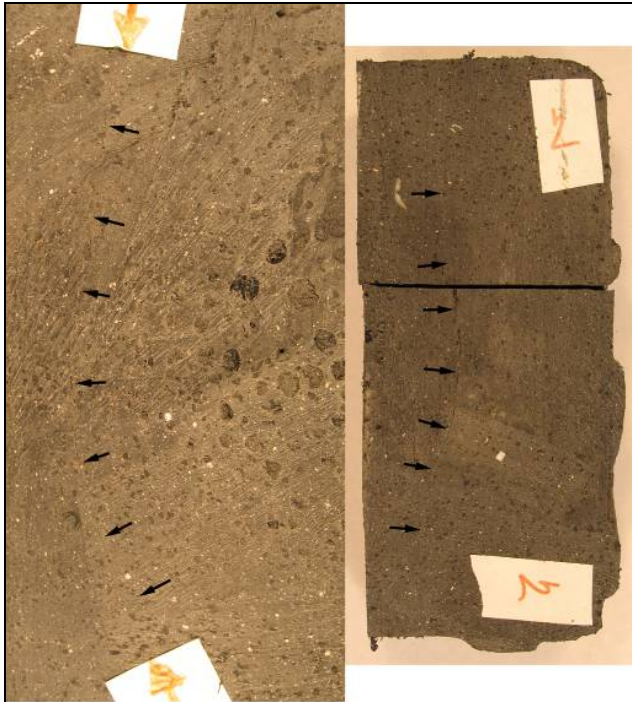


Figure 2. Internal Cracking along the Central Void Boundary

CHEMICAL AND PHYSICAL ANALYSIS

Chemical and physical analyses of plastic crossties were conducted to determine materials factors relevant to observed performance in track. Analysis consisted of thermal, x-ray diffraction, and separation of samples from crossties. The analysis showed that polyethylene was the main plastic ingredient in all crossties. Also observed in some crosstie types were polystyrene, rubber, glass fibers, and inorganic fillers.

The sources of polyethylene also varied by crosstie brand. Milk bottles and grocery bags are the two major sources of post-consumer plastic recyclates. Both were found in one plastic crosstie type, with only milk bottle recyclate in another. Grocery bag recyclates contain inorganic filler, which is used to help separate the bags.

Significantly large filler material was seen in some plastic crosstie samples. Inorganic particles that were silt and sand size by soil classification standards were found. Figure 3 shows the residue from one crosstie. There were also a few particles that were 0.25 inch in some of the crossties. The polyethylene and polystyrene found in plastic crossties was partially crystallized and cross-linked. Cross linking makes the crosstie more resilient and durable; however, this makes crosstie chemical analysis more difficult.

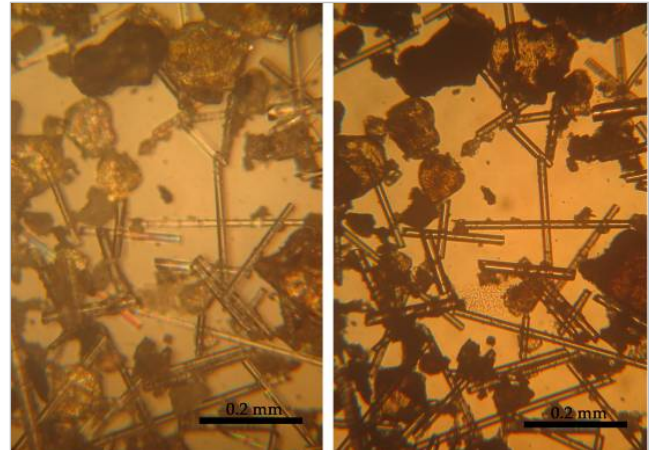


Figure 3. Plastic Crosstie Separation Residue Showing Glass Fibers, Rubber, and Sand Particles

SPIKE HOLE CRACKING

One leading failure mode of plastic crossties is spike hole cracking. Spike hole cracking occurs when a fastener is installed in a crosstie to hold a plate to the crosstie or the rail to the plate. In many cases, spike hole cracking is due to inadequate predrilling of holes in the plastic. Unlike wood, plastic crossties cannot compress or split locally around a driven fastener. When a fastener is driven into a plastic crosstie, the plastic either extrudes out the top or bottom of the hole, or the crosstie is fractured. Figure 4 shows plastic that has extruded from spike holes. For example, the screw spike design works well with wood crossties to minimize plate movement, but the wedge top can crack less compressible plastic crossties.



Figure 4. Plastic Extruded from a Cut Spike Hole

Figure 5 shows a typical crack from a screw spike hole. This crosstie was observed with the crack soon after installation. Study of spike hole cracks found that they usually are present soon after installation.³ While they may affect crosstie and fastener system performance, many survive in service for the life of the crosstie.



Figure 5. Spike Hole Cracking in Plastic Crosstie

The American Railway Engineering and Maintenance-of-Way Association has recommended practices for design and performance of crossties. These guidelines describe laboratory tests and expected minimum values for new crossties of various materials. Crossties that fail these tests are generally poor performers in mainline track. However, crossties that pass these tests may not provide economic service. The additional performance issues described in this *Technology Digest* should be reflected in future recommended practices.

CONCLUSIONS

Plastic crosstie material variability must be taken into consideration when designing crossties. The trade-off between initial strength and long-term durability must be carefully considered.

Dimensional stability and material uniformity (density) must be improved in extruded plastic crossties.

Fastener system design must also be considered when selecting crosstie materials and design parameters. Allowance for fastener attachment method and removal must be carefully considered.

FUTURE WORK

Additional measurement of the in-track installation loads, service environment, and effects of material variability will be conducted to better define design guidelines for plastic composite crossties. These additions will benefit all tie suppliers in understanding the railroad service environment.

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