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EVALUATION OF ENGINEERED-POLYMER COMPOSITE TIE PERFORMANCE IN REVENUE SERVICE

SUMMARY

The Federal Railroad Administration (FRA) and the Association of American Railroads (AAR) investigated the in-track performance of engineered-polymer composite (EPC) ties. This report summarizes the results from a revenue service test conducted by the Transportation Technology Center, Inc. (TTCI) between 2018 and 2021. Work completed before 2018 was summarized in a separate report [1].

Visual inspection identified two main types of defects often associated with EPC ties: center cracking and spike-hole cracking. In-track measurements indicated that the bending strain was well below the ultimate tie strength. Therefore, researchers concluded that fatigue failure resulting from dynamic cyclic loading caused both defects. The research team also found that differential thermal expansion affected the tie bending behavior and increased static track gage.

BACKGROUND

More than 90 percent of Class I railroad track in North America uses wood ties. In areas prone to rot and decay, wood ties may not remain serviceable for 10 years before replacement is necessary. These types of environments present an opportunity for the use of EPC ties, which may offer a longer life cycle [2]. In 2015, researchers installed two types of EPC ties in Class 4 tangent track in western Nebraska to evaluate their performance under heavy-haul traffic. Ninety-eight EPC ties were installed as pre-constructed panels at the test site.

OBJECTIVES

The EPC tie research in revenue service had two main objectives:

- Measure tie center bending strain in a heavy-haul freight environment. This data improves the understanding of the tie loading environment needed to address the tie center cracking issue.
- Investigate the thermal effects on two types of EPC ties (Type A and Type B). The study documents how temperature ultimately affects track gage and tie bending behavior.

METHODS

The test site used two EPC tie types (Type A and Type B) installed as panels in two zones. Each zone contained 49 ties of each type (Figure 1).

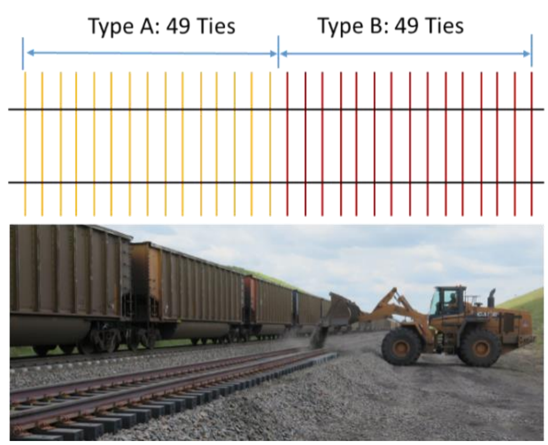

Figure 1. EPC tie test site in revenue service

This test was conducted in a heavy axle load, high tonnage, and high demand service environment. A premium fastening system (16-inch cast plates, drive spikes, and Safelok I clips) was installed for the EPC ties.

In this study, researchers conducted visual inspections to document tie failure modes. Strain gages were installed on the center top surfaces of ties to measure the center negative bending strains. Four ties of each type were instrumented with these strain gages. In addition, researchers measured static track gage using a gage bar during different times of the day to evaluate the thermal effects on the track gage of EPC ties.

RESULTS

Visual Inspection

Visual inspection found two types of defects: center cracking and spike-hole cracking. These defects were consistent with the findings at the test zones on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST) in Pueblo, CO [2]. Table 1 documents the observations of the two types of defects from each trip. As of November 2021, the two EPC tie test zones had accumulated approximately 800 million gross tons (MGT).

Table 1. Summary of visual inspection

Date	Occurrence of Defects	MGT
Apr. 4, 2018	16 center cracking	240
Sep. 24, 2018	3 center cracking	280
Sep. 30, 2019	8 center cracking	365
Apr. 19, 2021	4 center cracking 1 spike-hole cracking	480

Tie center cracking was the primary defect observed. A total of 31 Type A ties experienced the center cracking issue as of April 2021. All the center cracked ties were pulled out for inspection and replacement. Upon further inspection, researchers found that the cracked plane was typically associated with internal conditions (Figure 2). Due to the manufacturing process, all the EPC ties have a porous texture (i.e., small air bubbles less than 1/2 inch) in the core, as shown in Figure 2. However, the cracked ties were generally associated with voids over 1 inch (red circle in Figure 2) or the presence of multiple voids close to one another. It is worth mentioning that, despite failing in service, the installed ties passed the manufacturers' quality control (QC) inspection using X-ray. Therefore, the current QC process may need to be improved to control the size of voids or the presence of a certain size of void within a certain distance of another.

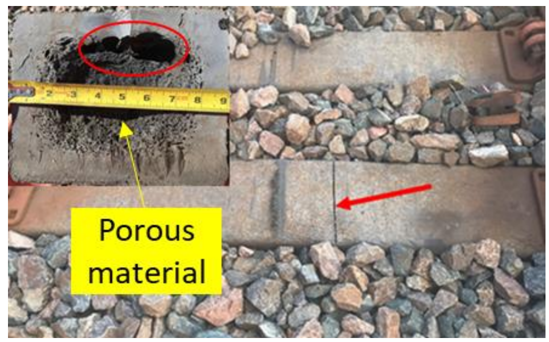

Figure 2. Tie center cracking and tie cross section on the cracked plane

Only one Type B tie had spike-hole cracking (Figure 3). This defect was also found on this tie type on the HTL [2]. This type of crack typically initiates at the spike hole and propagates to the edge of the ties.

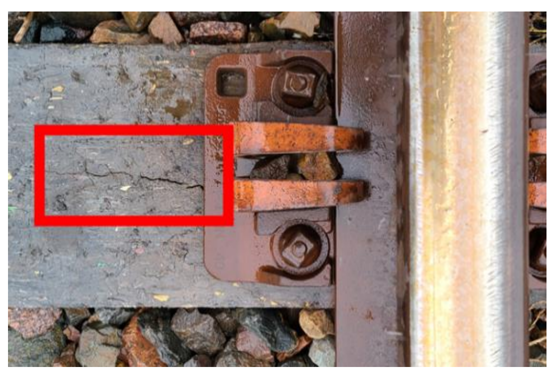

Figure 3. Tie spike-hole cracking

Tie Bending Behavior

To further investigate the mechanism of the two types of observed tie defects, researchers installed strain gages at both the tie center and rail seat areas on selected ties to collect tie bending strains under heavy axle load traffic. Four ties of each type were instrumented with these strain gages and with thermocouples to measure the tie surface temperature. The measurements were taken in the early morning and late afternoon of April 4 and 5, 2018, to quantify the temperature effect on the ties.

The strain range at the rail seat was lower than that at the center of the ties. The track where the strain data was collected had not been tamped since the installation of the ties in 2015. Approximately 350 MGT had accumulated at this site when the strain data was collected. Researchers observed the tie ends deflecting when trains passed by, suggesting the ties could have a center-bound support condition. In addition, the tie bending stress level (0.4–0.6 ksi) was below the tie modulus of rupture (3–4 ksi) at all times [1]. Therefore, researchers concluded that the tie defects in the center and rail seat areas were caused by fatigue.

Strain data also showed that temperature could affect the tie center bending behavior. The strain on the top surface at the tie center was measured at two different times of the day. The data in Figure 4 shows the strain measurements collected on the same EPC tie under the same type of train loading in the morning and in the afternoon.

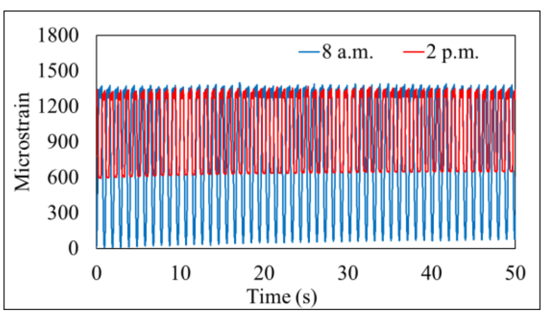

Figure 4. Tie bending strain in the morning and afternoon

Average temperatures at the tie top surface were 50°F (morning) and 90°F (afternoon). The ambient temperatures were around 50°F (morning) and 72°F (afternoon). The strain range in the morning (8 a.m., blue lines) was around 1,400 microstrain; however, it fell to 800 microstrain in the afternoon (2 p.m., red lines).

EPC tie material is generally more sensitive to temperature change than wood; this high-density polyethylene (HDPE) can expand 10–20 times more than wood [3]. The hypothesis for the variation in the bending strain throughout the day is that the EPC ties were straight in the morning when the temperature was more uniform within the body of the ties. When the ties were straight, the center-bound ballast support condition only supported the center of the ties, causing more center bending. However, with the differential temperatures between the top surfaces and the rest of the tie in the afternoon, the ties expanded more on the top surface, causing them to bend and become more conformal with the ballast surface. This would improve the support conditions and, in turn, reduce the strain range. A conceptual illustration of the tie shape change due to temperature is shown in Figure 5.

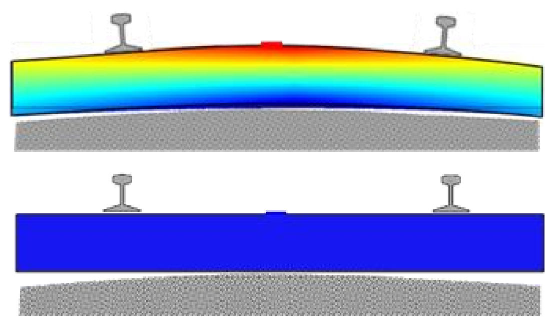

Figure 5. Tie shape at different temperature conditions

Static Track Gage Measurement

Static track gage was measured using a gage bar in the afternoon (ambient temperature: 70°F) on September 30, 2019, and in the morning (ambient temperature: 32°F) on October 1, 2019. Tie surface temperatures were similar to the ambient temperature due to overcast conditions. Researchers measured a total of 48 ties (i.e., 24 ties of each type). The results showed that the two EPC tie test zones experienced gage widening of 0.15–0.25 inch when the ambient temperature increased in the afternoon.

CONCLUSIONS

Field inspections showed that EPC ties have exhibited two types of defects since their installation in 2015: tie center cracking and spike-hole cracking. Thirty-one ties (Type A) were center cracked and have been removed. One tie (Type B) had spike-hole cracking. Field measurements showed that the tie bending stress level was well below the ultimate tie strength, indicating a fatigue failure mechanism. In addition, since center cracking is often associated with internal voids in the EPC tie centers, the sizes and spacing of the internal voids need to be controlled to ensure tie in-track performance.

Track performance was affected by temperature for both tie types. The center bending strain increased 30 to 60 percent due to the daily temperature swing. Also, the temperature differential at the tie surface could affect the EPC tie straightness, which can affect the propagation of tie center cracking. In addition, gage widening (0.15–0.25 inch) occurred in the entire test section when the tie temperature increased from 32°F to 70°F.

FUTURE ACTIONS

Based on test results from this study, TTCI is working with American Railway Engineering and Maintenance-of-Way Committee 30 (Ties) to improve the current guidelines for EPC ties. This includes addressing the failure modes and thermal properties of the EPC tie material.

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KEYWORDS

Engineered polymer composite ties, bending strain measurement, thermal effect