FAST Facility for Accelerated Service Testing TECHNICAL NOTE

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COMPOSITE WOOD TIE PERFORMANCE REPORT

by
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SUMMARY

This report presents the results of the Facility for Accelerated Service Testing (FAST) Composite Wood Tie Performance Evaluation performed at the Transportation Test Center (TTC) near Pueblo, Colorado. The purpose of the evaluation was to compare the performance of composite wood ties to standard wood ties under heavy traffic. Sample ties were initially tested on a load frame to measure the modulus of elasticity and ultimate load strength. During the service testing, 700 million gross tons (MGT) of traffic were accumulated on the FAST track. The composite wood tie sections were monitored regularly for track gage widening, spike pullout force, and maintenance manhours required to keep the track up to Federal Railroad Administration (FRA) Class 4 specifications. After the test, all ties were removed and examined for plate cutting and breakage.

Modulus of elasticity and load strength were found to be much less for composite wood ties than for conventional wood ties. Spike pullout force results were mixed but favored conventional hardwood ties by the end of the test. No significant gage widening occurred, although maintenance manhours were higher for wood reinforced composite ties, and "post-mortem" inspection revealed that the composite ties tested at FAST tended to delaminate (split) horizontally in the heavy service environment.

INTRODUCTION

The Composite Wood Tie Performance Evaluation portion of the FAST Wood Tie Experiment was initiated in 1976 and ran until 1982, during which time 700 MGT of heavy axle load traffic were accumulated. The purpose of the test was to evaluate the performance of composite wood ties and to determine their ability to resist mechanical wear and physical deterioration. Due to the relatively short duration of the test and the extremely dry climate at the TTC, environmental factors are thought to have had little influence on test results.

Reconstituted wood ties, which are the focus of this report, may be referred to variously as "composite" or "test ties", to distinguish them from conventional ties made of softwood (southern yellow pine) or assorted hardwoods.

TEST DESCRIPTION

The FAST Loop

FAST is a 4.8-mile, closed loop track located at the Transportation Test Center (TTC). It was built to general heavy mainline construction standards and is maintained to Federal Railroad Administration (FRA) Class 4 specifications in all test sections. There are 22 sections, each constructed to represent a different test configuration, grade, or curvature. Train operations are scheduled to accumulate about 100 million gross tons (MGT) of traffic per year using a test train typically made up of 4 locomotives and 70 loaded 100-ton hopper cars.

Figure 1 shows the FAST track with the composite tie test locations marked (Section 09 and Section 19). A summary list of the five test segments in these two sections is presented in Table 1. Section 09 is a tangent portion of track located between a turnout and a crossover; the ballast is blast furnace slag, and the mean train speed is 43 mph. Section 19 is made of two 300-foot spirals on granite ballast, and the mean operating speed is 37 mph. In these two sections all ties are 7" x 9" x 8'6" in size and are placed on 19½" centers. AREA 1:40, 7-3/4" x 14", A-punch (8 holes/plate) tie plates are used throughout, with four 5/8" x 6" cut spikes per plate. Every other tie is box anchored, and the rail is jointed, 136 lb/yd standard carbon rail.

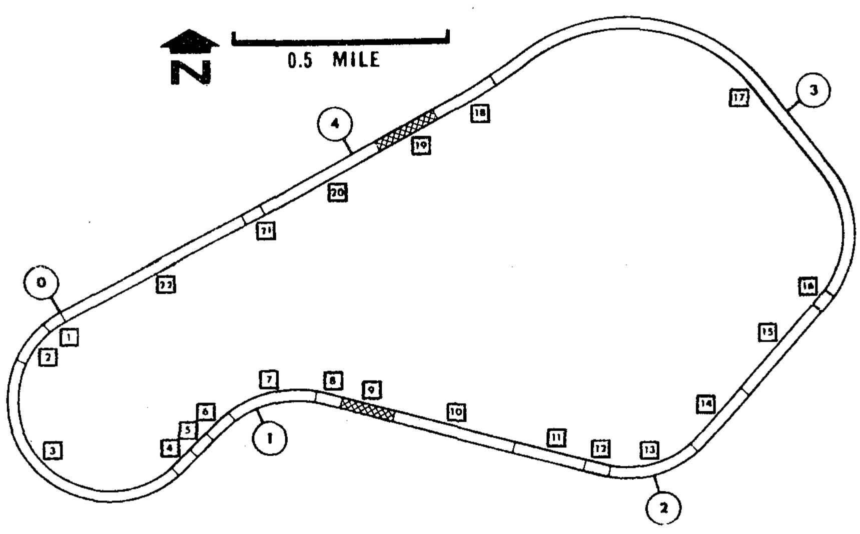

FIGURE 1. SCHEMATIC OF THE FAST TRACK, 1976-1982.

TABLE 1. TEST SEGMENT SUMMARY.

Geometry	Location	Ties and Pads
Tangent	Sect. 09, Ties 24 - 48	Composite with steel reinforcements, 1/4" rubber tie pads
Tangent	Sect. 09, Ties 49 - 72	Composite with steel reinforcements, no tie pads
Tangent	Sect. 09, Ties 73 - 108	Composite with apitong (imported wood) reinforcements, no tie pads
Spiral	Sect. 19, Ties 001 - 185	Southern yellow pine, no tie pads
Spiral	Sect. 19, Ties 186 - 371	Assorted hardwood, no tie pads

Lab Testing

The four types of ties being compared are steel-reinforced composite wood, apitong-reinforced composite wood, southern yellow pine, and mixed hardwood. The pine and mixed hardwood are conventional, solid sawn wood ties and are the base cases for comparisons. The composite ties are made of bonded wood chips reinforced with steel rods or with apitong (a coarse-grained Philippine hardwood).

To measure the modulus of elasticity and the ultimate load of the composite wood ties, sample ties were loaded as shown in Figure 2. The load was gradually increased and the deflection measured until the tie broke.

The results of this exercise are shown in Table 2. There was very little difference between the apitong- and the steel-reinforced ties in ultimate load or modulus of elasticity, but the conventional ties deflected less and sustained significantly higher loads than did the composite ties.

MEASUREMENTS, DATA, AND DATA ANALYSIS

The purposes of a railroad crosstie are to hold the two rails transversely secure at the correct gage, to distribute axle loads with diminished unit pressure to the ballast, and to anchor the track against lateral, longitudinal, and vertical movement.[1]* Therefore, gage widening resistance, spike pullout force data, and maintenance manhour requirements to preserve proper track geometry were used to compare the performance of the various ties.

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*References follow text.

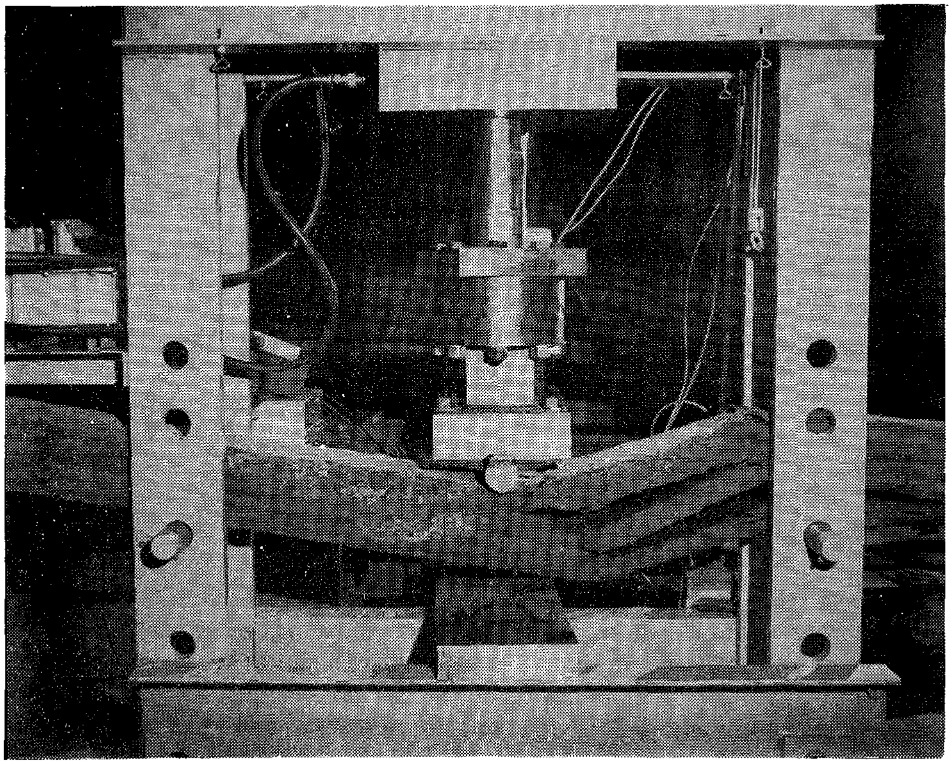

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FIGURE 2. LOAD AND DEFLECTION TEST.

TABLE 2. MODULUS OF ELASTICITY AND ULTIMATE LOAD

Tie Type	Modulus of Elasticity ($x10^6$ psi)	Ultimate Load (lbs)
Composite w/Steel	0.145	7,750
Composite w/Apitong	0.154	9,070
Conventional Wood Tie	0.588	49,000

Gage Widening

Track gage was measured by a track geometry car applying a 600-lb lateral load. From this value the static gage was subtracted and the rail wear accounted for, resulting in normalized gage widening data.

Figures 3 and 4 show the gage widening performance of the composite ties through 400 MGT. In the five test segments examined, no significant difference was found between the gage widening behavior of the solid wood conventional tie track (not shown) and the composite wood tie with either steel or apitong reinforcement.

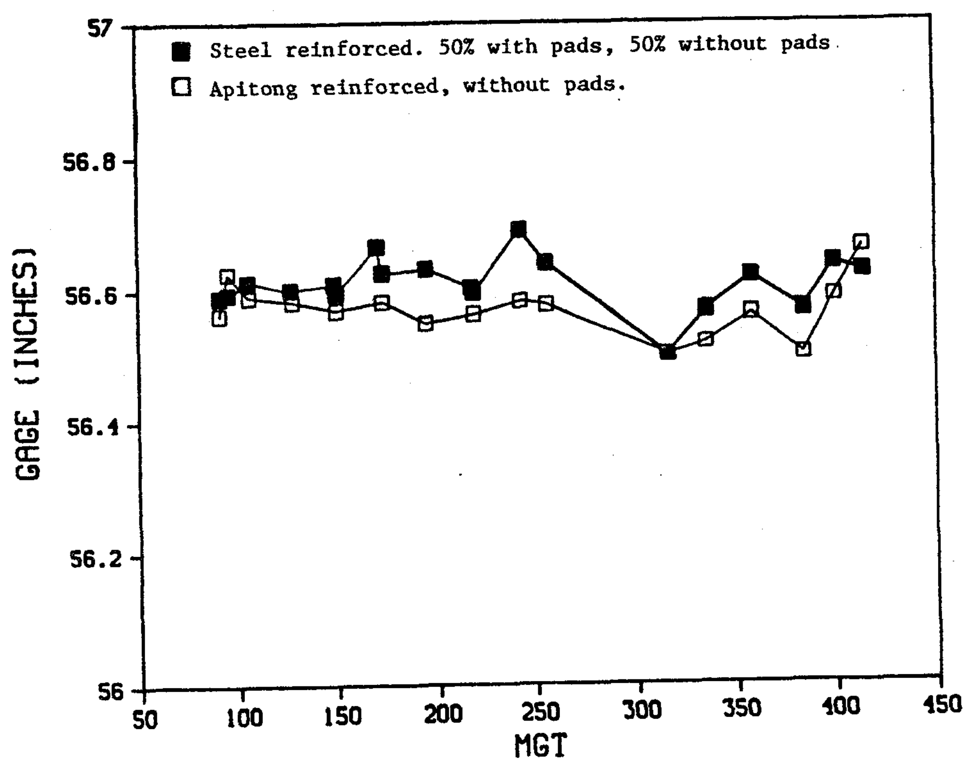

FIGURE 3. GAGE WIDENING OF RECONSTITUTED WOOD TIES, COMPARING APITONG-REINFORCED TIES WITHOUT TIE PADS VS STEEL-REINFORCED TIES WITH & WITHOUT TIE PADS.

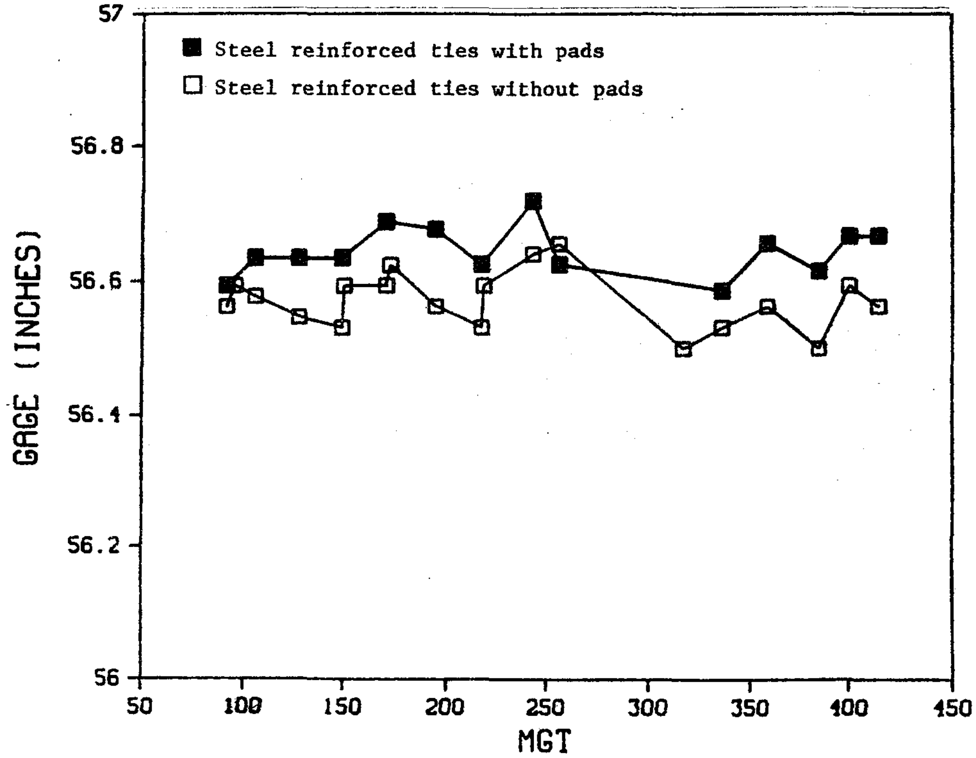

FIGURE 4. GAGE WIDENING OF RECONSTITUTED WOOD TIES, COMPARING STEEL-REINFORCED TIES WITH AND WITHOUT TIE PADS.

Spike Pullout Force

Spike pullout resistance measurements quantify the spike fastener system's ability to resist rail rollover and are an indicator of the general condition of the tie. The maximum pullout force was measured while a hydraulic puller lifted spikes until they were hand loose. The average maximum force values for each tie type are presented in Table 3. These data indicate that the spike pullout force of the conventional ties tested increased with tonnage while that of the composite ties decreased, In fact, spikes newly installed in composite ties required several times more force to be removed than spikes in conventional ties, but after 600+ MGT of service the opposite was true.

By the end of the test only 600 lbs (average) force was required to remove spikes from apitong-reinforced ties. Many of these spikes had worked partway out and required less than 50 lbs pull to remove (Figure 5).

Maintenance Manhour Requirements

The total accumulation of manhours for surfacing and lining per length of track is a practical indicator of the ties' ability to anchor the track against lateral, longitudinal, and vertical movement. While comparing maintenance requirements of each tie type it should be kept in mind that the solid wood ties (southern yellow pine, and hardwood) were on spiral track with granite ballast, while the composite ties were on tangent track between a crossover and a turnout, and on slag ballast.

TABLE 3. MAXIMUM PULLOUT FORCE.

SPIKE PULLOUT FORCE (POUNDS)

Tie Type	0 MGT	50 MGT	600+ MGT
Composite	4100*	4575*†	1100 (n = 21, σ = 1100)
With Steel	---	---	2200 (n = 8, σ = 1100)
With Apitong	---	---	600 (n = 13, σ = 600)
Southern Yellow Pine	1200 (n = 5, σ = 500)	1100 (n = 11, σ = 600)	2200*††
Mixed Hardwood	2600 (n = 6, σ = 800)	3000 (n = 15, σ = 700)	3800*

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* NOTE: Asterisked values are taken from Collister, Reference 2.
† Lab Simulation, 2.5 x 10^6 Cycles, 20,000 lbs Vertical, 7,500 lbs Lateral.
††Mixed softwood, not necessarily southern yellow pine.
n = Sample size
σ = One standard deviation

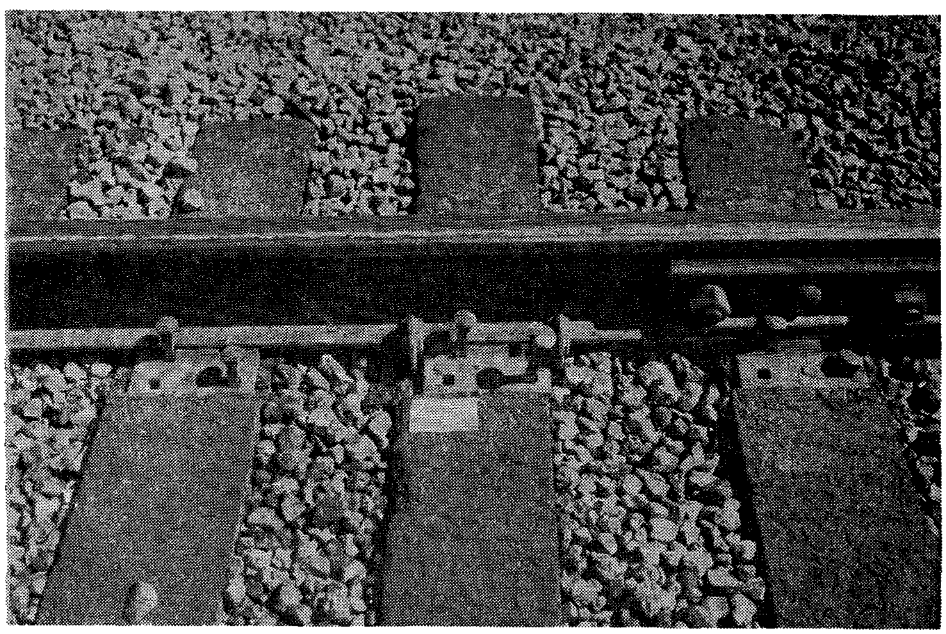

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FIGURE 5. SPIKES "WORKED OUT" OF COMPOSITE TIES.

Figure 6 shows the accumulated surfacing and lining manhours required to maintain FRA Class 4 standards per 100 feet for track of each tie type. There was very little difference in the maintenance requirements of each tie type until after approximately 350 MGT. At that point, the maintenance manhours for the apitong-reinforced composite tie escalated. By the end of the test, the apitong composite ties, located near a turnout, had required almost three times as much maintenance as the conventional ties, averaged. However, there was no significant difference between the steel-reinforced composite ties and the conventional solid wood. Overall, the southern yellow pine conventional ties required the least maintenance. Maintenance activity for test purposes, (rail changes, etc.), has been excluded from these data.

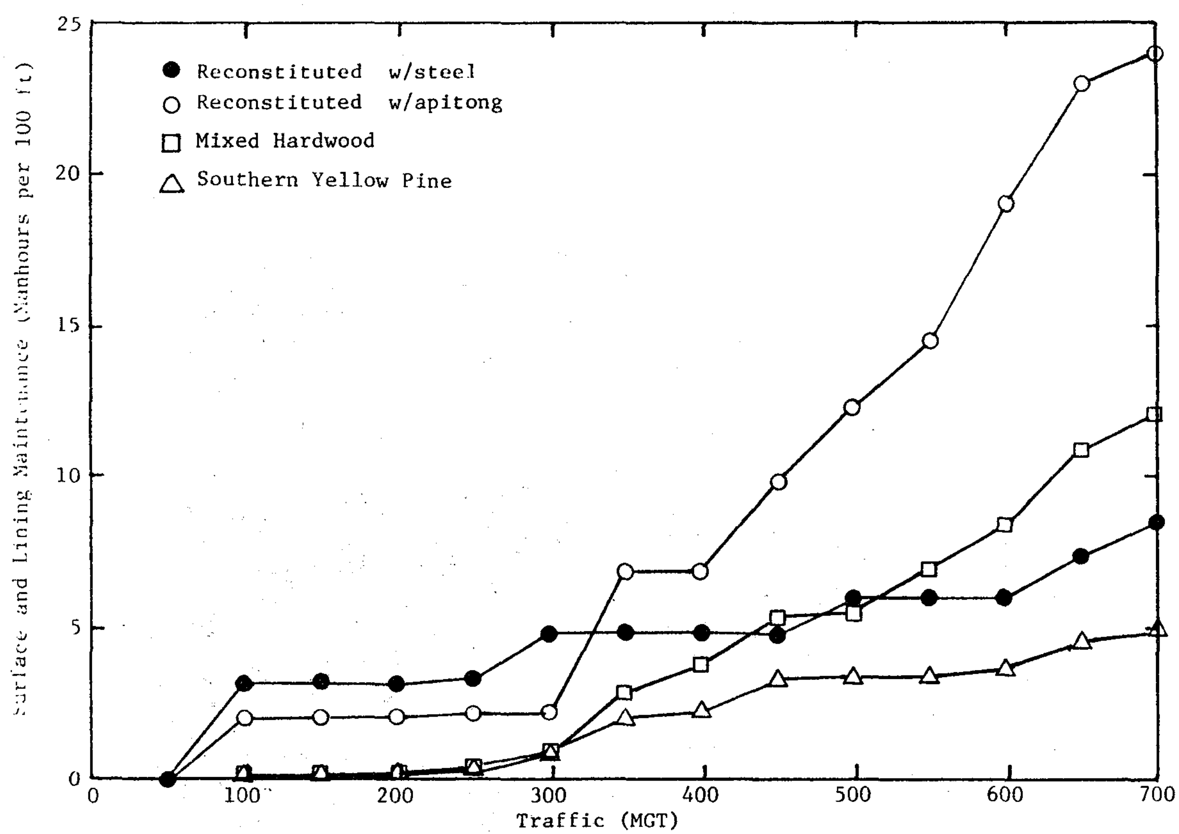

FIGURE 6. SURFACING AND LINING MAINTENANCE REQUIREMENTS.

Table 4 shows the surfacing and lining maintenance rates for each test segment.

TABLE 4. MAINTENANCE RATES.

Tie Type	Ballast	Geometry	Maintenance Manhours Per 100 ft Per MGT
Composite w/Steel	Slag	Tangent	0.010 (Sign. = 99%)
Composite w/Apitong	Slag	Tangent	0.035 (Sign. = 99%)
Southern Yellow Pine	Granite	Spiral	0.008 (Sign. = 99%)
Mixed Hardwood	Granite	Spiral	0.017 (Sign. = 99%)

TIE FAILURES

During the test some ties were removed and replaced due to visible failure. The criteria for removal were delamination, splitting, vertical breakage, or a combination of defects (discernable by simple visual inspections), which rendered the tie unserviceable. Table 5 shows the accumulated percent of ties removed during the test period for obvious service failure.

TABLE 5. TIES REMOVED FOR VISIBLE FAILURE DURING TEST.

MGT	Composite w/Steel*	Composite w/Apitong	Southern Yellow Pine	Hardwood
0	0	0	0	0
200	0	0	2%	0
400	0	0	3%	1%
600	0	20%	3%	1%
700	0	26%	3%	2%

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*As noted in text, hidden delaminations prejudice this data.

Although these data are not sufficient to predict or compare tie life, it is clear that the apitong-reinforced composite ties tested had a greater percentage of visible failure than did the other ties. The steel-reinforced composite ties had no visible failures during this test, although post-test inspection revealed that hidden delamination had occurred in more than 1/3 of both steel-reinforced groups.

At the end of this experiment the composite ties were removed from the track and inspected. The results of a post-mortem inspection are shown in Table 6. An average of 19% of the steel reinforced composite ties remained in "good shape" (reusable) while only 5% of the apitong-reinforced ties were in "good shape". The rubber pads used with half the ties appear to have reduced plate cutting, but their effect on other factors is uncertain.

TABLE 6. POST-MORTEM INSPECTION RESULTS.

	Good	Plate Cut Only	Delaminated*	Broken Vertical
Steel Reinforced w/pad	24%	8%	40%	28%
Steel Reinforced w/o pad	14%	52%	30%	4%
Apitong Reinforced w/o pad	5%	28%	20%	47%

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*Most delaminated ties also had substantial plate cutting, but these ties were only counted as delaminated.

Figures 7 and 8 are photos of horizontally delaminated and vertically broken composite ties.

Tie Plate Cutting

Tie plate cutting, the gouge of the tie plate into the tie, results in gage widening and reduced tie life. Plate cutting was measured according to FAST Static Measurement Procedure S-005. Reference nails were placed next to the tie plate on the field and gage side of each rail (See Figure 9). Plate cutting was then measured at the F^+, F^-, G^+, and G^- positions of both rails by determining the vertical difference between the reference nails and the fixture points.

Measurements were taken every 100 MGT and before and after all maintenance activity.

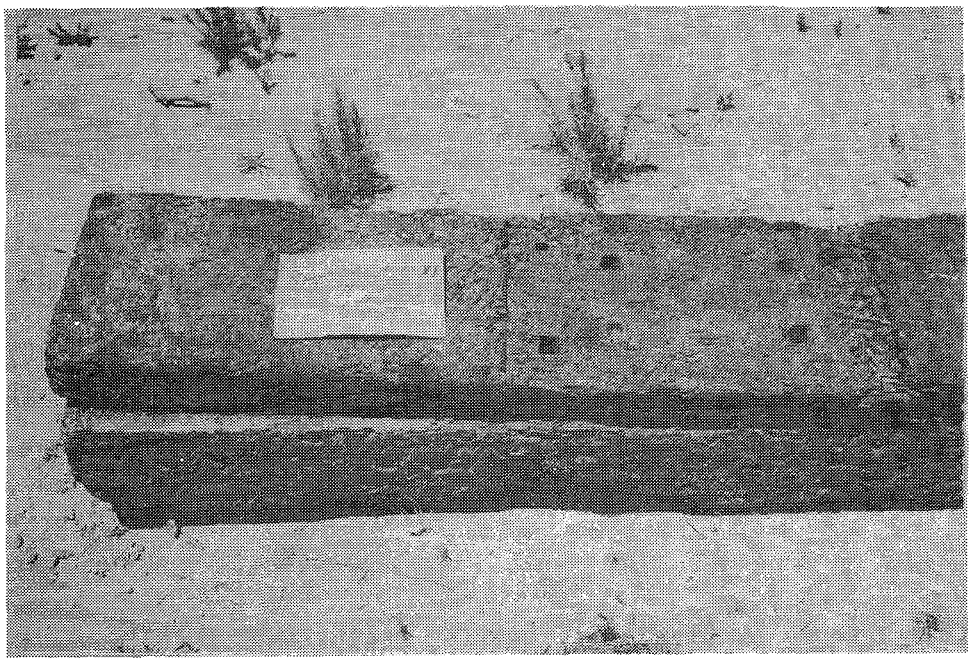

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FIGURE 7. HORIZONTALLY DELAMINATED COMPOSITE TIE.

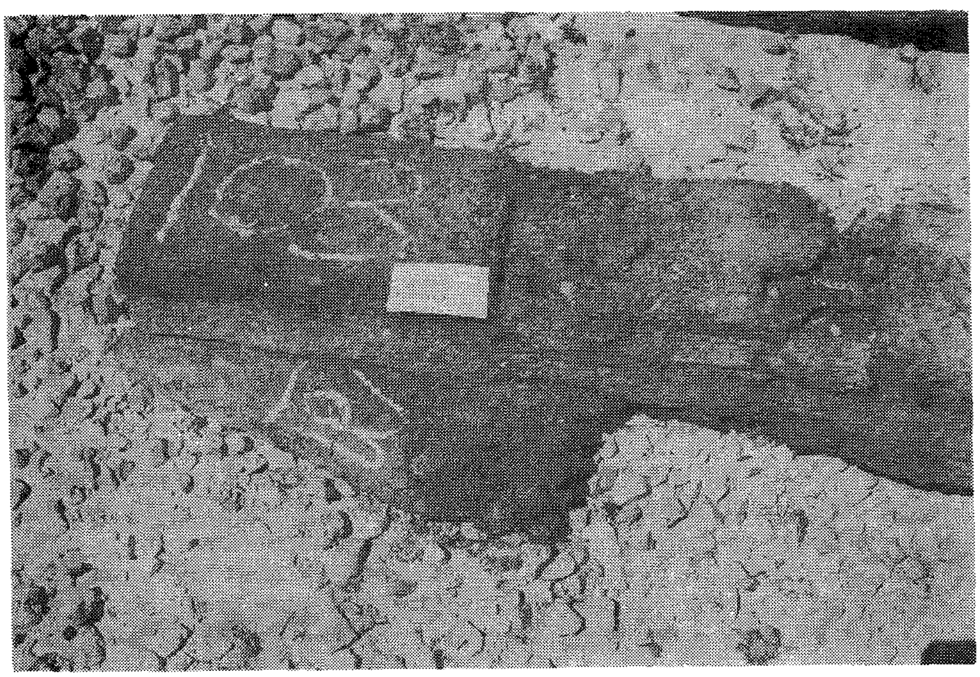

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FIGURE 8. VERTICALLY BROKEN COMPOSITE TIE.

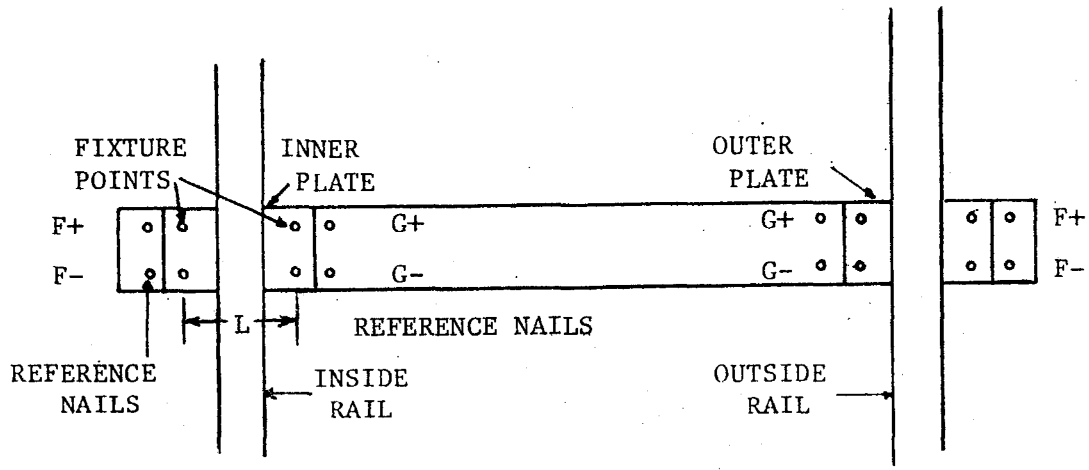

FIGURE 9. TIE PLATE CUTTING MEASUREMENT POINTS.

Tie plate cutting values were determined by the following two equations:

$$\text{Vertical Cutting} = \left(\frac{F^{+} + F^{-}}{2} + \frac{G^{+} + G^{-}}{2} \right) \div 2 \qquad \text{Equation 1}$$

$$\text{Cant Cutting} = \left(\frac{F^{+} + F^{-}}{2} + \frac{G^{+} + G^{-}}{2} \right) \div L \qquad \text{Equation 2}$$

The cant, or angle of the plate cutting, in many cases was not statistically different from zero. In the most severe case the cant rate was equal to 1.4188×10^{-5}/MGT or 8.129×10^{-4} Deg/MGT which produced a maximum cant of approximately 0.6° over the life of this test, (700 MGT). This value is small on a practical level, and therefore, all further plate cutting analyses will be based on the average of the gage and field side vertical plate cutting.

Table 7 shows the plate cutting results of these equations for each test segment.

Table 8 shows a statistical comparison of the plate cutting rates of each test segment. A significant difference was found in the gouging rate of the steel reinforced composite ties based on the use of soft rubber pads. However, the pads tended to extrude from under the tie plates (Figure 10), making the data a measure of pad thickness rather than of plate cutting. As a result, the plate cutting rate of ties with pads as measured should be disregarded.

The comparison of plate cutting rates of ties without pads indicates that the steel-reinforced composite ties performed better than the apitong-reinforced. No difference was found between the southern yellow pine and the hardwood, and, overall, there was no difference in the plate cutting properties of the conventional solid wood ties and the composites. Figure 11 shows typical platecut composite ties.

TABLE 7. PLATE CUTTING RATES.

Location	Vertical $\times 10^{-5}$ Inch/MGT Inside	Vertical $\times 10^{-5}$ Inch/MGT Outside	Cant $\times 10^{-5}$/MGT Inside	Cant $\times 10^{-5}$/MGT Outside
Comp w/Steel, Pad	16.0487	21.1360	-1.0063	N.S.*
Comp w/Steel, No Pad	9.4959	9.8891	-1.2917	1.4188
Comp w/Apitong, No Pad	18.5961	13.7405	-0.5015	N.S.
COMPOSITES, No Pad	14.2710	11.9394	-0.8295	0.8787
S. Y. Pine, No Pad	14.3710	11.5451	-0.5075	N.S.
Hardwood, No Pad	11.3326	10.6119	N.S.	N.S.
CONVENTIONAL, No Pad	12.5872	10.6877	0.3347	N.S.

*Not Significant at 95% level.

TABLE 8. PLATE CUTTING RATE COMPARISON.

	Vert. Inside ($\times 10^{-5}$ In/MGT)	Difference (95% Level)	Vert. Outside ($\times 10^{-5}$ In/MGT)	Difference (95% Level)
Composite, Steel Reinforced				
With Pads	16.0487	Yes	21.1360	Yes
Without Pads	9.4959		9.8891	
Composite, Without Pad				
Steel Reinforced	9.4959	Yes	9.8891	No
Apitong Reinforced	18.5961		13.7405	
Conventional, Without Pads				
Pine	14.3710	No	11.5451	No
Hardwood	11.3326		10.6119	
Ties, Without Pads				
Composite	14.2710	No	11.9394	No
Conventional	12.5872		10.6877	

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FIGURE 10. COMPOSITE WOOD TIES WITH RUBBER TIE PADS.

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FIGURE 11. PLATE CUT COMPOSITE TIES.

CONCLUSION

The composite wood ties used during this test are not as strong or as resilent as the conventional wood ties used. The conventional ties performed better overall. The results of the composite wood tie performance evaluation are summarized as follows:

- The modulus of elasticity, E, of a composite tie is approximately 1/4 that of a conventional wood tie, and the ultimate load carrying capability is only 1/6 that of a conventional wood tie.

- The initial spike removal force for both composite and solid wood ties was acceptably high; however, by the end of the test (six years, 700 MGT) the value for the steel-reinforced composites had dropped to equal that of southern yellow pine (far below the mixed hardwoods). The pullout force required for the apitong-reinforced composites in many case was almost nil.

  The pullout force for the composite ties decreased, while that for the conventional ties increased.

- The apitong-reinforced composite tie track segment required additional labor manhours per track length to maintain the track surface and line to FRA Class 4 standards.

- There is no significant difference between the plate cutting rates of the composite and the conventional ties.

- Post-mortem inspection indicated that 1/4" soft rubber tie pads reduce the occurrence of plate cutting on the steel reinforced composite ties (48% were plate cut with pads, and 82% were plate cut without).

- The composite ties tend to delaminate horizontally at the reinforcement location. An average of 35% of the steel-reinforced composites delaminated, as did 20% of the apitong-reinforced composites.

NOTICE

The results in this report were obtained under test procedures and criteria established within the FAST Program and are disseminated in the interest of information exchange. These data and results do not imply an endorsement of of the products tested by either the Federal Railroad Administration or the Association of American Railroads. Applicability of these results beyond the samples tested is not implied.

REFERENCES

1. Hay, W. W., Railroad Engineering, Second Edition. John Wiley and Sons, New York, N.Y. 1982.

2. Collister, L. C., "Results of Standard Wood Tie and Manufactured Tie Experiments at FAST," Procs. FAST Engineering Conference 1981. FRA Report TTC-82/01, Transportation Test Center, Pueblo, Colorado. p.61.

Composite Wood Tie Performance Report,
Newsletter, 1985
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FAST Facility for Accelerated Service Testing

TECHNICAL NOTE

The Facility for Accelerated Service Testing/High Tonnage Loop (FAST/HTL) is located at the Transportation Test Center in Pueblo, Colorado. The program is sponsored by the Federal Railroad Administration of the U.S. Department of Transportation in cooperation with the Association of American Railroads. Additional support to the program is provided by the railroad industry and the railroad supply industry. The program provides accelerated, full-scale testing of railroad track and mechanical components as well as applied research in the mechanics and behavior of railway track structures.

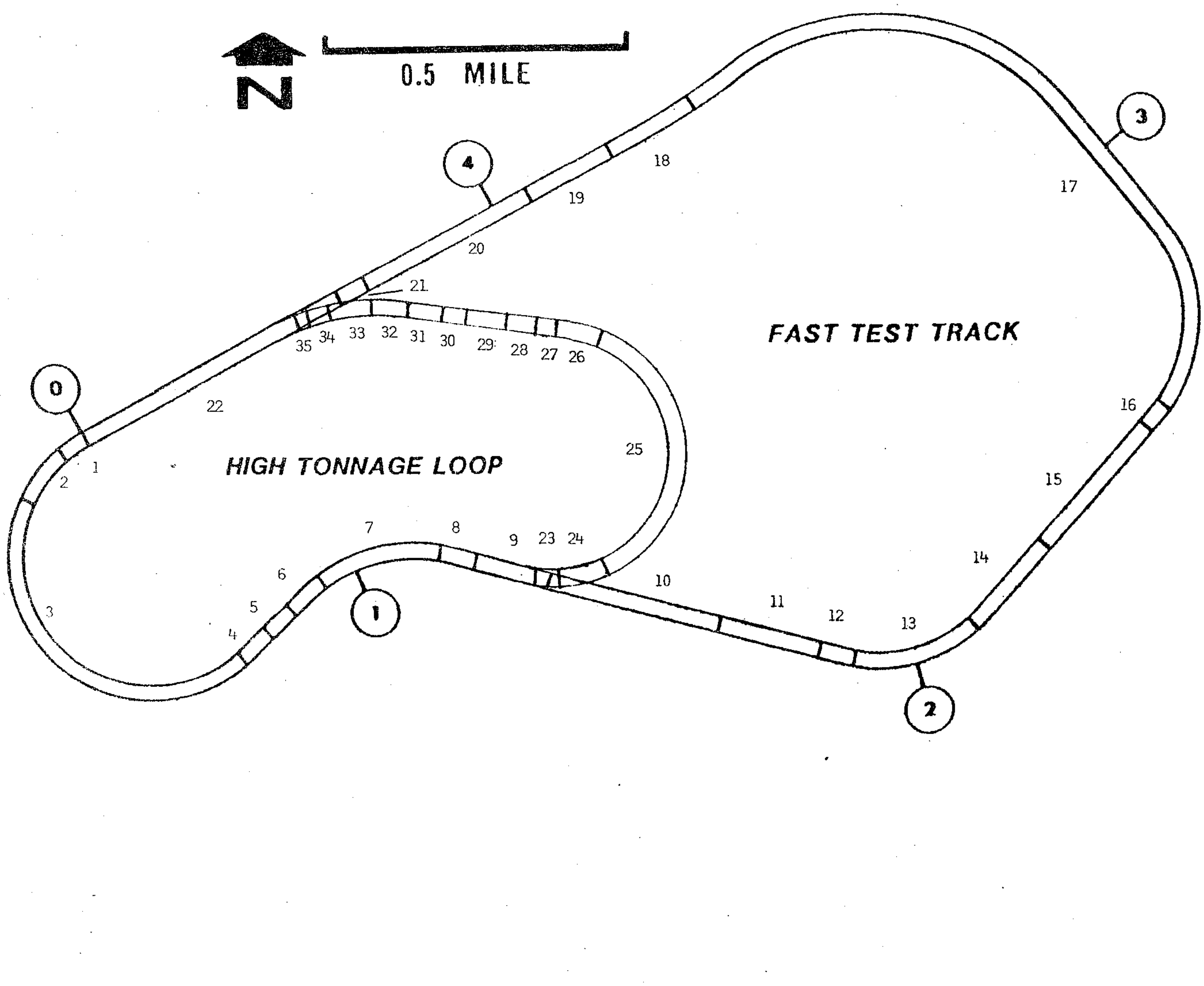
The FAST/HTL program is controlled by a Steering Committee composed of representatives from the Federal Railroad Administration, the Association of American Railroads, the railroad companies, and the railroad supply industry. Its policies are implemented through the FAST/HTL organization at the Transportation Test Center. Responsibility for the operation of the FAST/HTL program rests with the FAST/HTL Director and the FAST/HTL Project Manager. Experiment Supervisors are individually responsible for the conduct of the separate tests conducted on the FAST/HTL.

The FAST/HTL test facility is composed of two test tracks, the High Tonnage Loop and the FAST test track, and facilities for the maintenance of rolling stock and other operational support functions.

The High Tonnage Loop test track is 2.7 miles in length. This track is used for tests that require high exposure to train traffic and is an effective test bed for the measurement of wear and fatigue phenomena. Approximately 100 million gross tons of train traffic pass over the track every year, with periods of time reserved for the measurement of train and track components.

A train consist of at least three 4-axle, high horsepower locomotives and 75 to 85 cars operates over the HTL. A million gross tons of traffic exposure to the track can be generated in a single shift operation of the consist. The trailing tonnage is primarily composed of loaded 100-ton hopper cars (263,000 lb) with several empty and partially loaded cars interspersed. This combination of car types and loadings produces vertical and lateral load spectra similar to those found on many revenue service railroads.

The second test track is the FAST test track. This track is 4.8 miles in length, although approximately 1.5 miles of the track runs in common with the High Tonnage Loop. The FAST test track is used primarily for those tests that do not require high traffic exposure. Tests of this nature are primarily investigations into mechanisms of track and train component behavior.



THE FAST/HTL TEST TRACK