TECHNOLOGY DIGEST

TD-03-007

© APRIL 2003

TIMELY TECHNOLOGY TRANSFER

Work performed by Transportation Technology Center, Inc., a subsidiary of the Association of American Railroads.
Contact Rafael Jimenez, (719) 584-0691 with questions or concerns regarding this *Technology Digest.* E-mail: rafael_jimenez@ttci.aar.com.

Laboratory Testing of Synthetic Tie-Plugging Materials

by Rafael Jimenez, Joseph LoPresti, Luis Maal, James Rzonca, and David Davis

Summary

Transportation Technology Center, Inc. (TTCI) tested synthetic tie-plugging materials from three manufacturers to quantify their performance using cut spikes and screw spikes. The materials were tested in both dry and wet spike-kill simulation holes made in solid-sawn wood ties and plastic composite ties. One manufacturer's material was applied with a portable pneumatic gun; the second supplier used a hand-operated gun; and the third used an on-track production machine. The supplier who used the hand-operated gun repeated the cut spike part of the test using an on-track machine.

The insertion and extraction forces for cut spikes and the break-free torque and extraction forces for screw spikes were measured in each of the three materials. The results were compared to the forces measured in untreated new and used wood ties, untreated plastic ties, and in used wood ties plugged with typical wooden plugs.

Following are the major observations:

- The synthetic plugging materials filled the spike-kill simulation holes more completely than the wood plugs.
- In used wood ties, the average extraction forces for cut spikes in the synthetic plugging materials applied with a portable pneumatic gun and with on-track production machines were between 4 and 7 times higher than the forces measured in wood-plugged, spike-kill simulation holes.
- In used wood ties, two of the three synthetic materials applied to dry holes provided 1.8 times and 2.8 times more resistance to screw spike break-free torque than the wood-plugged, spike-kill simulation holes. In wet holes, the same two synthetic materials provided more resistance (1.3 and 2.1 times, respectively) to screw spike break-free torque. One of the materials, when used in dry holes, provided break-free torque that was comparable to the wood-plugged holes but about 50 percent less when used in wet holes.
- With dry holes made in used wood ties, two of the three synthetic materials provided an average resistance to screw spike extraction that was comparable to the wood-plugged, spike-kill simulation holes. The average extraction resistance measured with one of the materials was about 63 percent higher than in the wood-plugged, spike-kill holes. In wet holes, the average resistance to extraction measured in two of the materials was lower, but one was about 20 percent higher than in wood-plugged, spike-kill holes.
- After the 400,000-cycle load test, which simulated about 25 million gross tons (MGT), there were no indications of performance deterioration in any of the synthetic plugging materials.
- The synthetic plugging materials tested were not specifically formulated for use with plastic ties. Poor adhesion of the synthetic materials to the plastic ties in some cases allowed the material plug to turn as the screw spikes were turned. In plastic ties, the synthetic materials generally performed better with cut spikes than with screw spikes.

The long-term performance of the synthetic tie plugging materials tested cannot be predicted from these baseline results. The in-track test planned for the High Tonnage Loop (HTL) at TTC's Facility for Accelerated Service Testing (FAST) will provide actual performance data that may be used to correlate with laboratory test results.

Suggested Distribution:

- ❑ Maintenance-of-Way
- ❑ Track Maintenance
- ❑ Planning & Analysis

Transportation Technology Center, Inc.

INTRODUCTION AND CONCLUSIONS

One synthetic tie plugging material formulation from each of three suppliers was laboratory tested to measure the early-strength resistance to insertion and extraction and the extraction resistance available after limited cyclic loading. Transportation Technology Center, Inc. (TTCI), tested the materials as part of the Heavy Axle Load (HAL) program, jointly funded by the Federal Railroad Administration (FRA) and the Association of American Railroads (AAR). Tests were conducted at the FRA's Facility for Accelerated Service Testing (FAST), near Pueblo, Colorado.

The holding power and the insertion forces measured in the synthetic materials were compared to the same forces measured in three other conditions: untreated new and used solid-sawn wood ties, untreated plastic ties, and plastic and used wood ties with typical wooden plugs. Figure 1 lists the participating tie plugging material suppliers and the nomenclature of the two-part materials tested.

Figure 1. Participating Suppliers and Products Tested

Type	Supplier	Product Name (Two-Part Compounds)
HTT	Harsco Track Technologies, Inc.	UR2268A UR2268B
R-Sol	R-Solutions	System 1 Part A System 1 Part B
WVC	Willamette Valley Co.	Spikefast ES25–Resin Spikefast ES–ISO

The HTT product was delivered using a portable, pneumatically operated, two-cartridge gun system. The WVC product was delivered using an on-track production machine with the product temperature at 80°F.

Due to scheduling conflicts, the R-Sol product was applied using a portable, hand-operated, two-cartridge gun during the FAST/HAL program test. This application method had a significant effect on the performance of the product. Subsequent testing of the R-Solutions product, conducted under a proprietary contract, was performed using an on-track production machine with the product temperature at 105°F. The results of the proprietary testing are published here with the permission of R-Solutions.

TEST CONDITIONS

The synthetic tie plugging material tests and the wood plugged comparisons were done in spike-kill simulation holes to represent extreme conditions in a wooden tie. The spike-kill simulation holes were 11/16 inch in diameter for cut spikes, and 1-inch in diameter holes for screw spikes. In both cases, the holes were 5 1/2 inches deep. The cut spikes were inserted without pilot holes in the untreated ties and in the synthetic materials. The pilot holes for screw spikes were 11/16 inch in diameter.

The cut spike insertion measurements and the pilot holes for screw spikes were made between 30 and 60 minutes after the synthetic material was applied. The cut spike extraction measurements and the screw spike break-free torque measurements were made between 35 and 55 minutes after insertion. The early strength tests were performed with the synthetic material applied to dry and wet holes. To simulate wet revenue-service track conditions, the tests were conducted in holes that were pre-soaked with water overnight and filled with 10 milliliters of water prior to material application.

The cyclic load test was designed to determine if limited cycling significantly reduced holding power. Lateral tie plate and railhead displacement was measured at intervals during the cyclic test. The resistance to extraction of the cut spikes and the screw spikes was measured at the conclusion of the test.

The cyclic test was performed using a 6-inch rail section fastened to a half-tie with the synthetic materials applied to dry, spike-kill simulation holes. The 400,000-cycle test, where the applied loads are 17,000 pounds vertical and 7,500 pounds lateral, is roughly equivalent to 1,800 passes of a train (2 lead axles/car, 110 cars/train) on or about 25 MGT.

Figure 2 shows the test matrix of the early strength tests and the cyclic load tests.

TEST RESULTS

Cut Spikes in Wood Ties: Insertion Forces, Dry and Wet Application

Figure 4 shows the high, low, and average forces required to insert cut spikes, without pilot holes, into each of the synthetic materials. The insertion forces were measured with the materials applied into dry holes and again when inserted into wet holes.

A comparison is made between the cut spike insertion forces into:

- New and used untreated wood ties,
- Used wood ties plugged with wooden plugs in spike-kill simulation holes, and
- Used wood ties plugged with wooden plugs in vacated cut spike holes.[1] This data, previously published, is provided for additional comparison.

Figure 4 shows that the HTT and WVC materials and the R-Sol material applied with an on-track system provided either comparable or higher average insertion resistance than the untreated ties. The same materials provided higher average insertion resistance than both wood-plugged ties.

Figure 2. Test Matrix

Type	Spike-Kill Holes	Early Strength Tests	
HTT R-Sol WVC	Dry & Wet*	Cut Spikes in Used Wood Ties & Plastic Ties	Screw Spikes in Used Wood and Plastic Ties
		Measure Insertion & Extraction Force	Measure Break-Free Torque and Extraction Force
	Dry	**Cyclic Load Tests (400,000 cycles)**	
		Cut Spikes in Used Wood Ties	Screw Spikes in Used Wood Ties
		Measure Railhead/Tie Plate Lateral Displacement & Cut Spike Extraction	Measure Railhead/Tie Plate Lateral Displacement

** wet = holes pre-soaked and filled with 10 milliliters of water.*

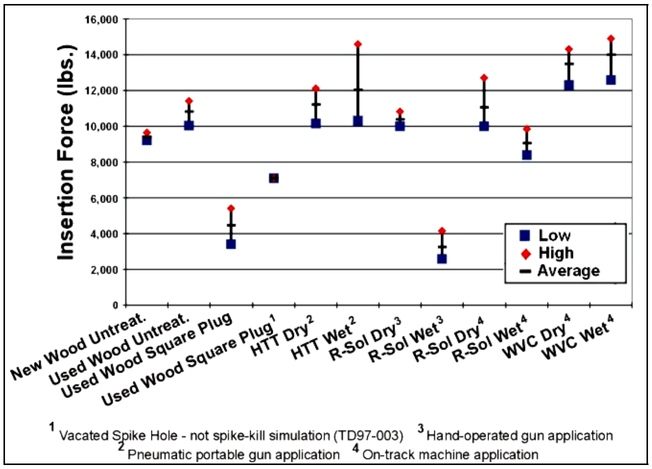

Figure 4. Insertion Forces, Cut Spikes into Synthetic Tie Plugging Materials in Dry and Wet Spike-Kill Simulation Holes

The average insertion forces measured in the R-Sol material applied with the on-track system into wet holes were significantly higher than those measured when the material was applied with the hand-operated, portable gun.

As expected, the average forces into the wood-plugged, vacated cut spike holes were higher than those into the wood-plugged, spike-kill simulation holes.

Cut Spikes in Wood Ties: Extraction Forces, Dry and Wet Application

Figure 5 shows that although all of the synthetic plugging materials provided less average holding power for cut spikes than the untreated new and used ties, the HTT, the WVC, and the R-Sol material from the on-track machine provided higher average holding power than both wood-plugged ties.

As with the insertion forces, the application system had a significant effect on the extraction resistance of cut spikes from the R-Sol material. The on-track system provided higher resistance in dry and wet holes than the material applied with the hand-operated, portable gun.

The extraction forces were measured on the same spikes used to measure the insertion forces. The comparison is made with the same untreated new and used wood ties and the wood-plugged (spike-kill simulation and vacated spike) holes.

Figure 6 shows the application systems used and the average insertion and extraction forces measured in dry and wet conditions. Also shown are the lower and upper 90 percent confidence limits.

The 90 percent confidence interval was calculated for the tabulated test results using the one-sample t-procedure. The wide confidence interval seen in some cases is due in part to small sample size, variability between ties, and possible variability within a product. The small-sample size factor should be significantly reduced in the upcoming in-track performance test.

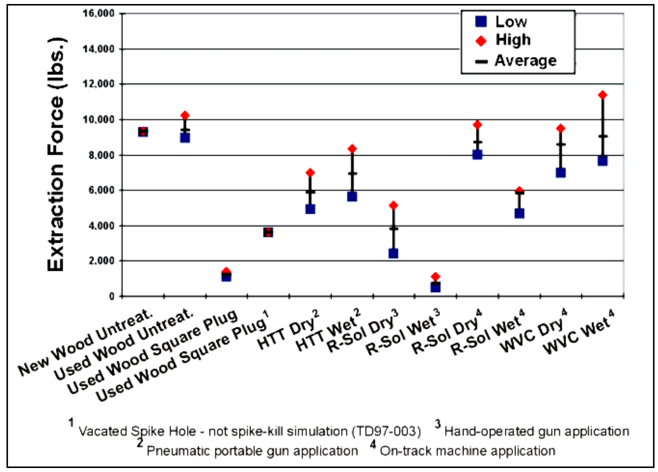

Figure 5. Extraction Forces, Cut Spikes from Synthetic Tie Plugging Materials in Dry and Wet Spike-Kill Simulation Holes

Screw Spikes in Wood Ties: Break-Free Torque and Extraction Forces, Dry and Wet Application

Figure 7 shows the application systems, the average break-free torque and extraction forces in dry and wet conditions, and the 90 percent confidence limits.

In used wood ties, the HTT and the WVC synthetic materials applied to dry holes provided 1.8 and 2.8 times more resistance, respectively, to screw spike break-free torque than the wood-plugged, spike-kill simulation holes. In wet holes, the same two synthetic materials provided 1.3 and 2.1 times more resistance, respectively, to screw spike break-free torque. The R-Sol material, when used in dry holes, provided break-free torque that was comparable to the wood-plugged holes, but about 50 percent less when used in wet holes.

With dry holes made in used wood ties, the HTT and the R-Sol materials provided an average resistance to extraction that was comparable to the wood-plugged, spike-kill simulation holes. The average extraction resistance measured with the WVC material was about 63 percent higher than in the wood-plugged, spike-kill holes. In wet holes, the average resistance to extraction measured in the HTT and the R-Sol materials was lower but in the WVC material, it was about 20 percent higher than in the wood-plugged, spike-kill holes.

Cut Spikes in Plastic Ties – Insertion and Extraction Forces – Dry and Wet Application

The HTT, R-Sol, and WVC materials provided comparable or higher insertion and extraction forces to that of the wood plugged, spike-kill simulation holes in plastic ties.

Screw Spikes in Plastic Ties: Break-Free Torque and Extraction Forces, Dry and Wet Application

Although some measurements were made of the break-free torque and extraction forces using the three synthetic materials in plastic ties, a complete data set was not possible due to the generally inadequate adhesion of the plugging materials to the plastic ties. The synthetic material plugs turned in some of the holes as the screw spikes were turned. The synthetic plugging materials tested were not specifically formulated for use with plastic ties.

Post Cyclic Test, Cut Spikes and Screw Spikes in Wood Ties: Break-Free Torque and Extraction Forces, Dry Application

Lateral displacement measurements at the railhead and the tie plate were taken at the start of the cyclic test and after 50k, 100k, 150k, 200k, 300k, and 400k cycles. After the 400k-cycle test, the cut spikes were measured for extraction force and the screw spikes were measured for break-free torque and resistance to extraction. All of the synthetic plugging materials provided the holding power required for the rail-section/fastening system to survive the 400,000 cycles without significant lateral displacement, fastener uplift, or deterioration of fastener extraction forces.

FUTURE WORK

With continued cooperation from the suppliers, TTCI is planning to conduct an in-track performance test to determine the holding power of the synthetic tie plugging materials after being subjected to heavy axle load traffic. A test zone will be established on the High Tonnage Loop (HTL) at the Facility for Accelerated Service Testing (FAST).

ACKNOWLEDGEMENT

The authors are grateful to the three synthetic tie plugging material suppliers who participated in the test: Harsco Track Technologies, Inc., R-Solutions, and Willamette Valley Co. and to the railroad/FRA Technical Advisory Group for their technical guidance. Additionally, the authors wish to thank Lewis Bolt & Nut Co. for their donation of the screw spikes used in the test.

REFERENCE

1. Oliva, D., Davis, D. D., Chow, P., and Meimban, R. "Performance Evaluation of Tie Plugging Remedial Treatments," *Technology Digest*, TD97-003, Transportation Technology Center, Inc., Pueblo. Colorado, February 1997.

Figure 6. Insertion and Extraction Forces for Cut Spikes from Synthetic Tie Plugging Materials Applied to Dry and Wet Spike-Kill Simulation Holes in Wood Ties (Lower and Upper 90% Confidence Limit)

	Avg. Insertion Force (lb.) [Lower & Upper 90% Confidence Limit]		Avg. Extraction Force (lb.) [Lower & Upper 90% Confidence Limit]	
	Dry Application	Wet Application	Dry Application	Wet Application
Untreated New Wood Tie	9,400 [9,200 – 9,600]	NA	9,300 [9,300 – 9,400]	NA
Untreated Used Wood Tie	10,800 [10,100 – 11,500]	NA	9,400 [8,700 – 10,100]	NA
Wood-Plugged Used Wood Tie Spike-Kill Simulation Holes	4,500 [3,500 – 5,500]	NA	1,200 [1,100 – 1,400]	NA
Wood-Plugged Used Wood Tie Not Spike-Kill Simulation Holes[1]	7,100	NA	3,600	NA
HTT (Pneumatic gun)	11,200 [10,500 – 11,900]	12,100 [9,900 – 14,200]	5,900 [5,300 – 6,500]	6,900 [5,600 – 8,300]
R-Sol (Hand-operated gun)	10,400 [10,000 – 10,700]	3,300 [2,400 – 4,100]	3,800 [2,800 – 4,800]	800 [600 – 1,000]
R-Sol (On-track machine)	11,100 [9,700 – 12,400]	9,100 [8,300 – 9,800]	8,700 [7,800 – 9,600]	5,800 [4,800 – 6,800]
WVC (On-track machine)	13,500 [12,300 – 14,700]	14,000 [12,700 – 15,300]	8,600 [7,300 – 9,900]	9,000 [7,100 – 11,000]

Figure 7. Break-Free Torque and Extraction Forces for Screw Spikes from Synthetic Tie Plugging Materials Applied to Dry and Wet Spike-Kill Simulation Holes (Lower and Upper 90 Percent Confidence Limit)

	Avg. Break-Free Torque (ft.-lb.) [Lower and Upper 90 Percent Confidence Limit]		Average Extraction Force (lbs.) [Lower and Upper 90 Percent Confidence Limit]	
	Dry Application	**Wet Application**	**Dry Application**	**Wet Application**
Untreated New Wood Tie	150 [110-190]	NA	14,200 [12,400-16,000]	NA
Untreated Used Wood Tie	90 [60-130]	NA	17,600 [17,200-18,000]	NA
Wood-Plugged Used Wood Tie, Spike-Kill Simulation Holes	100 [80-120]	NA	11,100 [10,300-11,800]	NA
HTT (Pneumatic gun)	180 [160-200]	130 [110-160]	11,000 [7,200-14,900]	8,600 [7,000-10,100]
R-Sol (Hand-operated gun)	80 [40-120]	50 [40-60]	11,900 [8,400-15,400]	3,800 [2,300-5,200]
WVC (On-track machine)	280 [220-340]	210 [140-290]	18,100 [12,800-23,300]	13,300 [9,700-16,800]