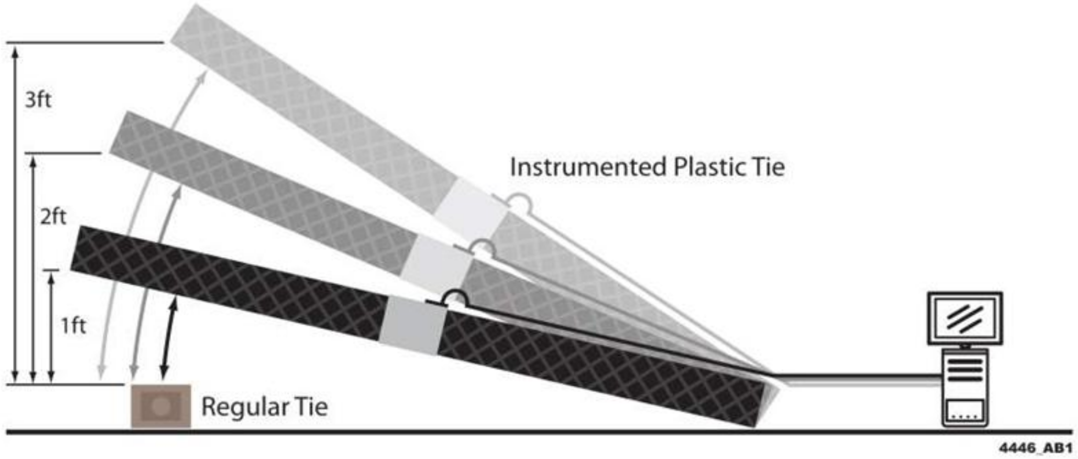
U.S. Department of
Transportation

**Federal Railroad
Administration**

Construction Loads Experienced by Plastic Composite Ties

Office of Research
and Development
Washington, DC 20590



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Damage to plastic composite ties during handling and track installation has been reported by a number of railroads. Results from a survey conducted to identify specific handling issues were used to develop field and laboratory tests to measure the loads plastic composite ties are subjected to during handling and installation. Results suggest ties that would otherwise pass current AREMA Chapter 30 qualification tests and survive in track may fail because of the single, one-time high loads they may experience during installation or handling. For this reason, users and suppliers should critically evaluate existing tests in order to determine if additional tests that apply higher, single-event loads should be added to the screening process. A summary of peak loads is provided in this report, along with suggestions to develop impact and bending tests that simulate those peak load levels for laboratory screening tests.

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METRIC/ENGLISH CONVERSION FACTORS

ENGLISH TO METRIC

LENGTH (APPROXIMATE)

1 inch (in) = 2.5 centimeters (cm)
1 foot (ft) = 30 centimeters (cm)
1 yard (yd) = 0.9 meter (m)
1 mile (mi) = 1.6 kilometers (km)

AREA (APPROXIMATE)

1 square inch (sq in, in^2) = 6.5 square centimeters (cm^2)
1 square foot (sq ft, ft^2) = 0.09 square meter (m^2)
1 square yard (sq yd, yd^2) = 0.8 square meter (m^2)
1 square mile (sq mi, mi^2) = 2.6 square kilometers (km^2)
1 acre = 0.4 hectare (he) = 4,000 square meters (m^2)

MASS - WEIGHT (APPROXIMATE)

1 ounce (oz) = 28 grams (gm)
1 pound (lb) = 0.45 kilogram (kg)
1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

VOLUME (APPROXIMATE)

1 teaspoon (tsp) = 5 milliliters (ml)
1 tablespoon (tbsp) = 15 milliliters (ml)
1 fluid ounce (fl oz) = 30 milliliters (ml)
1 cup (c) = 0.24 liter (l)
1 pint (pt) = 0.47 liter (l)
1 quart (qt) = 0.96 liter (l)
1 gallon (gal) = 3.8 liters (l)
1 cubic foot (cu ft, ft^3) = 0.03 cubic meter (m^3)
1 cubic yard (cu yd, yd^3) = 0.76 cubic meter (m^3)

TEMPERATURE (EXACT)

[(x-32)(5/9)] °F = y °C

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
1 centimeter (cm) = 0.4 inch (in)
1 meter (m) = 3.3 feet (ft)
1 meter (m) = 1.1 yards (yd)
1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm^2) = 0.16 square inch (sq in, in^2)
1 square meter (m^2) = 1.2 square yards (sq yd, yd^2)
1 square kilometer (km^2) = 0.4 square mile (sq mi, mi^2)
10,000 square meters (m^2) = 1 hectare (ha) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gm) = 0.036 ounce (oz)
1 kilogram (kg) = 2.2 pounds (lb)
1 tonne (t) = 1,000 kilograms (kg)
= 1.1 short tons

VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
1 liter (l) = 2.1 pints (pt)
1 liter (l) = 1.06 quarts (qt)
1 liter (l) = 0.26 gallon (gal)
1 cubic meter (m^3) = 36 cubic feet (cu ft, ft^3)
1 cubic meter (m^3) = 1.3 cubic yards (cu yd, yd^3)

TEMPERATURE (EXACT)

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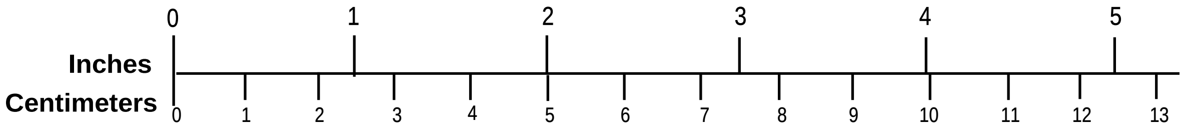
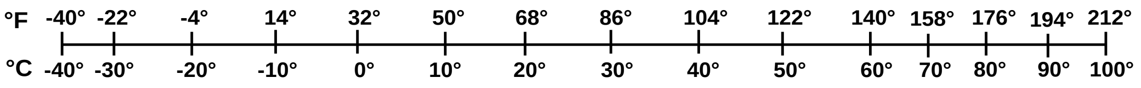


QUICK FAHRENHEIT - CELSIUS TEMPERATURE CONVERSION



For more exact and or other conversion factors, see NIST Miscellaneous Publication 286, Units of Weights and Measures. Price $2.50 SD Catalog No. C13 10286 Updated 6/17/98

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TTCI engineering personnel, Kyle Ninness, Sirius Roybal, and Bea Rael, collected and analyzed a wealth of data.

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Executive Summary

Damage to plastic composite ties during handling and installation has been reported by a number of railroads. In response to an American Railway Engineering and Maintenance-of-Way Association (AREMA) recommendation, FRA tasked the Transportation Technology Center, Inc. (TTCI) with investigating the reported problems. The intent was to use the results of this study to update, where necessary, the section on Engineered Composite Ties (Part 5) of Chapter 30 (Ties) of the AREMA Engineering Manual. The study concluded that occurrences of one time high loads are seen in the field during installation. A summary of peak loads is provided in this report with suggestions to develop impact and bending tests that simulate these levels in laboratory screening tests.

The study set out to determine if the loads plastic composite ties experience during handling and installation exceed those recommended in Chapter 30 of the AREMA guidelines for screening tests. Accordingly, TTCI conducted a comprehensive survey of users to identify specific handling and installation issues. The results of the survey were used to develop field tests to measure actual loads plastic composite ties are subjected to during handling and installation. Results were compared with current center and rail seat bending tests.

The results suggest ties passing current AREMA Chapter 30 qualification tests may exhibit failures earlier than they otherwise would once in track because of the single one-time high loads they experience during installation or handling. For this reason, consumers and suppliers should critically evaluate existing tests in order to determine if additional tests that apply higher, single-event loads should be added to the screening process.

The use of plastic composite ties by North American railroads has been gradually increasing over the past 15 years; however, most installations to date have been to evaluate or test new tie designs, or have been limited to very short sections of track. Widespread use of plastic composite ties as a replacement for wood ties has been limited due to cost and unknown short- and long-term performance issues. The above referenced recent section on plastic ties has been added to the AREMA Manual with FRA support, to provide consensus engineering guidance on the safety performance of composite plastic ties before their widespread use in U.S. railroads.

1. Introduction

In an effort to improve safety, as well as increase the use of track components manufactured from recycled materials, FRA tasked TTCI to evaluate plastic composite tie performance.

The use of plastic composite ties by North American railroads has been gradually increasing over the past 15 years; however, most installations to date have been to evaluate or test new tie designs, or have been limited to very short sections of track. In addition, replacement of wood ties with plastic composite ties has been limited due to cost and unknown short- and long-term performance issues.

1.1 Background

Although railroad use of ties manufactured from plastic composite materials has increased over the past 15 years, some users have reported damage when such ties are handled and installed in track. At the spring 2008 AREMA Committee 30 meeting, several railroads reported damage rates up to 20 percent for plastic composite ties during the installation process, before they were exposed to any train loads. The installation was based on the same handling and installation processes currently used for wood ties. Reported damage includes, but is not limited to, cracked and broken ties from dropping, spiking, and inserting ties in track. Although alternative procedures could reduce the chances of such damage, such a change would likely result in slower installation and increased costs, which would offset some of the economic advantages of using plastic composite ties. More significantly, hidden damage, such as cracking occurring during installation, could lead to premature failure of plastic composite ties, thereby impacting safety and long-term economics.

At present, most AREMA tie screening tests are based on train loads encountered by ties once installed in track. If ties are subjected to higher loads, even for one occurrence during installation, some AREMA test parameters may not sufficiently assess the adequacy of tie designs.

1.2 Objectives

This study was conducted to determine if the loads plastic composite ties experience during handling and installation exceed those used in the AREMA screening tests. If such loads are higher than what the current AREMA tie screening tests apply, laboratory procedures may need to be modified, or new tests may need to be developed to ensure adequate evaluation of alternative tie materials and designs.

TTCI will identify any issues related to damaging plastic composite ties during handling and installation and determine if forces causing such damage could be incorporated into laboratory tie screening tests. Future work in this area would include developing and demonstrating the laboratory tie screening tests designed to simulate higher, one-time forces that plastic composite ties must survive when being installed in track.

1.3 Overall Approach

Railroad users of plastic composite ties were polled to help identify issues related to tie damage during handling and installation. The results were used to develop a plan for evaluating loads where experience suggested handling or installation may be causing damage to plastic composite ties. Designated activities, such as tie handling, dropping, and installation, were then simulated using an instrumented plastic composite tie to measure the loads. If results suggested that changes or modifications to the existing screening tests would be extensive, then a follow-on program to revise the laboratory tie screening test procedures, and in some cases tie test fixtures, would be proposed.

1.4 Scope

TTCI identified issues of concern, as well as activities that could damage plastic composite ties during handling and installation, by surveying users of plastic composite ties. Based on the survey results, TTCI developed tests to measure loads applied during activities identified as possible sources of damage to ties. TTCI then assessed the test results and suggested further efforts needed to develop and demonstrate laboratory tie screening tests that would address the loads occurring during handling and installation of plastic composite ties.

1.5 Organization of the Report

A description of key survey results from polling railroad users of plastic composite is used to establish follow-on work to develop methods for measuring loads experienced by plastic composite ties from the end of the manufacturing process to the installation of the ties in track. The follow-on work is to include a description of installing and calibrating strain gages on plastic composite ties, tests to simulate dropping during unloading, and the monitoring of several key areas of the ties during typical tie installation and tie spiking activities.

2. Procedure

Existing and past users of plastic composite ties were surveyed to identify historical issues and observations that could be used to determine sources of significant damage to plastic composite ties during handling and installation. One key feature of plastic composite ties emphasized by suppliers is that they can be introduced into wood tie track using the same handling methods and equipment currently used for wood ties.

2.1 Railroad Polling and Interviews

Detailed phone interviews were conducted with representatives of railroads known to have used or tested plastic composite ties. The appendix contains their detailed responses. Below is a summary of key areas identified as likely sources of plastic composite tie damage during the shipping and installation process:

- Dropping of ties during unloading
- Spiking and tie plate hold down installation
- In plant handling and striking by forklift tabs
- Handling, stacking, and moving within manufacturer's plant

The following additional issues were identified, but were considered to be beyond the scope of the current project:

- Accelerated fatigue tests
- Accelerated aging tests
- Possible inadequate bending strength requirements
- Improved base stock quality control

2.2 Preparation and Calibration of Instrumented Plastic Composite Ties

Three plastic composite ties obtained from TieTek LLC were instrumented to allow bending strains to be measured during various handling and installation procedures (see Figures 1 and 2). During the handling process and the first railroad installation test, the strain gages on several ties were damaged, and two additional plastic composite ties were instrumented. These ties, manufactured by Recycle Technologies International, Inc., (RTI) were selected from a batch of ties donated to this project by BNSF Railway. Standard AREMA guidelines for center and rail seat bending tie tests were followed to apply loads to the plastic composite ties in order to calibrate the strain gages. The rationale for using standard AREMA tie tests to calibrate the strain gages was to provide a starting point for modifying the test procedures and loads, if the handling and installation test results suggested that minor modification of the AREMA tie screening test procedures was required and would be feasible. As ties could be subjected to both vertical and lateral bending during installation, both the top and the sides of the ties were instrumented with strain gages (see Figures 3 and 4).

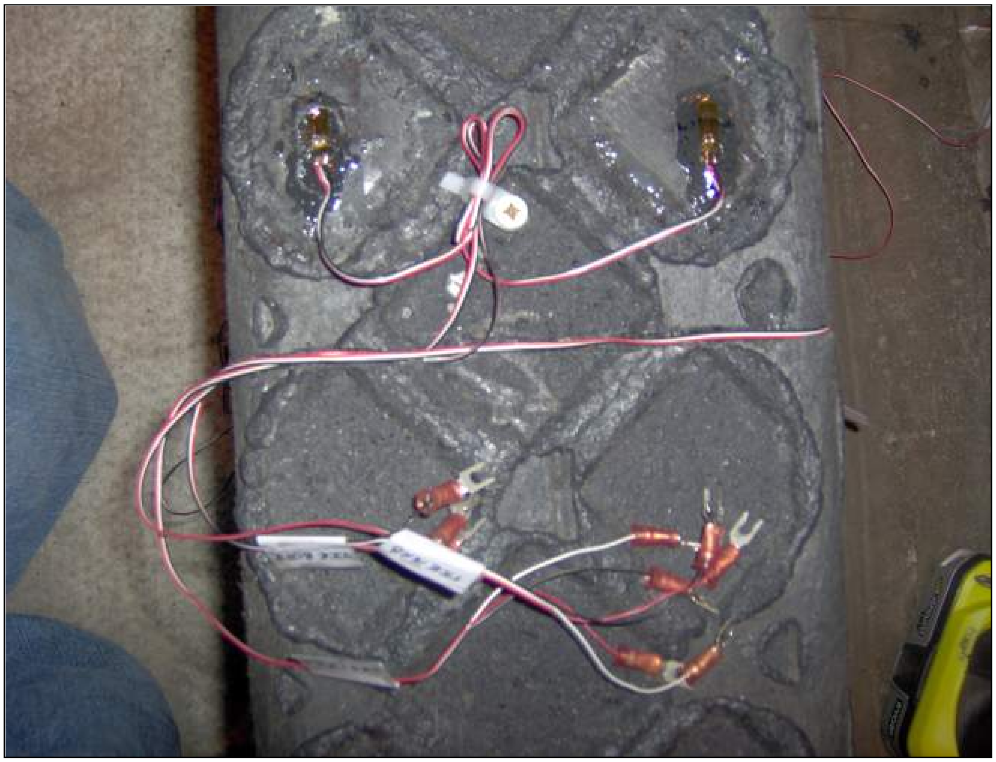


Figure 1. Strain gages bonded to bottom of the tie, prior to wire hookup.

Figure 2. Example of strain gage wiring at the tie center. The strain gages were protected under tape, with the wires leading to the end of the tie to allow data collection.

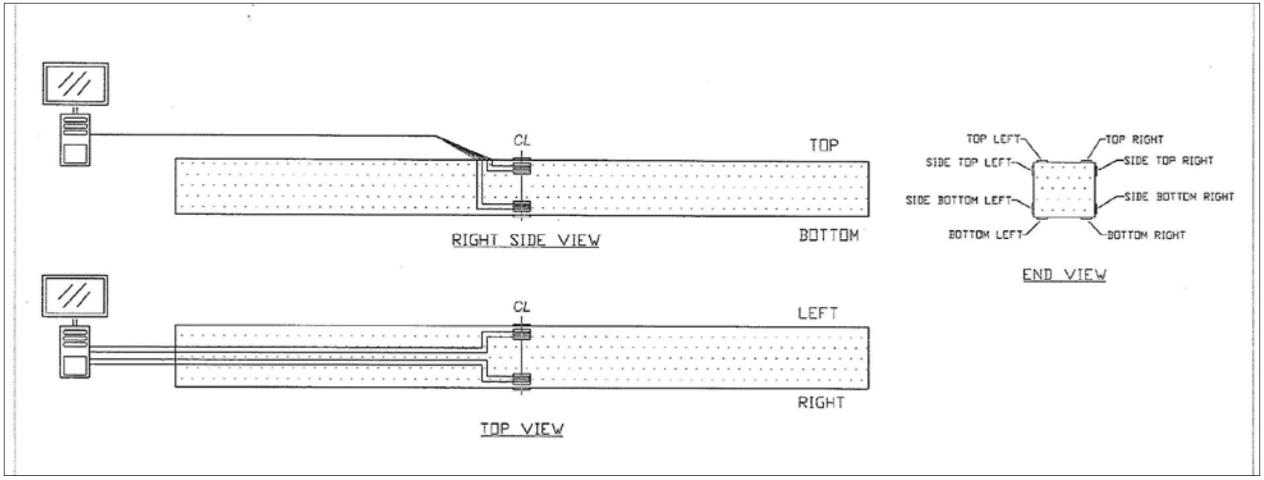


Figure 3. Location of gages for the field tie drop and stacking test.

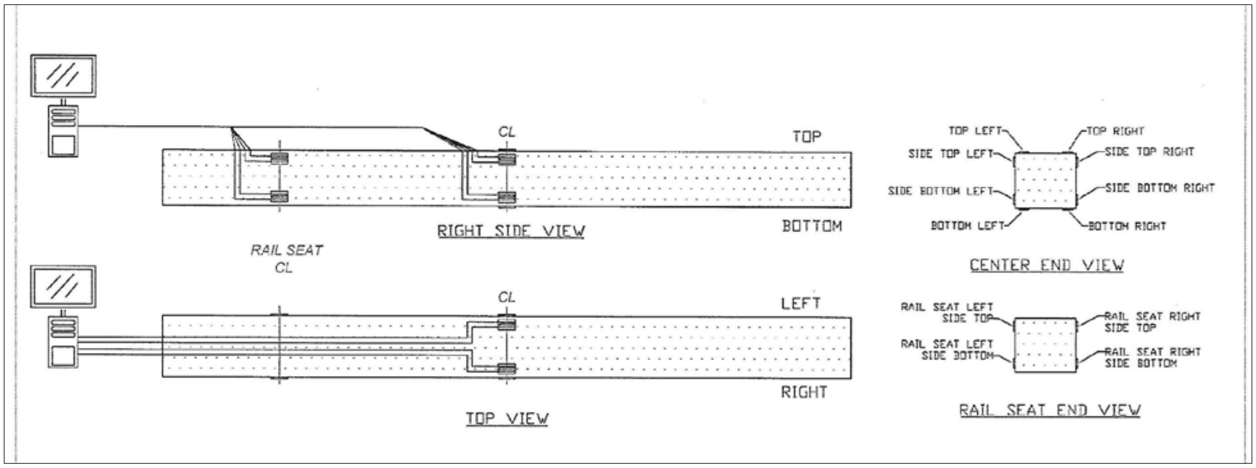


Figure 4. Location of gages for the field tie bending test.

Calibration in the center bending mode followed the AREMA tie test guidelines with 60-inch spacing of supports under the tie and center top loading at the middle of the tie. The standard test is configured to load from the top, and if shape factors dictate, the tie is also turned upside down and loaded from the bottom surface.

The loading configuration for standard AREMA tie tests utilizes the tie top and bottom, as that is the orientation for ties installed in track. However, because external tie loads during handling may not always be vertical, calibration was repeated after turning the tie 90 degrees so the 7-inch-wide side of the tie was on the bottom. For the first tie, a maximum calibration load of 15,000 pounds was used. Load versus deflection plots showed a very linear relationship; however, at the 12,000- to 15,000-pound load limit, there was an indication of a crack in the tie; thus, the remaining ties were calibrated using a maximum 8,000-pound center bending load.

Strain gages were also attached to the sides at the rail seat area on two of the first three ties instrumented, and the ties were then calibrated using standard AREMA rail seat bending configurations. The AREMA rail seat bending test setup is similar to the AREMA positive center bending test, but with the tie supported at 30-inch spacing centered on the rail seat. This is the standard AREMA test and was also limited to a maximum load of 8,000 pounds. For the calibration, only positive rail seat bending was conducted.

For each tie and unique strain gage location, a calibration curve of applied load versus measured strain was created. After calibration was completed, wires were routed, attached, and protected along the edge and top of ties to allow for field installation and handling.

2.3 Handling and Installation

Field and shop sites were selected to collect tie bending strain data during tie handling and installation. The ties were manipulated using standard handling practices. These simulations were intended to allow measurement of tie bending strains during shipping, stacking, and inserting into the ballast, as well as during the nipping and spiking operation.

2.3.1 Handling Ties Prior to Installation

The survey identified a concern that dropping plastic composite ties during handling may be causing hidden damage. Stacking and handling procedures for plastic composite ties were obtained from a tie supplier and a range of tests was conducted at the Transportation Technology Center (TTC) in Pueblo, CO. These tests included bouncing stacked ties on a forklift during transport and dropping ties banded in bundles. Results of these tests showed that bouncing stacks of ties during transport (e.g., driving a forklift over rough roads) produced strains less than 20 percent of the calibration limit. Other tests with alternative and “probably incorrect” stacking also produced very low bending strain levels. Damage from forklift tabs hitting ties was not simulated because basic training in proper operation of a forklift would ideally prevent such occurrences.

Data collected during the stacking and transport tests suggest that, in general, in-plant handling techniques do not damage plastic composite ties. The survey results also suggest that the handling processes causing the most damage to plastic composite ties are related to dropping ties during unloading in the field. Many railroads choose to drop bundles of ties, which often breaks the banding, allowing the individual ties to scatter and spreading the ties for easier handling during insertion into the ballast. To simulate this practice, procedures were developed for dropping a plastic composite tie onto an instrumented plastic composite tie and dropping an instrumented plastic composite tie onto a plastic composite tie placed on the ground. These procedures were configured with the intent that they could be repeated by other test laboratories. If the test data suggested damage could occur, a procedure would be developed to introduce such loads onto a tie during the tie screening tests. This follow-on effort could then be used to establish standardized tie screening tests.

Configuration 1, depicted in Figures 5 and 6, represents a condition where a plastic composite tie is tipped onto another plastic composite tie (or object), with one end of the tie on the ground and the other end falling from various heights. To safely conduct this test, the end of the tie was supported by a forklift at the desired height, then the forklift was quickly backed away to drop the tie. As the drop height increased, the tie tended to bounce in different directions, and some secondary bending loads were observed. Figure 7 summarizes the peak center (top and side) bending strain data for various drop heights for this configuration.

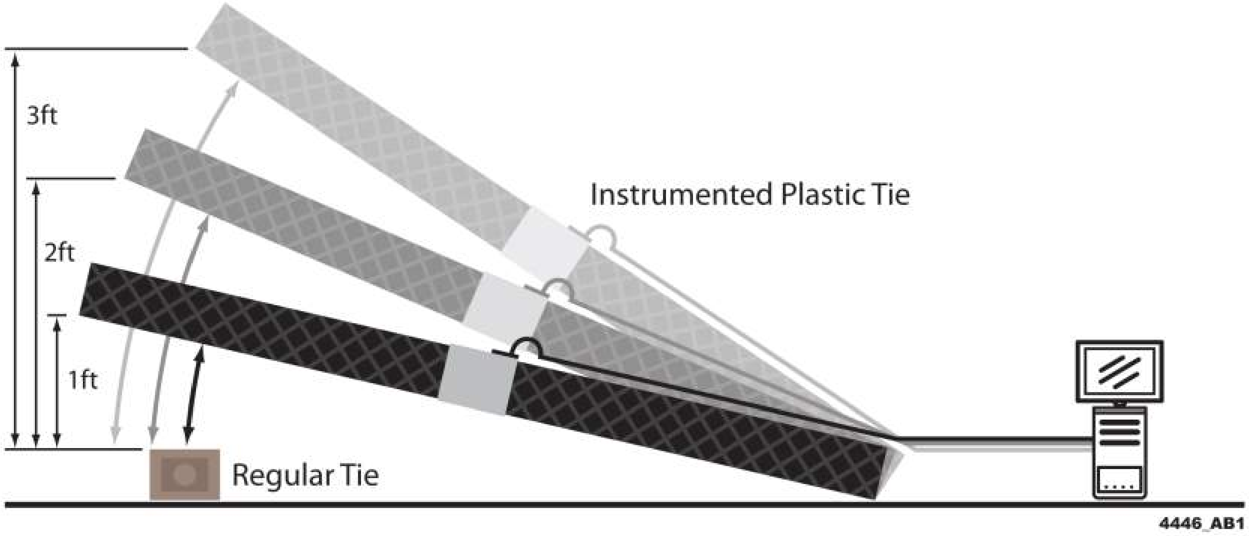


Figure 5. Schematic of Configuration 1 used to simulate dropping one end of a plastic composite tie onto another plastic composite tie or a fixed object.

Figure 6. Configuration 1: (Top) Immediately after release, during tie falling. (Bottom) As tie impacts the bottom, fixed tie.

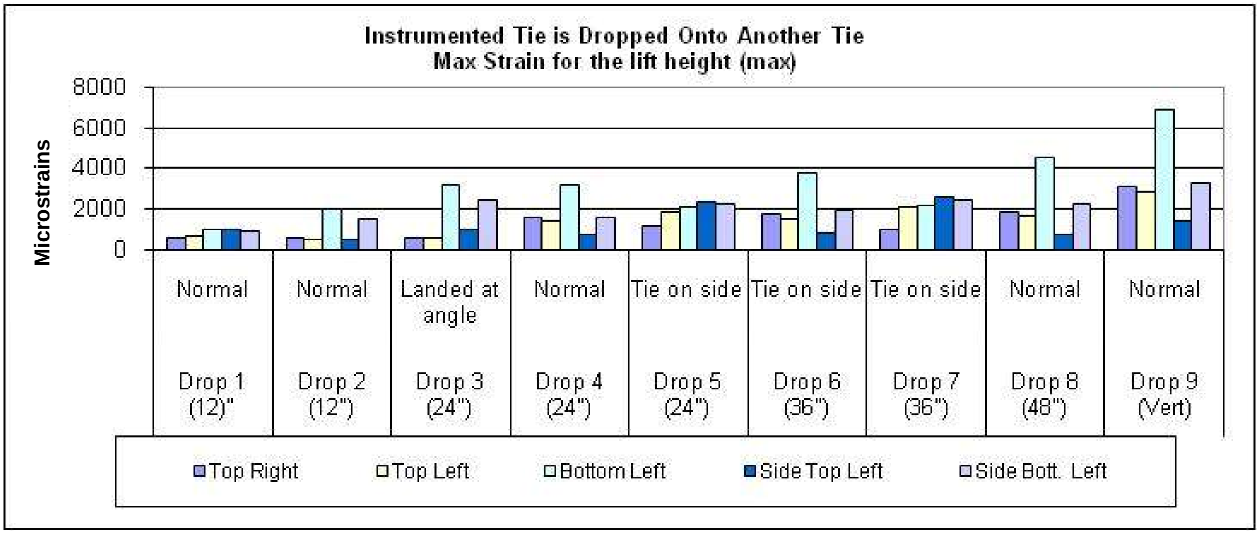


Figure 7. Peak center bending strain data for Configuration 1 for various drop heights. Drop 9, with the tie turned on its side, produced a peak impact load of 12,900 pounds.

To determine typical peak center bending strains for a plastic composite tie already placed on the ground and struck by a falling plastic composite tie, two configurations were evaluated. Configuration 2 is depicted in Figure 8, which measures how a plastic composite tie striking off center would apply a partial load during impact. Figure 9 summarizes loading observed for Configuration 2.

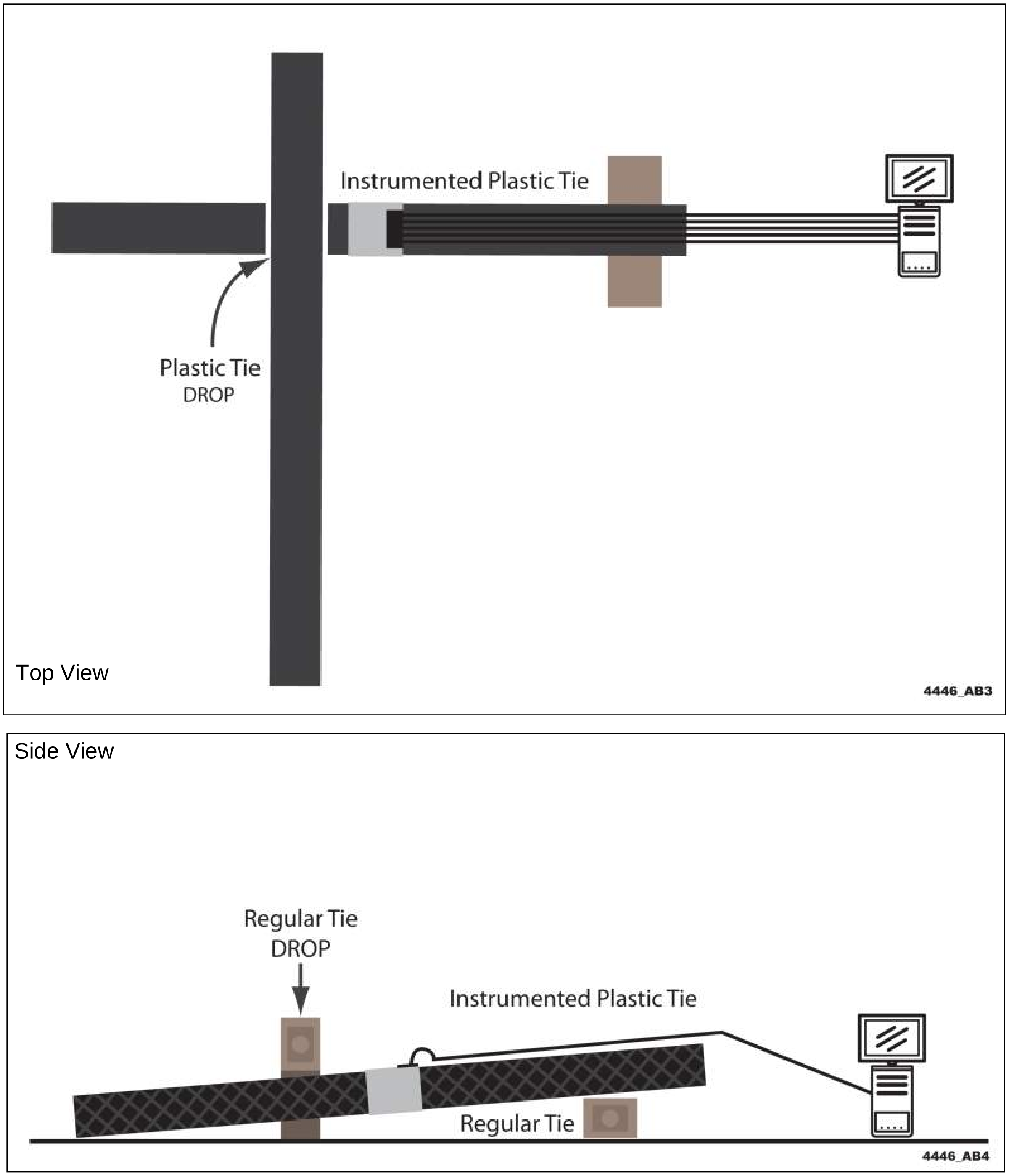


Figure 8. Configuration 2: (Top and Side Views) A partial load dropped on an instrumented plastic composite tie.

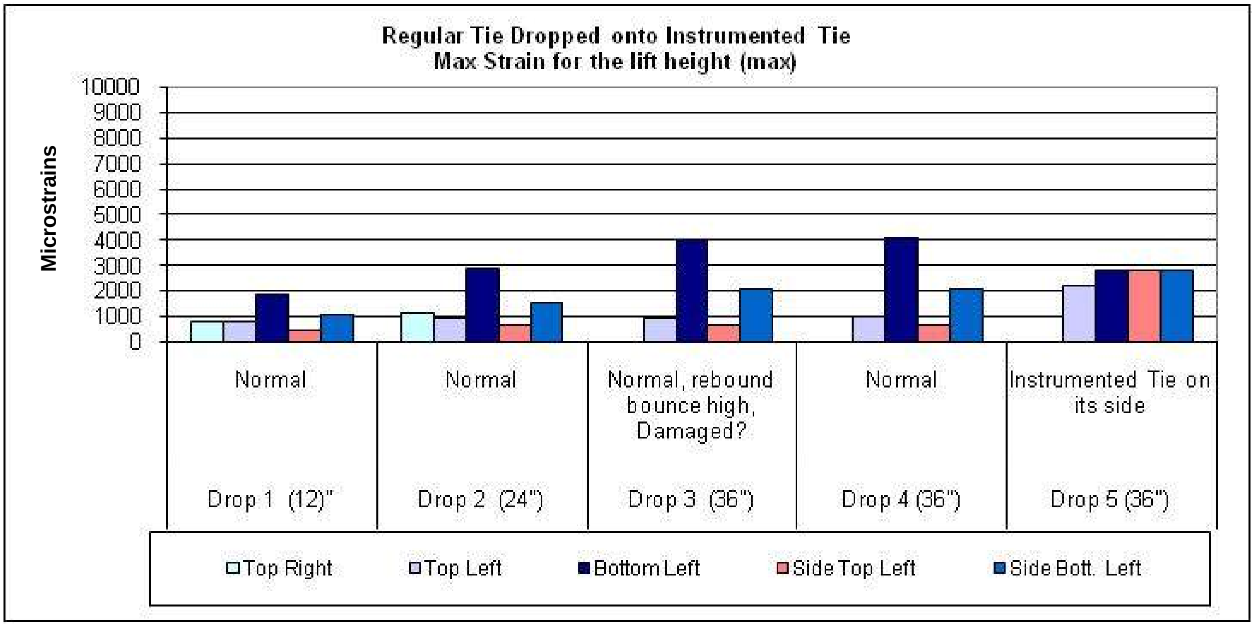


Figure 9. Summary of center bending strains for Configuration 2, a tie being struck by partial load. This configuration produced low center bending loads.

The maximum loads were generated when the full plastic composite tie was dropped onto another plastic composite tie. This was simulated by dropping a plastic composite tie in such a way that the full weight struck at the center of an instrumented plastic composite tie (see Figures 10 and 11). Figure 12 summarizes the impact strain data.

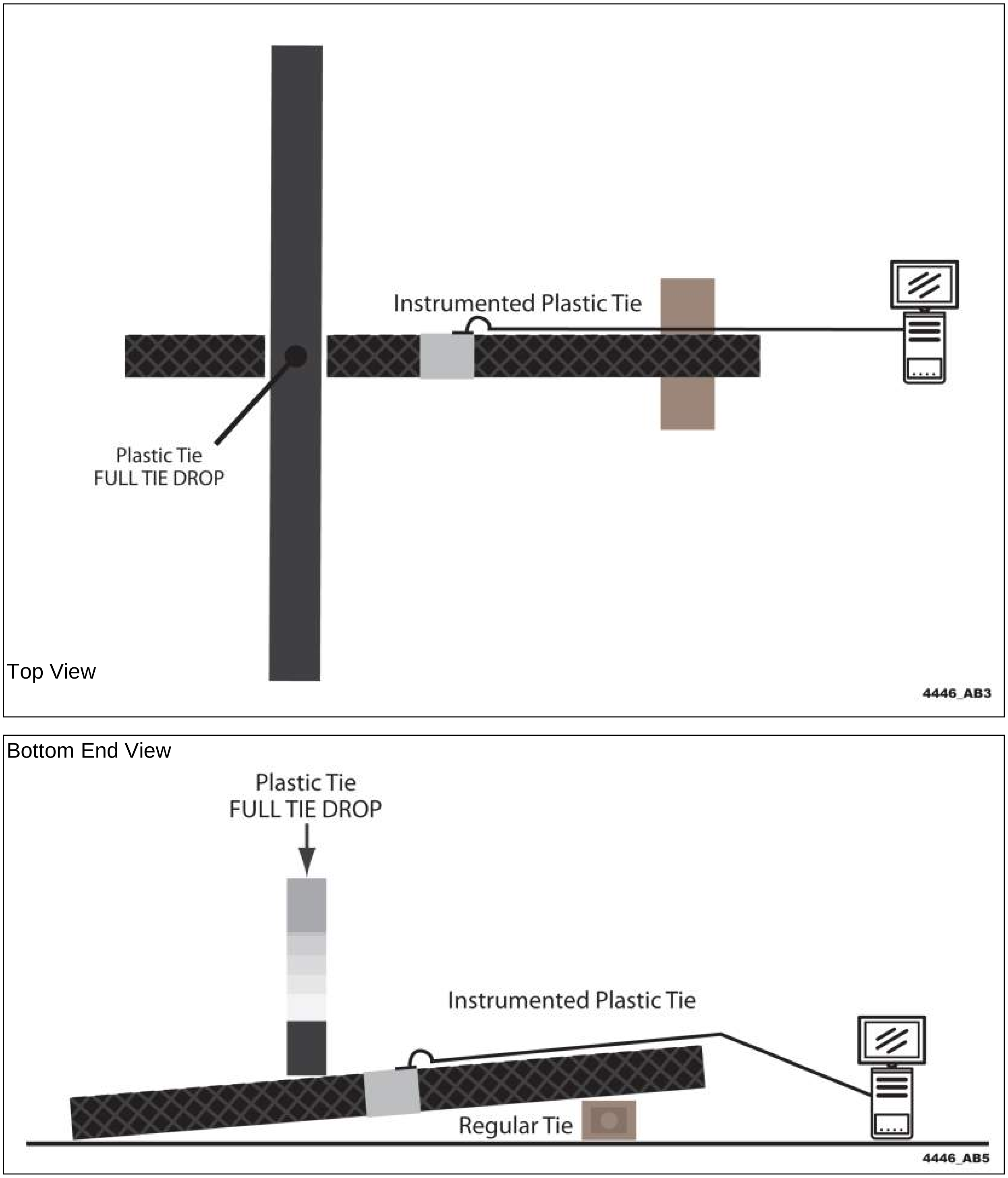


Figure 10. Configuration 3: (Schematic, Top and Bottom End Views) Full load dropped on an instrumented plastic composite tie.

Figure 11. Configuration 3: (Photograph) Full load about to be dropped on an instrumented plastic composite tie.

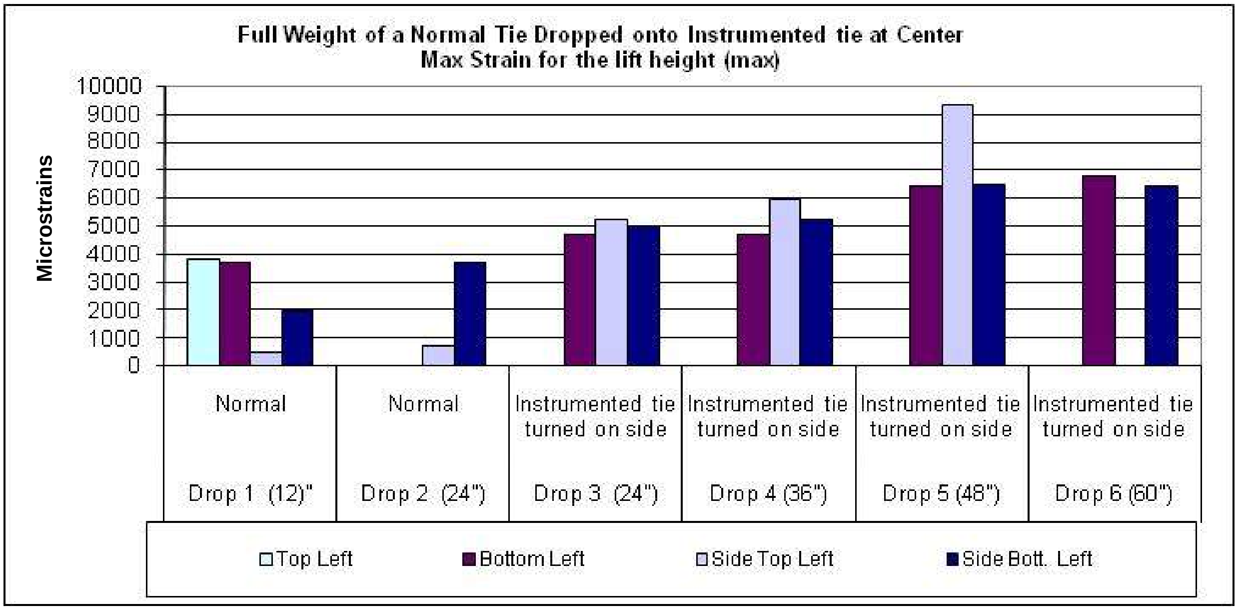


Figure 12. Summary of center bending strains for a plastic composite tie being struck by full load. A peak load of 16,500 pounds was produced on the top left-side of the tie during a 4-foot drop test.

Peak bending, which occurred during drop 5 from 4 feet, was observed on the side top left of the tie. Other locations exhibiting high strains were the bottom left and side bottom left of the tie. Figure 13 summarizes the calibration data (solid lines), the linear extrapolation of the calibration (dashed lines), and the peak strain measured during drop 5 from 4 feet. The 4-foot drop height produced a maximum of 9,350 microstrains, which, when extrapolated, suggests an impact load of approximately 16,500 pounds.

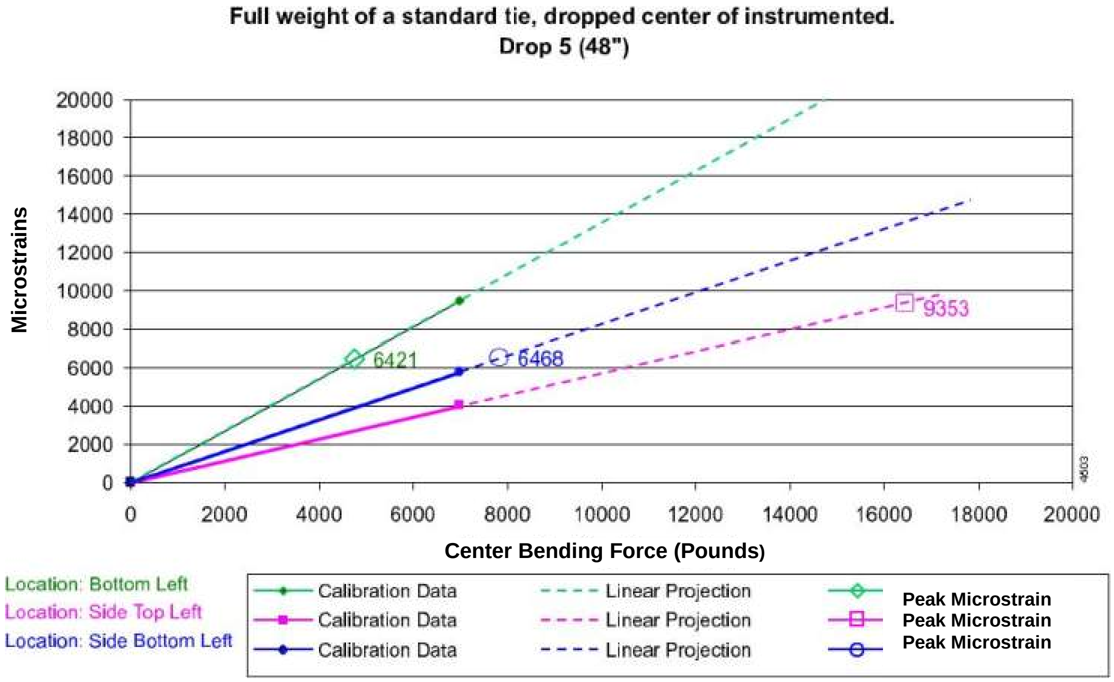


Figure 13. Summary of drop testing strains and corresponding center bending loads. The peak impact generated 9,353 microstrains, producing an equivalent load of 16,460 pounds.

Tie dropping results suggest bending strains approach, and in some instances, exceed the strains measured during the calibration procedures that used typical AREMA guides. The equivalent center bending load for current AREMA testing is 8,000 to 10,000 pounds, whereas the impact loads measured by dropping are at least 16,460 pounds.

2.3.2 Installation Loads at First Railroad Site

Several AAR member railroads offered assistance to conduct plastic composite tie installations with the instrumented ties using their tie insertion machines. CSX offered a location near its Richmond, VA, repair facility for measuring loads during installation. An additional series of installation tests was conducted on the BNSF. Data collection procedures were identical at both sites.

During plastic composite tie installation, handling, and spiking/nipping operations, strains at the tie center and rail seat were measured and recorded. Data were marked at certain events (such as when tie nippers were activated and ties were inserted) to determine which functions produced the highest bending strains.

As with the drop tests, peak forces during installation were determined by evaluating the time history plots of the strains from each strain gage location, then comparing the maximum strain to the projected calibration data. This process was repeated for each strain gage location. Figure 14 shows an example of a plastic composite tie being inserted and pulled against the rail, leading to high center bending and rail seat bending strains.

Figure 14. Tie insertion. The tie is bent while digging into the ballast at the far end and being pulled upward against the near rail.

At the CSX site, one instrumented tie was inserted and removed, then relocated to a new crib where the insertion process was repeated several times. During these activities, tie bending strains at the rail seat and the center of the tie were recorded. After the last set of insertions, a tie spiking machine was used to measure the strains produced by nipping and driving spikes into the tie.

As an example, the center bending strains measured during one insertion are summarized in the time history plot shown in Figure 15. Peaks in bending occurred at about 30 seconds into the event, and again at about 88 seconds. The highest observed peak exhibited a maximum reading of 15,622 microstrains, which is well above the microstrain level of about 9,000 produced during the laboratory center bending test and suggests that this installation generated center bending loads higher than that utilized in the laboratory proof test. Each type of composite tie material may react differently to one-time high loads. Any internal damage may result in accelerated degradation once in track; thus, detrimental effects, if any, on long term performance cannot be determined by this test.

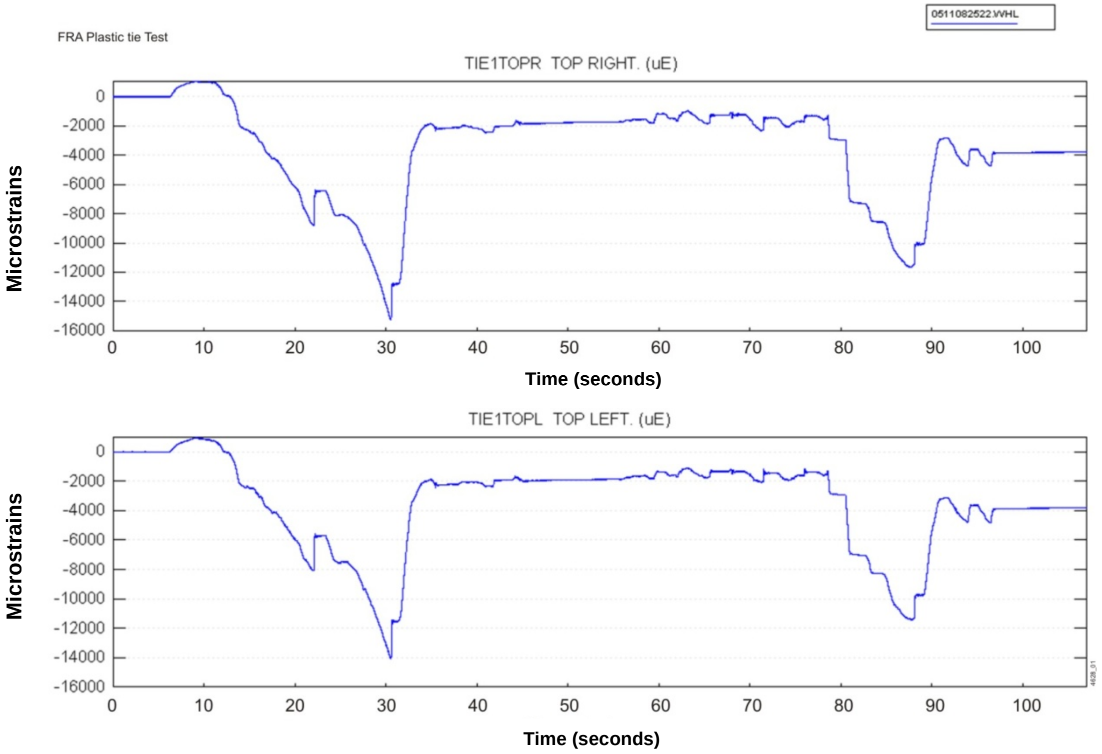


Figure 15. Time history of tie center bending at top of tie during installation. The peak strain is negative due to the tie being pulled up against the bottom of the rail. Peaks of 15,622 microstrains occurred approximately 30 seconds into the insertion activity.

Similar data were obtained at the rail seat during tie installation and at both the rail seat and tie center when the tie was nipped and spiked. A large amount of bending was visually noted during installation and was thought to have been past the linear relationship of load versus strain. Additional efforts to post-calibrate a different instrumented tie suggested that the strain load characteristics were linear, even well beyond the 10,000-pound limit used for calibrations.

Typically, after a tie is installed, a second machine follows to install spikes. This process grips the tie pulling it upward against both rails (termed “nipping” a tie), and is followed by a hydraulic hammer action that drives the spikes into the tie. Figure 16 shows the time history of two strain gage locations oriented to measure center bending (top) and rail seat bending (bottom) strains during a nipping and spiking operation.

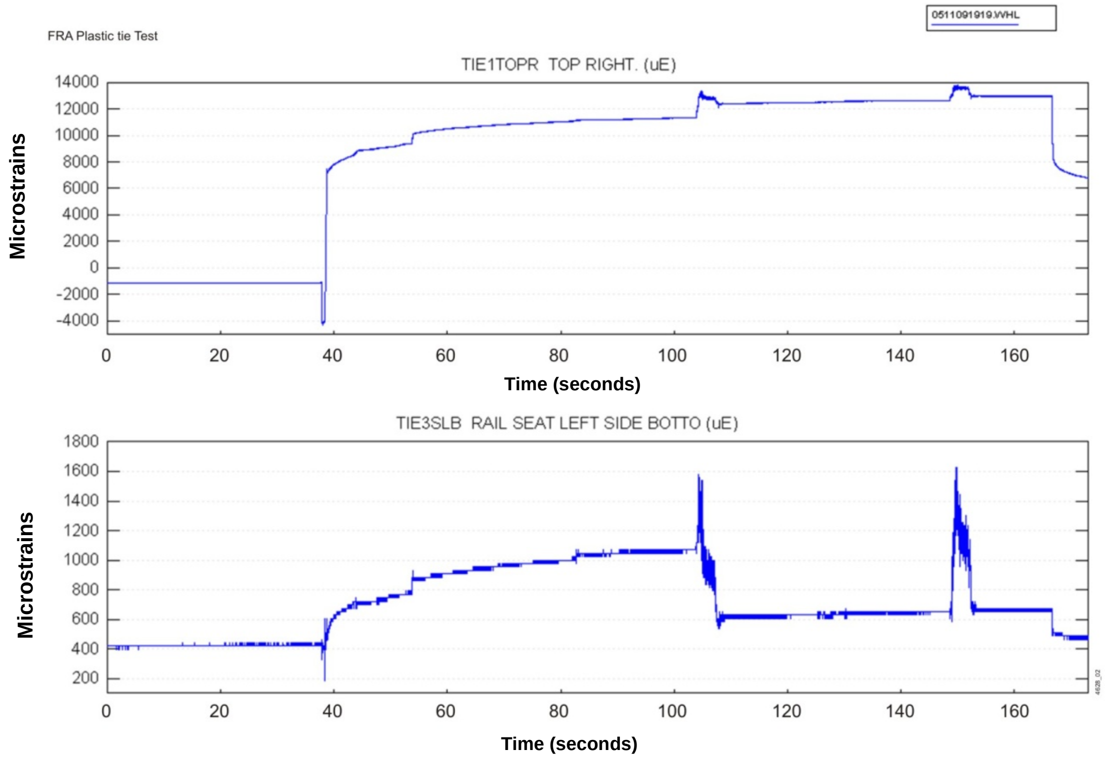


Figure 16. Center and rail seat bending strains during tie nipping and spiking. Nipping started at 40 seconds; note the high frequency impacts from spiking at time periods 105 to 109 seconds and 148 to 152 seconds.

Data in Figure 16 suggest that the nipping operation created center bending strains of 13,800 microstrains, while the rail seat bending strain was much lower. The spiking action is shown as short-duration peaks, but did not cause damaging strains in either location.

Figure 17 shows a summary of peak bending strains observed (for one of the many strain gages installed on the tie) during tie installation. Data shown is for the top right side of the tie, which indicated the highest bending strains of all the strain gages during the various operations.

The force values shown in Figure 17 represent the center bending load required to generate the strains observed when the tie is supported over a 60-inch span. A number of events earmarked in Figure 17 represent occasions during installation when peak loads were noted. The highest equivalent center bending force that occurred while pushing the tie during installation is shown as event 4; the highest center bending force that occurred during nipping and spiking is shown as event 7.

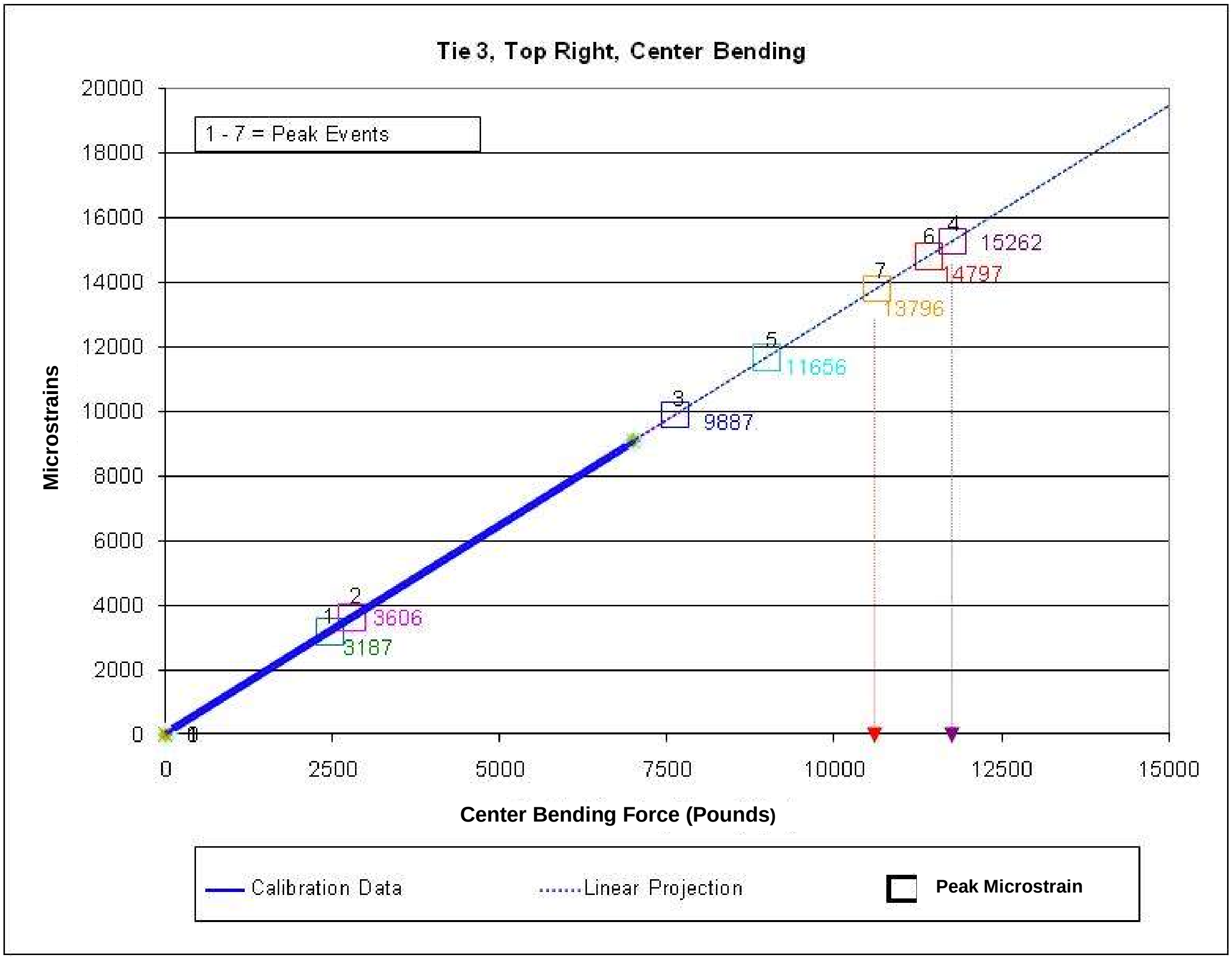


Figure 17. Peak strains during key events, with associated extrapolated bending forces. Events 1, 2, 3, 4, 5, and 6 occurred during tie insertion when pushing against ballast and/or lifting against rail. Event 7 occurred during nipping (10,640 pounds), and event 4 occurred during installation, when the ties were jammed against the rail (11,800 pounds).

The highest equivalent calibration loading appears to occur when ties are jammed under the rail during insertion (11,800 pounds) and when they are held against the rail during nipping operations (10,640 pounds). These values represent the maximum bending loads for tests conducted at the CSX site.

2.3.3 Installation Loads at Second Railroad Site

A similar set of installation procedures was conducted on the BNSF near Wichita, KS. In this case, two plastic composite ties were set on site ahead of a working production tie installation gang. Prior to the installation crew's arrival at the sites, each tie was set up with cables and data collection equipment. As part of the routine process for tie renewal, the tie gang first removed existing, bad (marked) ties, and then set new ties for replacement next to the track. One of the new wood ties was replaced with an instrumented plastic composite tie (see Figure 18). Note that the instrumented plastic composite tie was placed on the service roadside of the mainline, while the other new wood ties were placed in the area between the mainline and the siding. When the installation equipment reached the instrumented plastic composite tie, it was installed as part of the normal effort and then spiked.

2.4 Data Summary

As with the CSX site, after completing the tie installation on the BNSF, peak forces were determined by evaluating time history plots of the strains from each strain gage location, then comparing the maximum strain with the projected calibration data. This process was repeated for each strain gage location. Figures 18 and 19 show an example of a tie being laid out in advance of the crew, then being inserted at the BNSF site. Figure 20 shows an example of how much one tie bent while being inserted.

Figure 18. Instrumented tie being prepared for installation at BNSF site.

Figure 19. Instrumented tie during insertion at the BNSF site.

Figure 20. Maximum bending during tie installation.

The first instrumented plastic composite tie was inserted, and then the spiking machine was brought up to drive the spikes into the tie. The cables remained attached to allow the effect of nipping and driving spikes to be measured. Once the first tie installation was completed, a second instrumented plastic composite tie was prepared for installation and monitoring.

Forces applied to these ties during installation caused an upward bend around the rail seat. The tie remained bent after the insertion machine departed. This bend was removed, and the tie straightened out, by reverse forces being applied during the nipping operation, which holds the tie tightly upward against the bottom of the rails (see Figure 21).

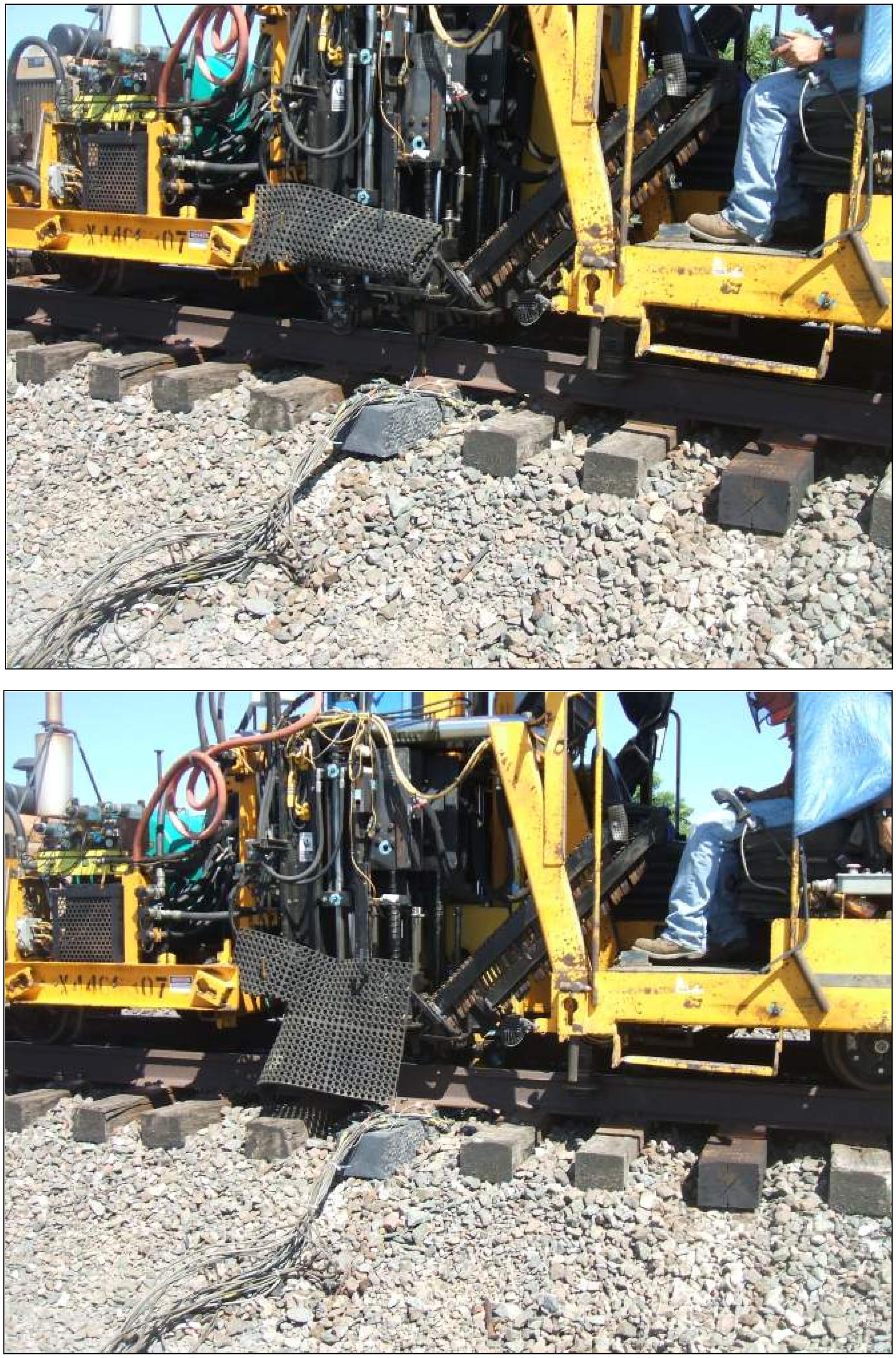


Figure 21. Nipping and spiking operation. The top photo shows the end of the tie bent upwards prior to nipping; the bottom photo shows the tie being straightened out by the nipping and spiking operation.

Equivalent forces from the data collected at the BNSF site were computed based on the calibration files for each strain gage location, as shown in Figures 22 to 27.

The average peak center bending load for each of the two ties was similar, with an equivalent force of about 7,600 pounds (see Figures 22 and 23). Note that although the forces are similar, the microstrain values recorded at these forces are very different and reflect the difference in calibration curves associated with the strain gages on each tie. This shows the need to use individual calibration files for each strain gage location, as microstrain values alone are insufficient to determine peak loads.

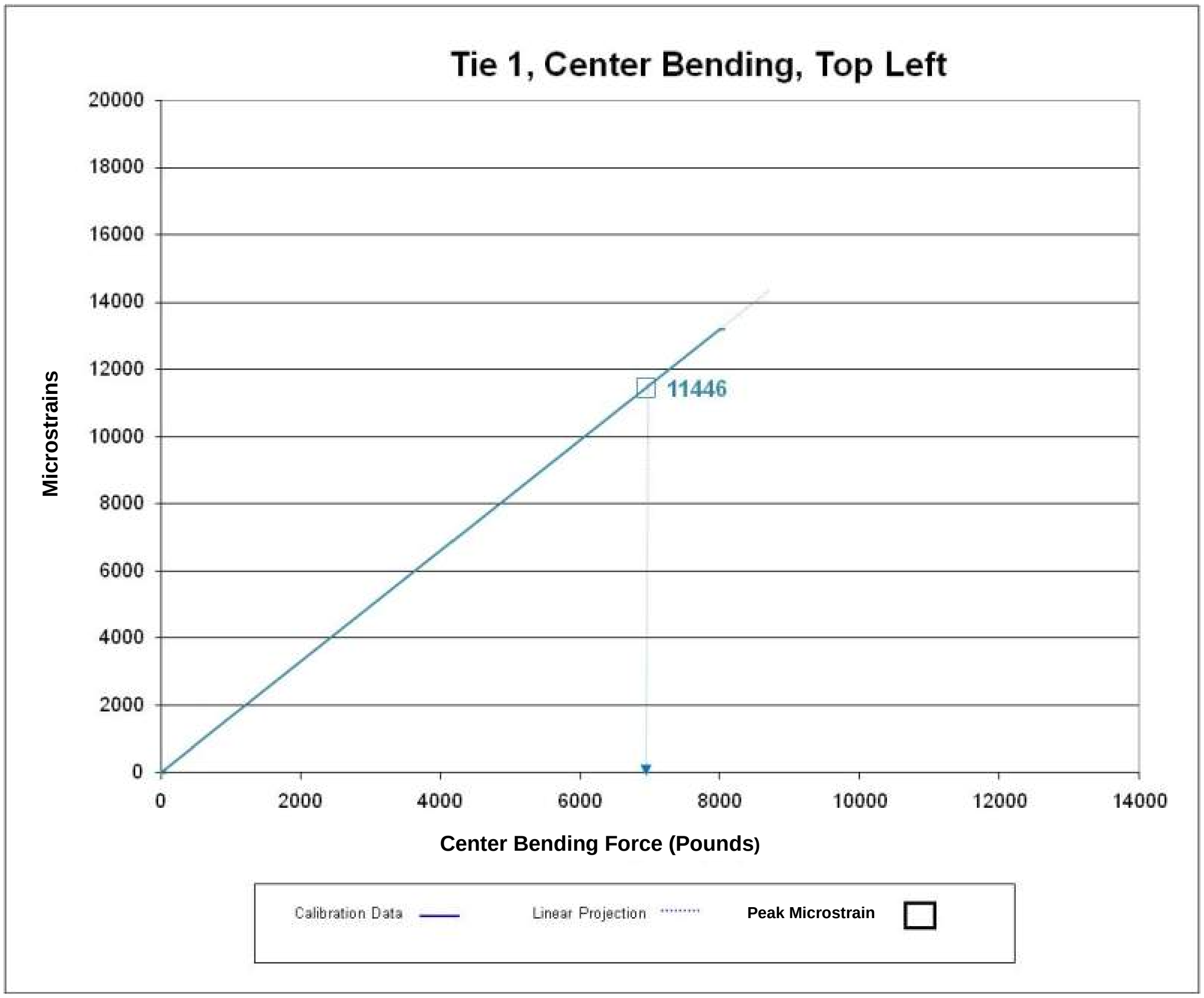


Figure 22. Peak center bending for tie 1 during installation.
Top left of tie, 11,446 microstrains producing an equivalent load of 7,622 pounds.

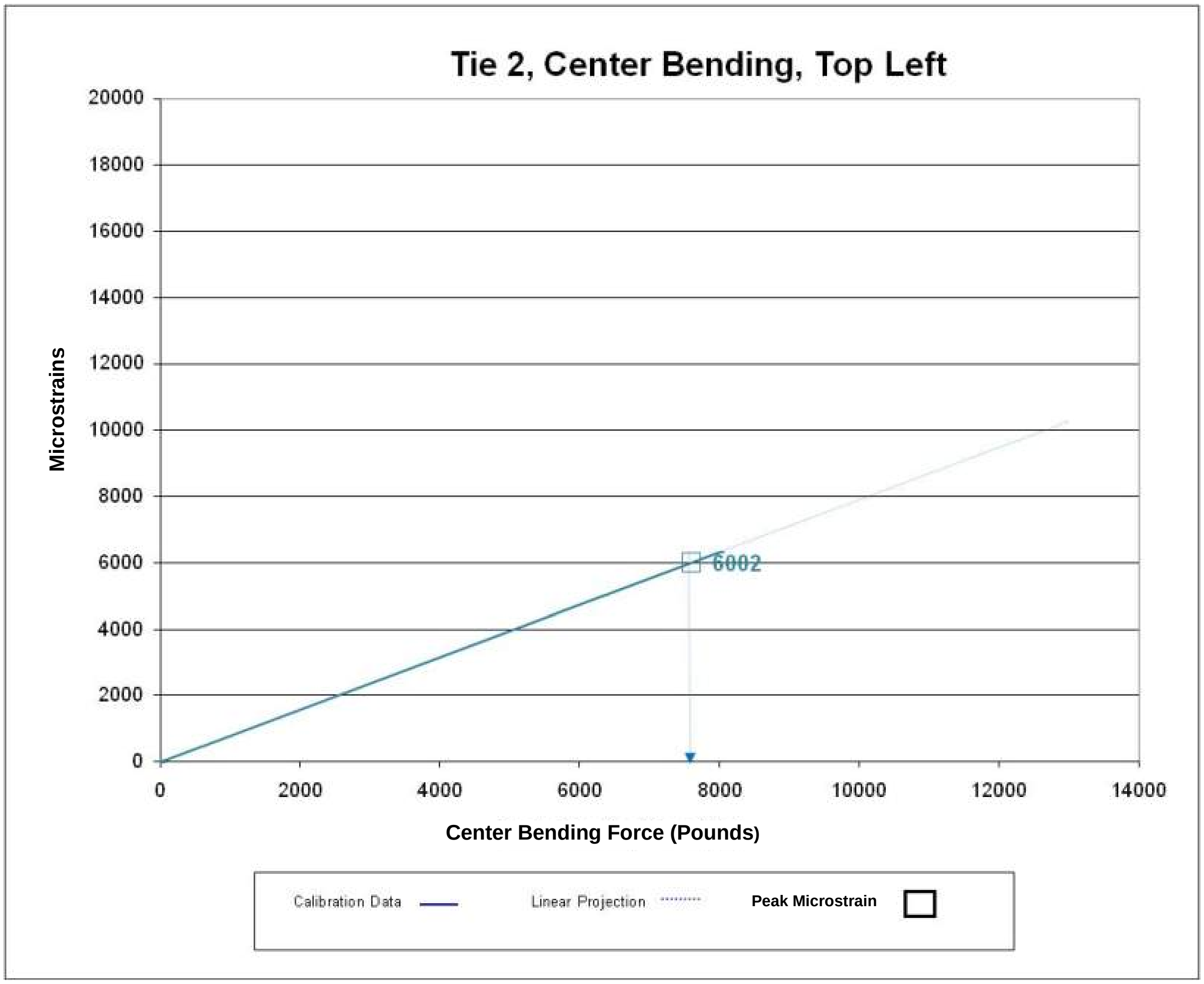


Figure 23. Peak center bending for tie 2 during installation.
Top left of tie, 6,002 microstrains producing an equivalent load of 7,596 pounds.

Figures 24 and 25 show strain data collected at the rail seat during the same time periods. The data show that rail seat peak loads of about 27,000 pounds for tie 1 and 12,400 pounds for tie 2 were attained. The single very high load observed during the installation of tie 1 was originally thought to be the result of debonding of the strain gage; however, subsequent rail seat strain data collected during nipping operations showed that the strain gage was operating normally and producing data within the range of the other strain gages.

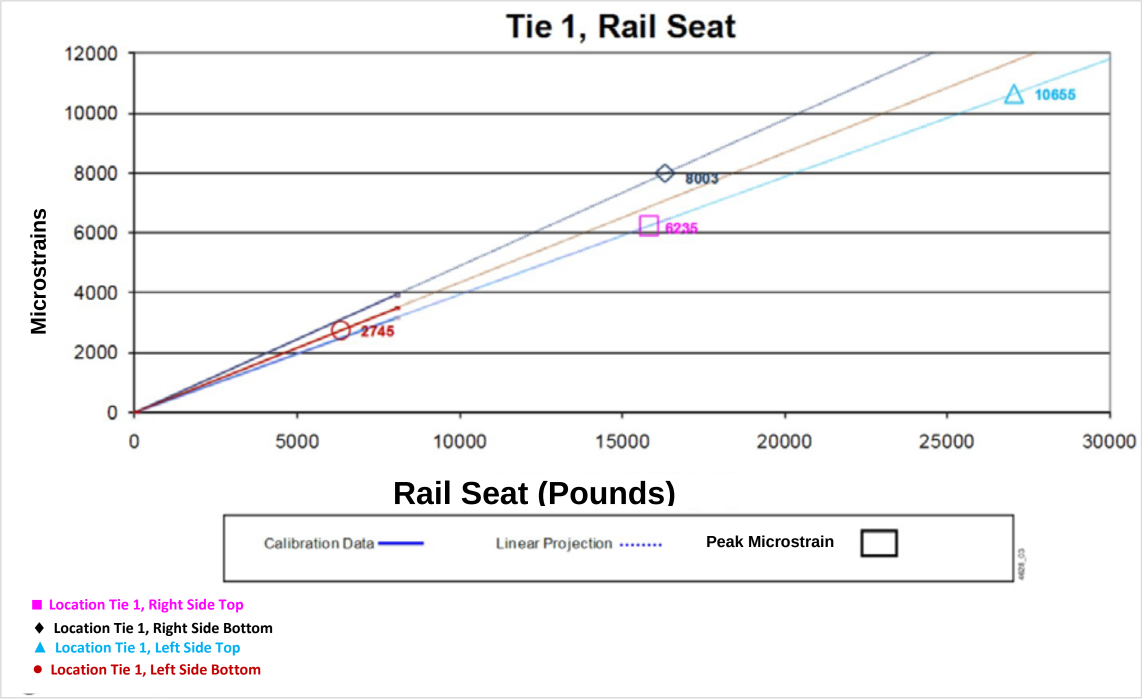


Figure 24. Peak rail seat bending for tie 1 during installation.
Peak loads of 16,333 and 15,835 pounds were observed on the right side of the tie; a single very high peak of 27,000 pounds was observed on the left top of the tie. Note that right and left side top had virtually identical calibration curves and thus appear as one line.

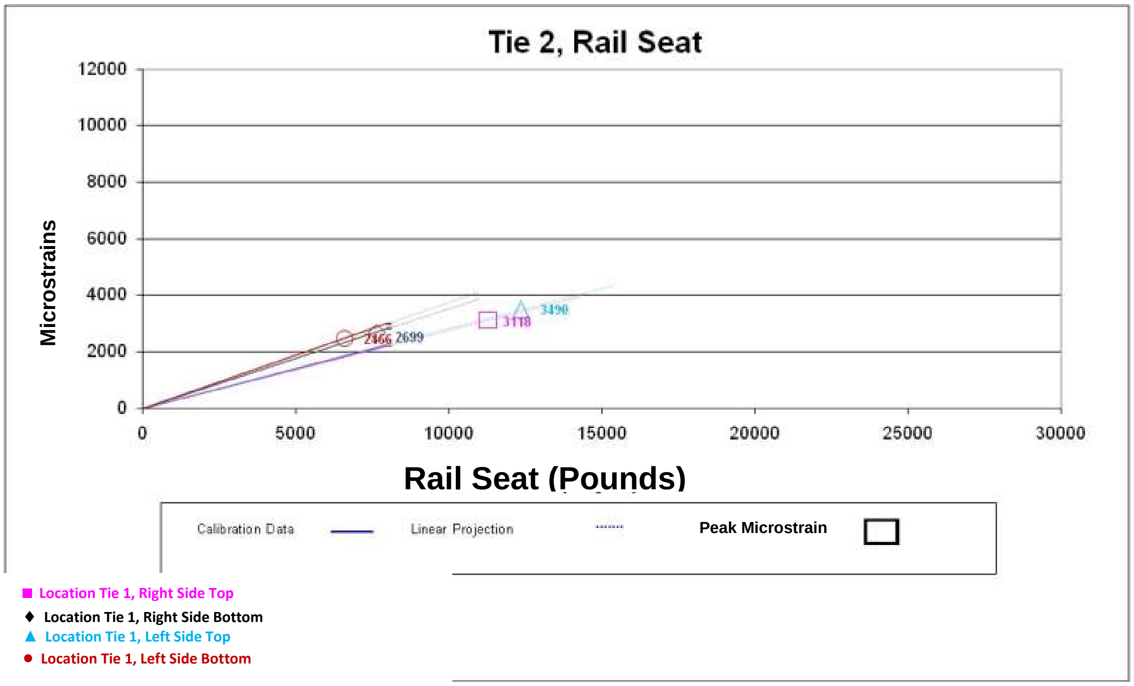


Figure 25. Peak rail seat bending for tie 2 during installation.
A peak strain of 3,490 micro-strain was observed on the top left of the tie, producing an equivalent load of 12,361 pounds.

Additional data were collected on these same two ties during follow-up nipping and spiking operations. Figures 26 and 27 show the peak strains measured at each strain gage during nipping of ties, which suggested a peak rail seat bending load of 15,200 pounds for tie 2.

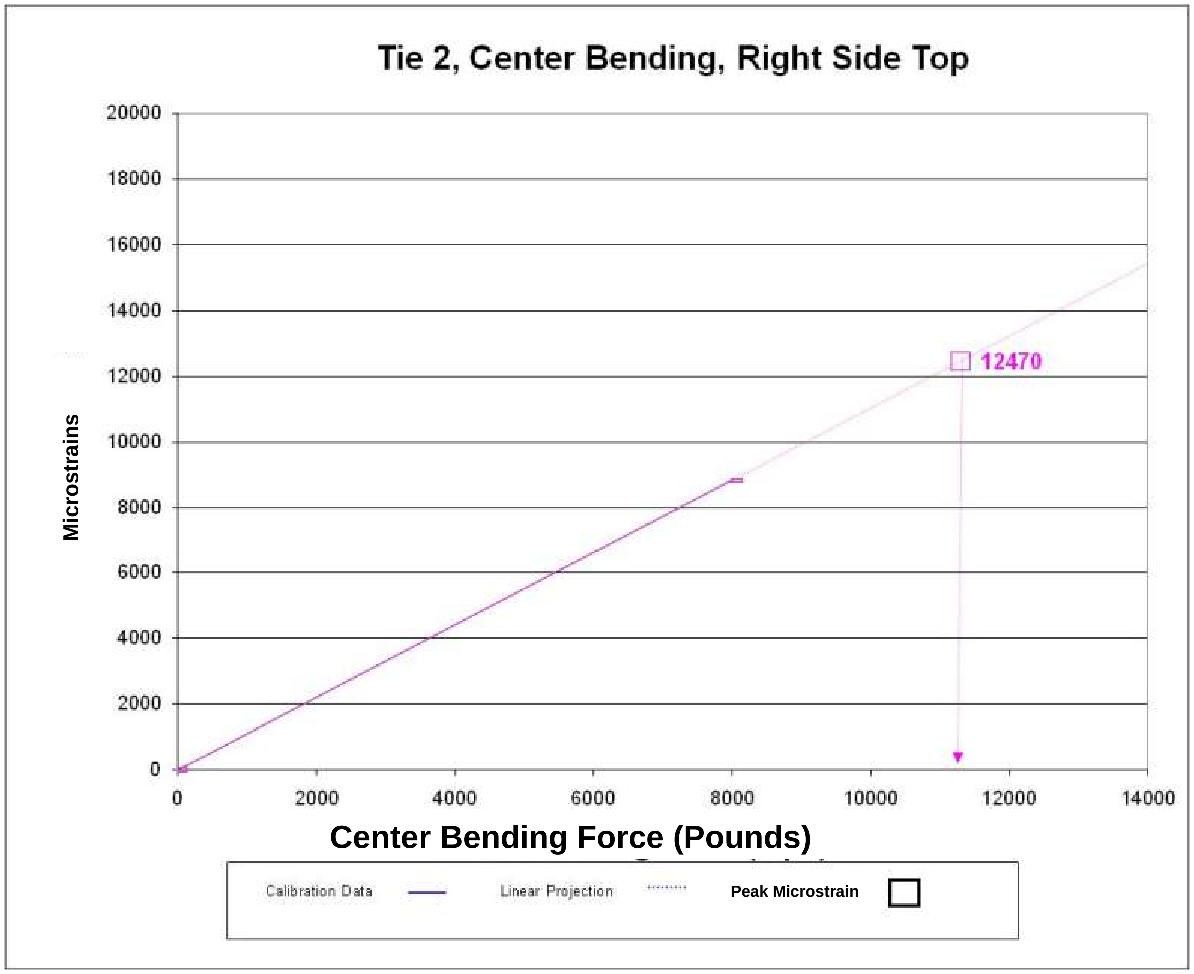


Figure 26. Peak center bending strains for tie 2 during nipping and spiking. A peak load of 11,300 pounds was observed on top right of the tie.

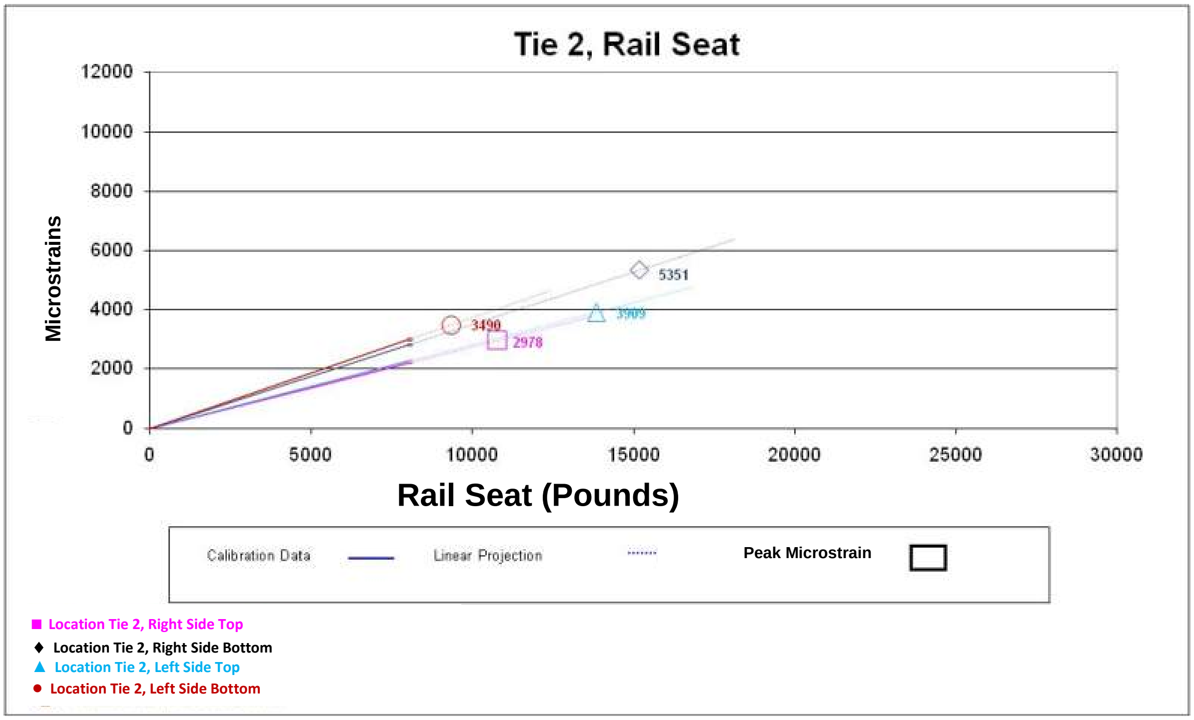


Figure 27. Peak rail seat bending strains for tie 2 during nipping and spiking. A peak load of 15,188 pounds was observed on right bottom of the tie.

3. Summary and Comparison of Field Sites

Bending forces at the center of the ties during installation on the BNSF were less than those observed during the CSX installation, as shown in Table 1.

Table 1. Comparison of peak bending loads measured during installation and tie nipping considered to be a long-term (> 2 seconds) duration event.

	CSX Site		BNSF Site	
	Rail Seat Bending	**Center Bending**	**Rail Seat Bending**	**Center Bending**
Insertion	**6,020 pounds**	**11,800 pounds**	**16,300 pounds (27,000 pounds)***	**7,600 pounds**
Tie Nipping	**10,640 pounds**	**9,000 pounds**	**15,200 pounds**	**11,300 pounds**

Table 2 shows the peak bending loads measured with tie on side during handling simulations, with center bending from tie dropping considered to be an impact or a short-term (< 0.1 second) duration event. Data were summarized from Figure 10.

Table 2. Peak bending loads measured with tie on side

Drop Height	Peak Center-Bending Load Top of Tie	Peak Center-Bending Load Bottom of Tie
2 feet	9,170 pounds	5,690 pounds
3 feet	10,482 pounds	5,690 pounds
4 feet	16,460 pounds	7,770 pounds
5 feet	Damaged Strain Gage	8,220 pounds

Some differences at the field test sites and in the test conditions may have influenced the tie bending results, which include:

- Ballast: The amount of force (and subsequent bending) to push ties into disturbed ballast is less than that of undisturbed ballast. During the BNSF installation, ties removed from track tended to loosen the ballast, while at the CSX site, where the test was conducted in a yard, existing ties were in such a stable condition that much of the ballast and subgrade was undisturbed during the removal process.
- Tie characteristics: The RTI ties used at the BNSF site are more flexible than the TieTek ties used at the CSX site. Because of this difference in stiffness, the ties installed at the BNSF may have been bent and not “dug” into the ballast as much, thereby reducing the effective bending force.

- Temperature: The ambient temperatures at various times during these tests ranged from 65 ºF to 106 ºF. The ties were calibrated in the shop at approximately 70 ºF, and the field installations ranged from 65 ºF (CSX) to 106 ºF (BNSF). While these extremes produced a range of comfort for the operators, tie bending characteristics over this 45-degree difference would be minimal. However, if tests were run with subzero and frozen ballast conditions, then the tie bending characteristics (along with subsequent calibration curves) would be more pronounced.

Data collected during the simulated tie handling tests and the actual tie installation tests at the field sites suggest that some of the following activities can cause bending loads that exceed the loads applied during the standard tie screening tests described in AREMA Chapter 30. Key areas where high bending loads were observed include:

- Dropping over 4 feet onto the side of a tie
  - Impact load, short-duration event (< 0.1 second)
  - 16,500-pound impact at the tie center
- Pushing tie into the ballast and up against rail during installation
  - Moderate-duration event (2 to 5 seconds)
  - 11,800-pound center bending loads
  - 16,300-pound rail seat bending loads
- Tie nipping between rail grips
  - Duration 5+ seconds
  - 11,300-pound center bending loads
  - 15,200-pound rail seat bending loads
- Rail spiking did not introduce high bending loads at the rail seat or the center of the ties

Survey results regarding cracked ties due to spiking were mixed. To reduce the chance of cracking, one user has instituted a system-wide policy that all plastic ties are to be prebored/predrilled (usually in the field) prior to spiking. This has alleviated problems experienced in the past with cracks originating from spike holes during installation. In addition, one railroad reported that using machines that combine hydraulic push followed by pounding also solved spiking problems. Other railroads have reported that predrilling is not an option and that ties must survive installation without such effort to be acceptable for use. In such instances, a screening test of candidate ties subjected to spiking would be required to determine if cracking would be an issue.

During field installation tests supporting this project, ties were not predrilled prior to spiking and no issues of cracking were noted. Also, in the past, laboratory testing at TTC using a variety of spiking patterns has rarely generated cracks. Where cracking occurred, it was usually associated with spikes driven very close to the edge of the tie.

Supplier response to the issue of cracking has been mixed: some claim their tie designs can be installed without preboring, some include preboring directions with their tie designs, and others simply do not address the issue.

This is a topic about which railroad users have not reached a consensus, and recent experience has shown that when using modern automated spiking equipment, the problems observed in the past are no longer cause for concern. Also, an increased use of direct fixation systems requires plates to be held down with screw or drive spikes, which requires preboring of all holes.

An issue related to preboring (not cracking) is disturbed material from the spiking operation. When dealing with conventional wood ties, the metal spike tends to compress wood cells as it is inserted. This is the case if wood ties are prebored or not. However, when plastic ties are not prebored, there is no cellular-like material at the outer surface of the tie to compress, and the material displaced from the spike insertion process has no place to go. It is often displaced upward around the spike hole opening and can push the tie plate up. While this has been observed at a number of locations where ties were not prebored, it was not reported on the survey as a major issue.

Although this evaluation monitored the installation techniques for only two railroad-operated tie insertion machines, they were selected based on the fact that they represent typical industry tie installation procedures. Additional measurements might be considered to further determine peak loads; however, on any given day, a machine could be out of adjustment or have worn controls resulting in different loading conditions. One of the machines used in these tests was brand new, having been recently delivered (CSX), while the BNSF site used a machine already used in the field. Both showed the potential of imparting high loads to plastic composite ties during installation.

The recommendation is to provide information in this report to the appropriate AREMA committee (i.e., Committee 30, ties, Subcommittee on composite ties) for further use and possible incorporation into laboratory tie screening tests.

Additional work that utilizes the load and impact data shown in this report to develop and demonstrate possible alternative laboratory tie screening test procedures is recommended.

Other concerns identified during the railroad surveys suggest a need for fatigue and accelerated service life prediction tools for plastic composite ties. The failure mode and degradation of wood ties is somewhat known; this is not the case for plastic composite ties. Wood ties tend to degrade at differing rates and provide known indicators or visual signs of distress such as cracking, cutting, and splitting. Because plastic composite ties are produced from engineered materials, the rate of degradation may be less variable, resulting in larger portions of the same batch failing or wearing out at the same time. Thus, future work is recommended to address the fatigue and aging characteristics of the materials used to manufacture plastic composite ties.

4. Laboratory Simulation Test Results

As a follow on to field testing, limited laboratory testing was conducted. Laboratory tests were developed to simulate loads and/or deflections observed during plastic tie handling and installation. Such tests would be part of a screening process users (railroads) could elect to use to ensure that ties survived from manufacture to installation. Potential users, including tie suppliers, should evaluate the handling, unloading and distribution, and installation procedures to be used. If these appear to follow the processes simulated in the field test portion of this project, then additional proof testing may be warranted. As an alternative, users may elect to change certain processes for tie handling and installation to limit impact and bending loads likely to occur when using ties that are subjected only to existing laboratory screening test loads and procedures.

Existing AREMA screening tests have been developed based on expected track loads and are generally in line with similar standards for other tie and fastener systems. Data from field measurements confirm that ties can be subjected to one-time (often short duration) loads that exceed basic bending tests, as specified in AREMA procedures. There is no standard composite tie material or design. Thus, every supplier may utilize a different type of mixture for the basic material and can produce ties with shape factors, internal bracing, or reinforcement bars. These are all proprietary designs, and each may react differently to one-time high loads. Internal damage may result in accelerated degradation once in track, but detrimental effects, if any, on long term performance cannot be determined by these tests.

Due to a limited budget, tests and configurations that are not currently part of standard AREMA procedures were not conducted. Thus, simple bending (center bending and rail seat bending) configurations with the higher loads suggested by the results in Section 3 of this report, Tables 1 and 2, were not conducted.

Other tests, such as those that measure impacts from dropping, do not have an equivalent test in the current AREMA Chapter 30. For this reason, TTCI concentrated its efforts on simulating impact loads. Accordingly, new or revised test fixture configurations were developed. To determine if target loads were being generated, tests were conducted using instrumented ties. After validating applied loads, additional noninstrumented ties were tested to determine performance and survivability. These additional ties were from a supply of composite ties donated by a member railroad and represented a cross section of suppliers.

Impact loads can be applied by hydraulic or gravity drop methods. Based on the results of the impact loads, the goal was to simulate short duration impacts observed when ties are dropped from a 5-foot height, producing impact loads of duration < 0.1 seconds and up to 16,500 pounds of force at the tie center.

4.1 Lab Bending

A limited attempt was made to determine how comparably with field values impact loads could be simulated using hydraulic rams since many laboratories are already equipped with that equipment. If such a test were conducted, it would be relatively low cost, easy to carry out, and would allow widespread use of the results because the test configuration is already identical to that specified in AREMA Chapter 30, 2.2.3, Test 1C, Bending – Center Negative. For such a test, AREMA specifies that the tie is tested “upside down,” with the top of the tie supported on pads spaced 60 inches apart. A load is then gradually applied to the bottom of the tie at the center, and bending and load are measured.

For this simulation, TTCI laboratory engineers installed an instrumented tie and supported it as specified by AREMA. The loading cycle was then applied to impact the tie with increasing load. Table 3 shows the results.

Table 3. Peak bending loads and deflections measured using a hydraulic ram. Tie supported on two supports separated by 60 inches.

Run No.	Force (lb)	Tie Deflection (in)	Time (sec)
1	6241	0.63	2
2	5533	0.531	1
3	3735	0.318	1
4	8154	0.82	1.4
5	8959	0.994	1.94
6	11399	1.524	3.22
7	13423	2	3.96
8	15322	2.567	5.19
9	15113	2.429	4.45
10	12488	1.62	1.8
11	14434	2.063	1.85
12	16065	2.528	1.05

Data in Table 3 suggest that while an impact load close to the target of 16,500 pounds was obtainable, the time needed for the hydraulic force to apply this load was longer (more than 5 seconds) than what a tie would experience during dropping. This time period does not simulate the short duration impacts in the field, could result in fracture or permanent bending that might fail a tie, and would not be reflective of a realistic field experience. For this reason, further investigation using either conventional or specialized hydraulic rams was not considered.

4.2 Drop Test

A number of suppliers have developed their own in-house custom drop tests to comply with customer requests to address tie breakage due to handling. Those that were shared with TTCI staff were “one off” configurations using a variety of materials on hand; in one case, a part of a railroad wheel was dropped from a predetermined height and was used to show customers that ties could survive impacts and derailments. No calculations regarding energy or what the drop height represented or how others could repeat the tests in the same fashion were supplied. The existing drop fixture at TTC (Figure 28) was designed for other uses and was equipped to drop a 63-pound load from a maximum height of just over 11 feet. TTCI made slight modifications to the fixture to determine if bending and impact loads could be measured and simulated on a repeatable basis.

Figure 28. Drop load fixture located at TTC in the Component Test Laboratory.

The weight drops from a given height and is kept on course by a vertical retaining shaft. The drop weight strikes the test sample at the bottom of the shaft. However, the current fixture provides only a small opening (Figure 29), which limits the width of a sample. Thus, some ties can only fit when placed sideways (shown in Figure 30); this simulates a tie being struck on its side, not top.

Figure 29. Drop load fixture showing opening at bottom and vertical drop load.

Figure 30. Drop fixture with tie placed on its side. Note the supports are still spaced at 60 inches apart, simulating the loading of other AREMA tests.

Before testing, the kinetic energy was computed at a point just prior to impact produced by dropping various weights from heights allowable with this fixture. This kinetic energy was compared with that produced by a 200-pound object (similar to the weight of some plastic composite ties) from a 5-foot drop height (see Table 4).

Table 4. Calculated impact kinetic energy (pound-foot) produced by dropping various weights from two different heights.

Drop Weight (lb)	Height (ft)	Impact Velocity (ft/sec)	Impact Kinetic Energy (lb-ft)
Target Calculation			
100	5	17.9	500
200*	5	17.9	1000
500	5	17.9	2500
Correlation Calculation			
63	11	26.6	693
100**	11	26.6	1100
200	11	26.6	2200

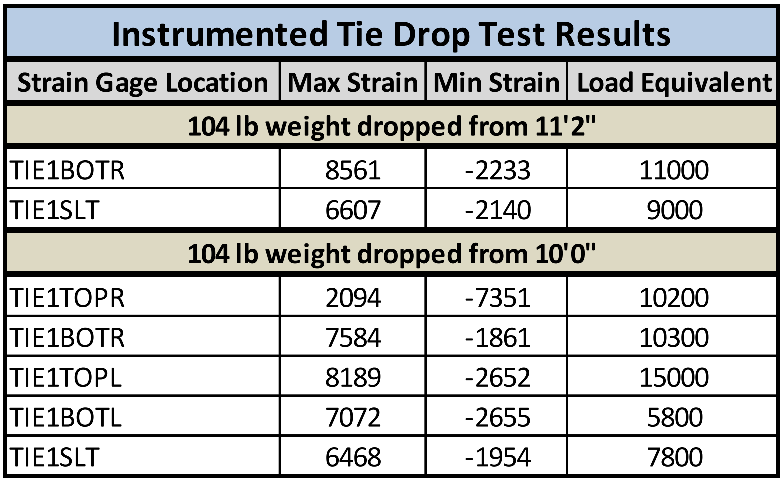
*Target energy developed by dropping 200-pound tie 5 feet

** Closest correlation within existing machine dimension limits

Table 4 shows that impact speed is significantly different based on drop height. This difference may be eliminated by fabricating a much heavier weight dropped from a reduced height; however, physical constraints of other components, as well as budget limitations, reduced the modifications that could easily be conducted on this fixture.

For this series, evaluations were conducted using the remaining instrumented ties; however, several broken or inactive strain gages limited the data. Table 5 shows a summary of gage locations on the tie and equivalent impact loads.

Table 5. Drop tests using an instrumented tie at room temperature, 104-pound weight.



Instrumented Tie Drop Test Results

Strain Gage Location	Max Strain	Min Strain	Load Equivalent
104 lb weight dropped from 11'2"			
TIE1BOTR	8561	-2233	11000
TIE1SLT	6607	-2140	9000
104 lb weight dropped from 10'0"			
TIE1TOPR	2094	-7351	10200
TIE1BOTR	7584	-1861	10300
TIE1TOPL	8189	-2652	15000
TIE1BOTL	7072	-2655	5800
TIE1SLT	6468	-1954	7800

BOTR – Bottom of tie, right side
BOTL – Bottom of tie, left side
TOPL – Top of tie, left side
SLT – Side of tie, left side, top

Results shown in Table 5 suggest that with a drop height of 10 to 11 feet, the impact load is close to the range observed in the field when ties are dropped. It should be noted that damage to composite materials from impacts is based on a number of factors including:

- Material compliance
  - Type of resin (plastic)
  - Amount of resin, filler material
  - Existence of internal bracing or reinforcement rods
- Temperature of material
- Speed at impact
- Type of impact and what is simulated
  - Tie hitting a rock
  - Tie hitting another tie
  - Angle of impact
  - Sharp or blunt object
- Support conditions
  - Center of tie
  - End or angle

Clearly, one test configuration cannot adequately address all variables that could be encountered in the field. The "proof of load" drop tests were conducted first on instrumented ties, then on a number of other ties, to determine if damage occurred. A series of drop tests was also conducted on frozen ties because ties are often shipped in open cars, under a wide range of weather conditions. These tests were conducted on noninstrumented ties from a range of suppliers. Ties donated by BNSF for this test include samples from:

- Axion
- RTI
- Integrico
- Dynamic Composites

It should be noted that these samples, although "new, old stock" and never installed, were all 2–4 years old at the time of testing and represent state of the art from 2003 to 2006. Newer designs of these ties may have updated materials or configurations and produce different performance. As Figure 31 shows, one tie suffered surface chipping when the weight was dropped on its side.

Figure 31. Surface damage (large chip) on tie after drop test, room temperature.

Table 6 shows the impact test results of the frozen ties from the four suppliers.

Table 6. Result of drop testing frozen ties.

Low Temperature Drop Test Results			
100-pound weight dropped from 11 feet **Ties soaked for 24 hours at a temperature of -41ºF**			
Tie	**Surface Temp.**	**1¾ in deep**	**Results**
1	-7	-	Did not break. Slight indentation at impact and small crack developed. Outer surface of tie was cracked before cold soak. Tie was cut into as tie bounced and hit drop test fixture.
2	-20	-33	Tie broke into 3 pieces.
3	-13.5	-27	Did not break. Slight indentation at impact.
4	-18	-18	Did not break. Slight indentation at impact. Tie was cut into as tie bounced and hit drop test fixture.

Results summarized in Table 6 show that when impact testing frozen ties, some samples exhibited minor surface damage and, in one case, broke into several pieces. Similar tests conducted on all samples from the same suppliers at room temperature did not show any fracture failures, but one tie did experience surface damage.

It should be noted that representative samples of all ties supplied for this last series of tests had been installed in Class I tracks for some period of time in the last 5–6 years. Some of these tie designs did exhibit failures during spiking and installation, thereby becoming candidates for this test.

5. Recommendations

Information gathered during the last phase of Task Order 241 suggests that ties passing current AREMA chapter 30 qualification tests may fail during installation or handling, but will survive in track. For this reason, consumers and suppliers should critically evaluate existing tests and determine if additional tests that apply higher, single-event loads should be added to the screening process. TTCI suggests future work in the following areas:

1. Demonstrate new test configurations (e.g., drop tests) and higher load tests (center bending) on a wider range of ties to ensure correct values are being proposed. Conduct bending load (center and rail seat) tests on a variety of tie materials using the higher loads outlined in Section 3 of this report to complete testing over the load range of interest. Use the existing AREMA fixture and setup procedures, but revise the length of time for ramp up loading and hold and release of loads. Note that maximum bending (center deflection) does not have to be limited to that specified in current tests, provided the tie returns to acceptable straightness for spiking operations. As ties may be installed when cold, consider tests at a lower temperature limit.
2. Conduct additional drop tests to address test rig configuration issues. Additional repeated tests need to be conducted and results measured to ensure statistical repeatability before recommending a new test procedure or fixture. That is, one or two ties tested two to four times is probably not enough of a basis to accurately specify a new test. Revise tables and recommended test fixture requirements as needed.
3. Develop accelerated aging tests, which are considered a form of fatigue or durability testing. Some railroads have used the existing wood tie aging formula, which may offer a fairly good starting point. However, some plastic materials used in composite ties may actually become “hardened” because of a change in the degree of crystallinity. High-density polyethylene is a semi-crystalline polymer. With multiple cycles of heating and cooling, the crystallinity can increase, increasing the modulus (stiffness) during the accelerated aging process and providing false test information. To improve this procedure, information on aging of composite ties and materials currently in use, along with knowledge of plastic and resin deterioration processes, would be desirable.
4. To ensure widespread use of results, testing procedures need to be carefully defined and described. Specialized fixtures and equipment need to be affordable so that a wide range of laboratories and operators can conduct these procedures.

6. References

American Railway Engineering and Maintenance-of-Way Association. 2010. *Manual of Railway Engineering*, Chapter 30 – Ties, Lanham, Maryland.

Appendix.

TTCI®
Transportation
Technology Center, Inc.

Questionnaire Responses of Three Class I Railroad Users of Plastic and Composite Ties

Task Order 241

By Richard Reiff, Principal Investigator II

Introduction

Background and Objectives

Federal Railroad Administration (FRA) contracted Transportation Technology Center, Inc. (TTCI) under Task Order 241 to compile an assessment of the use of plastic and composite ties by the railroad industry in North America. This report provides a summary of responses from three Class I railroad users of plastic and composite ties. It is based on written responses and follow-up telephone interviews.

Overall Approach

The major question areas and responses were as follows:

- Quality Control (not a question, but offered from two sources—one sponsor and one railroad)
- Handling and Shipping
- Insertion into Track
- Hold Down Systems
  - Spiking (conventional cut spikes)
  - Drive or screw spikes
- Other Issues
  - Modulus of Elasticity
  - Temperature Effects

Questionnaire Responses

Quality Control

Railroads have relied on suppliers to perform quality control. Unlike wood ties, for which most railroads have years of experience and trained inspectors, composite ties are made of a "new material" and little or no firsthand railroader expertise is available in the area of plastics and composites. There is little knowledge of the cause and effect, or of what to expect when base stock or manufacturing processes change, except that changes in raw materials or processes can and do often alter the field performance of plastic and composite ties.

The inbound material stream of the plastic base stock (recycled or raw) is an essential parameter to control. Other parameters are not as well understood, and, in some cases, failures due to changes in material or manufacturing processes do not become visible until after many years of service. These issues suggest the need for more sophisticated accelerated fatigue, life cycle, and weathering screening tests.

Suggestion: Improve best practices to determine which process changes (e.g., base stock, manufacturing process, etc.) are most critical to performance. Also, development of fatigue testing is needed, but is beyond the present project's scope.

Concern: Some suppliers' materials are more sensitive than others; therefore, vendor specific tests and tolerances may be required. Proprietary material and manufacturing processes must be addressed.

Handling and Shipping

1. **Forklift Damage—**Front edge of tines can chip and damage ties, as seen in the factory and when unloading equipment in the field.
2. **In Track Distribution—**unloading from open cars

One railroad reported no damage issues. Other railroads reported significant problems when ties were dropped.

Some railroads do not issue special instructions, and ties are generally loosely loaded in cars, not bundled. Tie bundles are dropped into open cars, straps cut, and ties not neatly stacked. At the unloading site, tie grapple equipment pick up five to eight ties at a time and drop them from 3 to 5 feet while the work train is moving 2–3 mph. This process helps distribute ties along the track and enhances the efficiency of installation crews. Ties can drop onto each other, onto rocks and crevices, and be damaged.

Early versions of some ties by some suppliers were more prone to this damage. Recent supplier changes have improved tie resistance to impact.

Suggestion: Develop a standardized drop test to screen new tie designs and materials prior to mass production, using periodic inspection depending on manufacturing processes and sensitivity. Contact vendors to determine a starting point for the drop test. Develop a small tool impact test to simulate forklift damage.

Concern: Some suppliers' products or materials are more sensitive than others to drop damage. There is a need to obtain a supply (5 to 10 ties) of previous or outdated tie versions that are more sensitive to dropping damage (e.g., maybe designs that are out of date or redundant) to validate test procedures.

Insertion Into Track

TTCI editorial note: During interviews and responses, at no time did the use of track laying machine (TLM) become an issue. While the use of TLM machines is a common concern with alternative concrete ties, the lack of concern suggests that out-of-face replacement of existing ties with plastic composite ties is not being considered. Plastic and composite ties are not being considered for long segments, but for new construction, spot replacement and intermixing with existing ties, not production installation. This limits the range of handling issues, but also limits the areas of potential application.

There is a wide range of tie insertion equipment, as well as gang size, gang production, and training, used by railroads. The objective is to make plastic and composite tie handling consistent with wood ties. Generally, the old tie is pulled out and the new tie is forced into the opening. Sometimes the tie binds vertically or horizontally and breaks.

Several railroads reported damage (bending fracture) when ties were inadvertently cocked during the insertion process. In some cases, equipment utilized by these gangs is being phased out. One railroad's solution was to develop a bending tolerance (+/- range) for one vendor, but the same bending tolerance values did not apply across the board for other vendors.

- Example from one railroad: Set up for an American Railway Engineering and Maintenance of Way Association (AREMA) type center bending test (60-inch support spacing, load middle of tie), then push down at the middle to a 1-inch deflection. The load at 1-inch deflection must be at least 550 pounds, but not greater than 950 pounds. If the load is less than 550 pounds, it shows that the tie is too flexible, and if the load is more than 950 pounds to get a 1-inch deflection, it is an indication that a particular brand of tie is too brittle. The upper load value may be specific to various designs.

Suggestion: Improve best practices to determine bending force limits that simulate forces and deflections likely to be seen in track. Note that some tie insertion processes or machines can bend ties longitudinally and not vertically, thus bending test and limits may need to be oriented in two planes.

Concern: Some suppliers' materials may be more sensitive than others and may require vendor specific tests and limits to ensure strong ties are not culled out. There is a need to determine in-house production variability to specify how often to repeat a test (e.g., every 100 ties, every 500 ties, etc.).

Hold Down Systems

Spiking (conventional cut spikes)

Most railroads do not pre-bore ties (either in the factory or in the field) and spike directly into the tie. Thus, the preferred installation method is no predrilling of holes, either before delivery or in the track. This allows ties to be interspaced with other wood ties. A major issue when holes are not prepared, other than increased observations of cracking, is that excess material tends to be extruded out of the sides (i.e., sides of spikes at the point of entry to the tie) causing interference with the full tie plate fitting to the tie. There is need for tie material that does not extrude when spiking without predrilled holes.

One railroad does predrill holes in the field because this ensures limited spiking damage.

Spiking machine variations can result in damage. One railroad has found that the pushing (hydraulic control) insertion tends to result in damage or cracking. Thus, tie spiking machines with push and hammer spike have had the push function disabled, and spikes are only hammered in.

Also, during the spiking process, the tie nipper devices that only pull at the middle of the tie are disabled because this tends to apply a larger than desirable center bending load during the spike driving effort. Older tie nippers that pull from the outside, or new nippers that pull from the inside but under each rail seat, do not show this damage.

Some railroads test tie types for spiking by driving a spike 1 inch from the edge and conducting AREMA type pullout and side push tests. Modifying and standardizing AREMA spiking tests for composite ties is needed to comply with such screening methods.

When holes are to be predrilled for spikes, most railroads usually specify the same size used with wood ties ($^{9}/_{16}$ inch); some railroads request that the supplier specify the hole size. These different approaches to determining hole size suggest either a standard hole size be specified (i.e., a railroad industry request to standardize the size for either wood or composite ties), or a methodology be developed to determine optimum hole size for a specific tie material.

Drive or Screw Spikes

When installing screw or drive spikes, all railroads predrill (in the field or in the shop) holes, generally $^{11}/_{16}$ inch. Again, one railroad requests that the supplier specify the hole diameter. This same railroad also utilizes two drills, one size for the treaded body ($^{11}/_{16}$ inch) and a larger size for the upper taper part of a screw spike, which reduces the likelihood of cracking.

Other Issues

Modulus of Elasticity

One railroad raised an issue regarding the AREMA Modulus of Elasticity (MOE) for composite ties, which is currently 170,000 pounds per square inch (psi). This MOE may be too low. The value was developed by a committee years ago using available product information; it was not determined based on what was needed for long term track performance. This value may be a contributor to poor long-term performance as seen by ballast degradation, churning, and tie plate cracking when composite ties are subjected to extended traffic.

Temperature Effects

One railroad stated a concern regarding the effect of temperature on basic performance: essentially, some products might need to be tested cold and/or hot depending on expected service environment and known sensitivity.

Recommended Next Steps

Based on recommendations and the scope of this FRA project, the following tasks are proposed for plastic and composite ties:

1. Develop a drop test procedure.
2. Develop and improve existing AREMA spiking screening installation test procedures to include:
    a. Spike driving issues (push versus hammer)
    b. Pre-bore issues (hole size, location next to tie edge)
    c. Non pre-bore issues (test for material upset)
3. Evaluate existing AREMA center bending test requirements and modify to address tie installation loads—tie nipping and tie insertion.
4. Develop forklift impact damage test for tie surface damage.

5. Develop standard practices for user inspection at tie manufacturing plants.
6. Future (beyond current scope and budget):
    a. Accelerated fatigue tests
    b. Accelerated aging tests
    c. Improved base stock quality control

Required Resources

TTCI

- Provide instrumentation support for one or more ties to determine loads, impacts, and forces based on items 1 through 4 above.
- Coordinate laboratory and field data collection to measure loads.
- Ensure source of any sample ties obtained by request remain proprietary.

Railroads

a. Coordinate field inspection and measurement support with TTCI.
b. Supply samples of ties previously displaying undesirable characteristics (i.e., susceptible to chipping or breaking during dropping, etc.) for use in laboratory test validation. In some cases, ask railroads to work with suppliers to obtain out of production or older sample ties that have been improved.

Suppliers

a. Provide tie samples with known deficient characteristics to benchmark tests, and then provide improved ties to validate test screening capabilities.
b. As part of developing inspection and quality control best practices, provide information about which manufacturing processes and stock materials are most likely to change tie performance characteristics.

Abbreviations and Acronyms

AREMA	American Railway Engineering and Maintenance-of-Way Association
FRA	Federal Railroad Administration
RTI	Recycle Technologies International, Inc.
TTC	Transportation Technology Center
TTCI	Transportation Technology Center, Inc.