The Plastic Composite Ties in Brazil

Challenges and Solutions in large scale installation

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Short Biographical Sketch
Leonardo S. Soares
Leonardo Soares is a consultant in railway engineering at the National Transportation Agency of Brazil. Before June 2013 he worked for 8 years at MRS Logistics assuming positions of Track Maintenance Manager, Track Specialist and Track Engineering Coordinator. He was responsible for implementing and testing the installation of plastic composite ties in large scale and degradation studies of geometry as a function of transport. He established methodology to analyze geometric defects according to the degradation rates. Member of technical committees of regulation and standards for track and infrastructure, rail, ties, ballast and rolling stocks. He is a member of AREMA since Dec/2011.

ABSTRACT

The studies for application of plastic composite ties in Brazil started in 2004. The choice of plastic composite was based on an alternative to existing wood ties. The main questions for this decision were related to the adaptability of existing equipment maintenance, installation and better LCC when compared to wood. The technology and manufacturing process would be similar to existing in USA.

The first recommendation of the AREMA Subcommittee 30 (6) was to follow in general the tests indicated for concrete tie. Currently it is known that most of the tests and trials for approval of concrete tie has no meaning or indexes directly applicable to plastic composite ties.

In early 2007, an extensive program of field tests with the installation and monitoring 1,800 plastic composite ties produced by four Brazilian
manufacturers in activity is initiated. In 2010 a project for the acquisition, installation and monitoring 60,000 plastic composite ties is started.

This work will present the performance analysis of plastic composite sleeper as well as the limitations / restrictions on the installation in heavy haul lines. Procedures that ensure optimum performance even in larger scale of application and manufacturing will also be presented.

Key Words: Railway; Plastic Composite Tie, Plastic Composite Tie Performance.

INTRODUCTION

Determining the best kind of ties to be used has always been a crucial decision point for railway companies. The amount of material involved and the life cycle cost (LCC) become crucial to the success of maintaining a safe and efficient transportation.

Historically Brazilian railways have been using hardwoods as the only material for manufacture ties. There was a lack of control of extraction of native woods, as well as a low demand for ties due to low transport rates done by the railroads in the post construction.

With the increase of transport volume of all national railways, the demand for ties which was initially not significant started to raise. The high demand for hardwood ties caused an environmentally effect, and the search for more raw material crossed the boundaries of sustainability.

Because of this situation, the railroads started the development of new alternatives for ties. However, the particular condition of Brazilian rail network imposed a number of restrictions to traditional alternatives to the use of hardwood ties, such as steel ties and concrete ties. Eucalyptus from replanted sustainable forests, besides having mechanical property less than hardwood, were in a condition of high competition in the rail market; after all, most national railroads opted for immediate replacement of your requests for woods from sustainable forests.

In mid-2004, predicting the occurrence of such a situation in the domestic ties market, Brazilian railways began the development of a plastic composite tie prototype with local suppliers, following North American Railroads (3), (4) (5) references. The first applications were done and showed satisfactory results. The acquisition of plastic composite ties increased in subsequent years as well as the development of new producers, more technologies and new alternatives. In 2010, one Brazilian railroad together with FINEP (public company under the Ministry of Science and Technology, created to promote and fund innovation, scientific and technological research in businesses, universities or private institutions) started a big program with the acquisition, installation and monitoring of 60,000 plastic ties.
This work will present the performance analysis of plastic composite tie, as well as the limitations / restrictions on the existing track. Procedures to ensure optimal performance will also be presented.

**DEVELOPMENT AND EMPLOYMENT OF PLASTIC COMPOSITE TIE IN BRAZIL**

The first application of plastic composite ties in Brazil occurred in 2003, when approximately 500 plastic composite ties were imported from the USA, manufactured in dimensions (7 in. x 7 in. x 102 in; 180mm x 230 mm x 2,600mm) and applied on the main line of a Brazilian heavy haul railroad in broad gauge (63’ ≈ 1,600 mm). In mid-2004, a traditional manufacturer of plastic objects for industrial and residential use (poles, crossarms, pellets, decks, stairs, rustic furniture, etc.) partnered to develop plastic composite ties to broad gauge. The technology and manufacturing process were similar to the existing in USA. In November 2004, 50 plastic composite ties were purchased and installed into different sections of track.

In 2004 there was no definition at AREMA for the laboratory tests and manufactures approval for plastic ties. The first recommendation from AREMA was to follow broadly the tests indicated for concrete tie and was only published in 2005. Currently it is known that most of the tests and trials for approval of concrete tie has no meaning or indexes directly applicable to plastic tie. In November 2006 the book "Recycled Plastic Tie" (2) was published, where the author, Nelson Assad relates the first experience of manufacturing / application of Brazilian plastic composite tie assisting in the development of future ties.

Between 2005 and 2007, three new manufacturers of plastic composite ties started in the market in Brazil. All of them are located in the state of São Paulo, two operating facilities for the manufacture of poles and crossarms converted to the manufacture of ties. All owners have their own industrial and confidential process. In early 2007 an extensive program of field tests with the installation and monitoring of about 1,800 recycled plastic ties produced by four manufacturers in activity started.

In 2010 about 60,000 ties were installed in a Brazilian heavy haul railroad. With the large-scale installation conditions failures that had not been identified in previous years were observed. The root cause for these failures were problems from manufacturing, but also procedures errors during installation and maintenance services. Once identified the failures, there were simple and viable alternatives to mitigate the impacts, which once made will ensure an increasingly safe application of this new alternative tie.

**MAJOR TYPES OF FAILURE**

For the development of behavioral studies of plastic composite ties in lines of high tonnage transported, the railroads created test sites for installation and
monitoring. The locations selected to verify the behavior were chosen following the future needs of the companies and in order to expose the ties to high stress. In December 2010 there were eighteen test sites in Brazilian rail network. The philosophy of test sites followed the recommendations of AREMA: the minimum amount established of 100 ties installed in a single block without interleaving with any other kind of tie. At these points performance information were collected as well as the initial failures happened. Noteworthy that the month of December 2010 was deterministic, since the first test site has accumulated more than 300 million gross tons without any defect. In addition, three other test sites were approaching 200 million gross tons transported without damage.

![Test site of composite plastic sleeper](image)

The fact that the national plastic composite ties reach a number between 200 and 300 million gross tons transported in late 2010 was crucial for continuing acquisition of this material in the next years. It may seem little, but 300 million gross tons transported represent a useful life of 15 years for lines where averaging 20 million gross tons is transported per year. Currently for the same 300 million gross tons using Brazilian recycled wood tie (treated eucalyptus) is estimated a useful life of approximately 4 years.

To define the migration of a high tonnage railway tie matrix is essential that all possible impacts are evaluated for such decision. Even for a sleeper that meets all technical requirements and with satisfactory performance, any "failure in scale" can be catastrophic if not properly controlled and mitigated.

As described by W. Vidon in his work "Recycled Plastic Tie - A Viable Solution to Timber Tie" (1), there are 5 modes of failure known to the plastic tie:

1st) Cracks in the area of fastening during the installation of the tie;
2nd) Excessive change of gauge in a hot climate region;
3rd) Premature fracture of tie plates in older installations (above 900 MGT);
4th) Fracture and cracks in the area of fastening, occurring sometime after installed;
5th) Fracture in the central region of tie (Center Bound Tie or Vertical Pumping).
The failure modes # 4 and # 5 were found on the installed ties. The other modes of failures were not observed probably due to the differences between the North American and Brazilian railroads, or simply due to the ties have not yet reached tonnage as ties installed in North American railways (over 900 mgt).

In further studies on existing faults in ties applied, it the root cause of such occurrences was identified and mitigation measures were created so that they do not occur.

Generally, fractures and cracks in the region of fastening is presented in the Figure 2 and Figure 3:

- Figure 2 - Crack initiation near the fastening system
- Figure 3 - Advanced crack near the fastening system

During the analysis, it was found that there are two possible causes for this type of occurrence.

The first question comes from the installation process. The main way to check this root cause is the appearance of the crack as shown in Figure 2, small and close to the screw spike. It was found that in some ties that had this type of failure, the pilot hole does not hit enough to screw spike insertion depth. Thus,
during the tightening of screw spike there is not enough depth, forcing the point of the screw spike against the bottom of the hole and breaking the fibers of the tie near the end of the thread area. The first noticeable crack appears a few days after installation with the passage of a few trains.

The immediate correction of this failure is the use of the adequate tools for installation of plastic composite ties by the maintenance crews. Correct drills with greater depth are ideal, leaving enough space to the screw spike and without loss of torque, which in this particular case must be greater than 300kN. In the case of the appearance of cracks in the advanced stage, also near the fastening region, the origin of the problem is related to a manufacturing fault. For this case there is presence of oversized holes or excess porosity within the fastening area, as shown in the Figure 4 and Figure 5:

![Figure 4 – Porosity inside the composite plastic tie](image)

![Figure 5 - Porosity present in the region of fastening](image)

The identification of porosity inside the plastic composite tie can be further improved; however, good results are correlated to the modulus of elasticity. The testing to determine the elastic modulus as recommended by AREMA serves as great reference in identifying this type of failure. Furthermore, the group of ties with such failures presents in some cases a lack of flatness in one of its ties faces. Such a lack of flatness identifies a failure in the cooling process after the extrusion and the presence of air inside the tie. Identified such symptoms and verifying the modulus of elasticity of tie without this failure becomes more assertive possible identification of this occurrence.
To minimize the occurrence of this type of failure the ideal is to monitor and implement corrective measures during the manufacturing process. The extrusion time and cooling temperature of the plastic material is not adequate with the speed and temperature requested for the fabrication process. As each provider has specific molds for ties, this process will suffer variations that need to be understood and implemented so that, during extrusion, the whole shape of the sleeper is filled uniformly (both in temperature and quantity of material) and the cooling time of the material is properly controlled.

The other mode of failure, the fracture in central region of the tie (Center Bound Tie or Vertical Pumping), differs from the situations previously presented because it’s caused by the infrastructure in which the tie has been installed. This is the most predominant failure at the ties and is considered the most dangerous failure.

The fracture in the central region of the tie, as the name implies, is a crack in the middle of the tie as shown in Figure 7:

Many mistakenly believe that this type of problem occurs specifically with plastic ties. Looking in more detail this situation, we can also find this event on wood ties (Figure 8). Another point that may also explain the presence of this effect is
the need for making the counter-deflection in the middle of the steel tie to prevent warping during the working regime (Figure 9).

Based on this information, it is clear that the fracture in the central region of the tie is more related to the installation site than to tie itself. Of course, due to the construction methods, plastics ties are more susceptible to failure under these conditions. Thus, it has become essential to research the ideal way to eliminate this effect.

W. Vidon in his work "Recycled Plastic Tie - A Viable Solution to Timber Sleeper" (1) reports that the same defect occurred in the ties installed in some railways:

"This typical fracture is known as "Center Bound Tie" in the international technical literature. Being the result of vertical deformation (up) in the center region of the tie because of an action of the negative moment between the rails, caused by migration of ballast stone for the middle of the tie, and subsequent compaction and density, forming support in the center of the tie. (…)"

"The tie for broad gauge (1.60 m) with 2.80 m length have the sum of shoulders equal to 1.2 m (1.2 m = 2.8 to 1.60); 25% smaller than the distance from broad gauge (1.60 m). Therefore, it is characterized as a short tie and have pronounced tendency to warp upward. This occurs for both wood ties and recycled plastic ties. Meter gauge ties 2.20 m long, has the dynamic behavior of a "long-tie" and hardly suffer the effect "Center Bound Tie"."

The problem is completely justified since the places of occurrence of this failure mode are places with high rates of geometric instability and with presence of ballast problems.
Figure 10 - Beginning of Bound Center Tie or Vertical Pumping in the region of dirty ballast

The most efficient way to control the occurrence of Bound Center Tie or Vertical Pumping and consequently reduce the rate of plastic composite tie failure in these regions is related to the quality of the ballast and tamping.

The region to be tamped in the plastic composite tie is essential. For the best performance of the tie the ballast tamping conditions should inhibit negative moments in tie center as shown in the Figure 11:

Figure 11 - Negative moment at the center of the tie with the passage of trains

It is necessary an improvement in ballast tamping methods to prevent the occurrences of fracture failures in central region of plastic composite tie, for example, tamping focus of protection (post installation) and mechanized geometric correction in regions as shown in the Figure 12:

Figure 12 Regions to be tamped to mitigate the impacts caused by the negative moment at the center of tie

CONCLUSIONS

For performance check was conducted monitoring of the test sites of recycled plastic ties from 3 suppliers located in different regions.
The Table 1 shows a fragment of the table used:

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>LINE</th>
<th>NUMBER OF TIES</th>
<th>SUPPLIER</th>
<th>PROTOTYPE</th>
<th>TIES FAILED</th>
<th>% FAILED</th>
</tr>
</thead>
<tbody>
<tr>
<td>PORT REGION</td>
<td>MAIN LINE</td>
<td>100</td>
<td>C</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NORTH</td>
<td>MAIN LINE</td>
<td>100</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CENTER</td>
<td>MAIN LINE</td>
<td>100</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CENTER</td>
<td>MAIN LINE</td>
<td>200</td>
<td>B</td>
<td>2</td>
<td>0</td>
<td>0</td>
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<tr>
<td>CENTER</td>
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<td>C</td>
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<td>0</td>
<td>0</td>
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<td>CENTER</td>
<td>MAIN LINE</td>
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<td>B</td>
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<td>0</td>
</tr>
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<td>MAIN LINE</td>
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<td>A</td>
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<td>0</td>
</tr>
<tr>
<td>CENTER</td>
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<td>C</td>
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<td>0</td>
</tr>
<tr>
<td>SOUTH</td>
<td>MAIN LINE</td>
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<td>A</td>
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<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SOUTH</td>
<td>MAIN LINE</td>
<td>180</td>
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<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>SOUTH</td>
<td>MAIN LINE</td>
<td>100</td>
<td>C</td>
<td>2</td>
<td>9</td>
<td>9</td>
</tr>
<tr>
<td>MOUNTAIN RANGE</td>
<td>MAIN LINE</td>
<td>100</td>
<td>A</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MOUNTAIN RANGE</td>
<td>MAIN LINE</td>
<td>100</td>
<td>B</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MOUNTAIN RANGE</td>
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<td>7</td>
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<td>PORT REGION</td>
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<td>11</td>
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<tr>
<td>PORT REGION</td>
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<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PORT REGION</td>
<td>MAIN LINE</td>
<td>100</td>
<td>C</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PORT REGION</td>
<td>MAIN LINE</td>
<td>100</td>
<td>C</td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

**TABLE 1 – Testes sites locations**

Table 2 shows accumulation of transport in million gross tons transported (average of all test sites until 26/07/2012); the test sites with index greater than 2% of ties failures were not considered in the calculation:

<table>
<thead>
<tr>
<th>SUPPLIER – PROTOTYPE</th>
<th>ACCUMULATED MGT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>296.98</td>
</tr>
<tr>
<td>B-3</td>
<td>364.67</td>
</tr>
<tr>
<td>C-1</td>
<td>178.34</td>
</tr>
<tr>
<td>C-2</td>
<td>332.39</td>
</tr>
<tr>
<td><strong>GLOBAL AVERAGE</strong></td>
<td><strong>293.10</strong></td>
</tr>
</tbody>
</table>

**TABLE 2 – Accumulated MGT per supplier and prototype**

Converting the accumulated in the branches, it becomes possible to estimate the useful life (in years) of the ties that are still installed (Table 3).

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>MGT TRANSPORTED</th>
<th>LIFE ESTIMATIVE (YEARS)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>A-1</td>
</tr>
<tr>
<td>SOUTH AND CENTER</td>
<td>95.38</td>
<td>3.11</td>
</tr>
<tr>
<td>NORTH</td>
<td>44.50</td>
<td>6.67</td>
</tr>
<tr>
<td>PORT REGION</td>
<td>14.84</td>
<td>20.01</td>
</tr>
<tr>
<td><strong>GLOBAL AVERAGE</strong></td>
<td><strong>51.57</strong></td>
<td><strong>9.93</strong></td>
</tr>
</tbody>
</table>

**TABLE 3 – Life estimative per location**

It is found that when compared to the currently used eucalyptus ties (5 years of life) the recycled plastic tie promoted increases in lifespan of at least 95% in general average.
Branches with higher traffic densities not present significant results due to the short monitoring period, however, already have life equal to the eucalyptus ties.

Note that this estimate may change according to the conditions of application sites, as well as the quality of the manufactured batch.

As conclusions, it is possible to highlight:

- Plastic composite tie is an attractive substitute for wood ties; it reduces the amount of pollutants like plastic bags and containers, PET bottles, jars and flasks).
- Plastic composite ties has inherent and natural resistance to moisture, rot, to the action of insects / fungi without the addition of toxic agents for pretreatment;
- Up to 26/07/2012 the testes sites of plastic composite ties showed an estimated life 95% higher than the eucalyptus ties used the services of maintenance teams.
- Recyclable plastic tie is the only one that can be worked in conjunction with wooden ties. Due to its shape and characteristics it may be interspersed with wooden ties without the loss of line surface. This condition allows the alteration of a railway ties without any interference in the working methods of maintenance teams.

ACKNOWLEDGEMENTS

The results of this work should be thankful to the early studies by Walter Vidon Junior and professor Nelson Assad. In addition, Bruno Igel and Rodrigo Creato on continuous improvement of performance studies recyclable plastic ties through the company Wisewood should also be reported, making each day the plastic tie a reality at Brazilian railroads.

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