# *Studying the Effects of the Loram HP Shoulder Ballast Cleaner on Brazilian Heavy-Haul Railways*

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**Abstract:** This study focuses on the imperativeness of well-maintained railway ballast and its effects on the life of rolling stock, wheels, rail, ties, and other track structure components. If ballast is improperly maintained, several problems can occur on the track and/or with the rolling stock, including serious derailment accidents. This essay presents the results of utilizing a Loram High Performance Shoulder Ballast Cleaner (SBC) to clean railway ballast. Several measurements have been taken by MRS-Logistics to determine the effects of shoulder ballast cleaning, including the rate of contamination in the ballast, the track modulus, track geometry, and track quality index. Measurements were taken both before and after shoulder ballast cleaning, as well as before and after heavy rain events. Presented through the collected data outlined in the following sections, shoulder ballast cleaning is proven to be an excellent method in the restoration of track drainage, particularly in tropical areas that experience heavy rains on an annual basis.

**Keys-Words:** Track Quality Index; Shoulder Ballast Cleaner; Management Components

## 1. INTRODUCTION

Proper performance of ballast is essential to the safe, efficient operation of "heavy-haul" railways. Through proper drainage maintenance, a railroad can optimize the life of its components of the track and rolling stock. Several issues can arise with rails, signals, fasteners, and/or ties that are attributable to unstable track due to degradation of ballast. If left unattended, these issues can eventually lead to the weakening of the ballast to the point that its no longer able to withstand the loads of the trains.

To maintain its strategic position as a premier supplier of rail transport services in Brazil, MRS Logistics must design and execute track maintenance strategies that extend the life of the assets while being performed in a manner that has little disruption to customer shipments. Since the beginning of 2007, MRS-Logistics, has used a Loram High Performance Shoulder Ballast Cleaner (SBC) as the exclusive method of ballast maintenance. Over 800 km of main line has been cleaned with the SBC with minimal track occupancy (less than 400 hours).

## 2. RAILWAY BALLAST

The railway ballast section is a layer of stones placed below the superstructure of the track and above the sub-ballast to provide stability to the track. Standard ballast is made up of various grain sizes(usually a mix of crushed rock, slag, or volcanic ash) which are uniformly graded and angled, free from dirt, and free of cementing properties.

The railway ballast has multiple functions that contribute to the life and performance of the railway line. Many researchers have presented in detail the many functions of ballast. The following highlight the most important functions of the ballast layer [1]:

- Keeps the track in the desired position, resisting vertical, lateral, and longitudinal loading
- Provides elasticity and resistance to dynamics of the the track
- Evenly distributes the forces exerted by the rolling stock to the layers of the infrastructure
- Ensures the immediate drainage of rain water

The ballast must allow recovery of the geometry of the line, especially the longitudinal and transverse leveling responsible for smoothness and ride quality. The ballast must also have the following qualities:

- Resilience to the shocks

- Dimensions that allow the interposition between and under the ties
- Ability to fill the depressions of the platform or sub-ballast and allow for perfect leveling of the rails
- Resistance of atmospheric agents
- Permeability to achieve drainage of rain water

**3. DEGRADED BALLAST**

Over time, degradation of the ballast occurs due to a number of factors. The following are the main factors [3]:

- Chemical deterioration of the particles due to natural weather conditions
- Contamination of materials transported (iron ore, coal, sand) because of the migration of fine materials to the bottom of the ballast
- Mechanical degradation of particles due to traffic and trains over time, especially during geometric corrections

When 2% of its weight is composed of particles less than or equal to 6.0 mm in diameter, the ballast layer is considered to be contaminated [4].

To measure the rate of contamination in the ballast, Selig and Waters (1994) created the Fouling Index (FI). The formula for contamination of the ballast is expressed as follows:

$$FI = P_4 + P_{200} \tag{1}$$

where $P_4$ and $P_{200}$ are the bystanders in weight percentages, respectively in size 4 and 200 sieves. The following are the classifications:

FI < 1 – *Clean Ballast*

1 ≤ FI < 10 – *Moderately Clean Ballast*

10 ≤ FI < 20 – *Moderately Contaminated Ballast*

20 ≤ FI < 40 – *Significantly Contaminated Ballast*

FI ≥ 40 – *Highly Contaminated Ballast*

**4. TRACK MODULUS**

To effectively analyze the behavior of the track, it is important to note that the superstructure and infrastructure are considered a continuous elastic beam, capable of supporting the efforts of the rolling stock and transferring it to the lower layers.

Thus we have [5]:

$$u = \left[ \left( \frac{P}{Y_0} \right)^4 \frac{1}{64EI} \right]^{\frac{1}{3}} \tag{2}$$

where:

$u$ - track modulus
$P$ - load each axle
$Y_0$ - maximum rail deflection
$E$ - rail modulus elastic
$I$ - rail inertial moment

Since the values of the track modulus are directly related to the ballast, this indicator has been used frequently by researchers in the field to determine the rail ballast behavior[6].

According to international classification models, modules values at [5]:

- Below 14 MPa $\rightarrow$ *poor track*
- Between 14 and 28 MPa $\rightarrow$ *fair track*
- Above 28 MPa $\rightarrow$ *optimal or good track*

**5. SHOULDER BALLAST CLEANING PROCESS**

The purpose of shoulder ballast cleaning is to remove the layer of ballast located at the end of the ties called "head of the sleeper", sift it, and return it to the line with only material considered suitable for the track. The fine contaminant material is removed and discarded from the platform.

Additionally, a scarifier undercuts the tie up to 5 inches, ensuring rain water is drained properly.

According to Selig (1994), the ballast permeability is directly related to the degree of contamination of the ballast. Figure 1 shows the condition of permeability due to the degree of contamination of the ballast:


Fig. 1 (a) Highly contaminated ballast

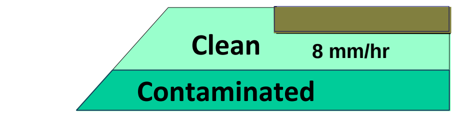


Fig. 1 (b) Contaminated ballast

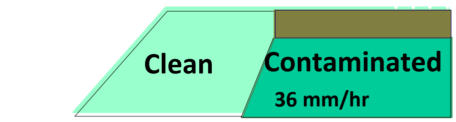


Fig. 1 (c) Moderately clean ballast

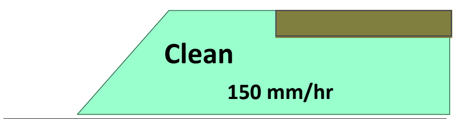


Fig. 1 (d) Clean ballast

**6. THE LORAM HIGH PERFORMANCE SHOULDER BALLAST CLEANER (SBC)**

In April 2007, the MRS started the process of shoulder ballast cleaning with the Loram High Performance Shoulder Ballast Cleaner (SBC).

Using the least track occupancy possible, the SBC has the capacity to clean at 2.0 miles per hour and is completely controlled by a PLC system, reducing maintenance and operational costs. Figure 2 shows a photograph of the machine in the courtyard of the company in Juiz de Fora – MG.

Fig. 2 Loram Shoulder Ballast Cleaner

In less than two years of use, the MRS SBC has had an output of approximately 500 miles, operating on a variety of railways and throughout high density traffic. The Steel Line has been a challenge because of the high volume of traffic, and the Center Line because of its highly contaminated ballast and age.

Figure 3 illustrates where the machine worked on MRS Lines.


Fig. 3 SBC coverage in 2007 & 2008

After utilizing the SBC on the ballast shoulder on the Steel Line wich contains a large amount of mudspots, the route has a significantly better appearance after a rainfall (see Figure 4).

Before After

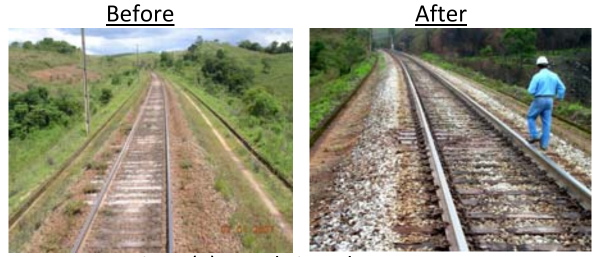

Fig. 4 (a). Steel Line - km105 + 980

Before After

Fig. 4 (b). Steel Line – km 110 + 300

**7. FIELD TESTS**

Undisturbed samples were collected at three points of the Steel Line for characterization of the layers of sub-ballast and sub-bed.

The points were defined:

- Km 18 + 732 (Quatis-RJ)
- Km 105 + 450 (Bom Jardim – MG)
- Km 258 + 915 (São João Del Rei – MG)

After characterization of the infrastructure, samples were taken from the ballast shoulder at each point before and immediately after cleaning. Also collected were samples of the shoulder ballast to measure the composition of the ballast after a period of rain (see Figure 5).

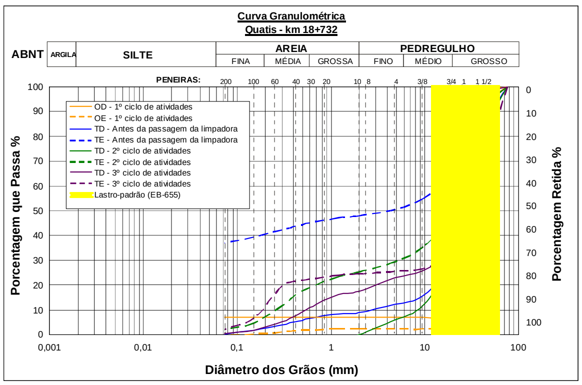


Fig. 5 (a). Compare grain curves from Quatis-RJ

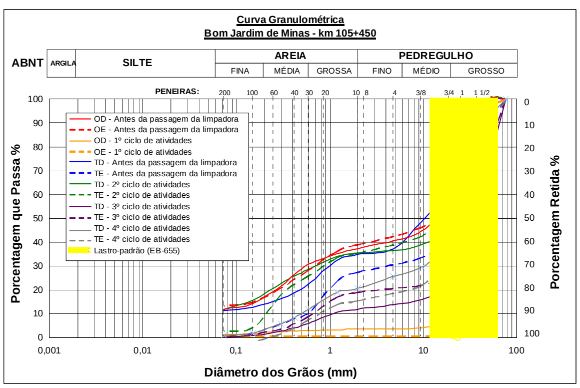


Fig. 5 (b). Compare grain curves from Bom Jardim - MG

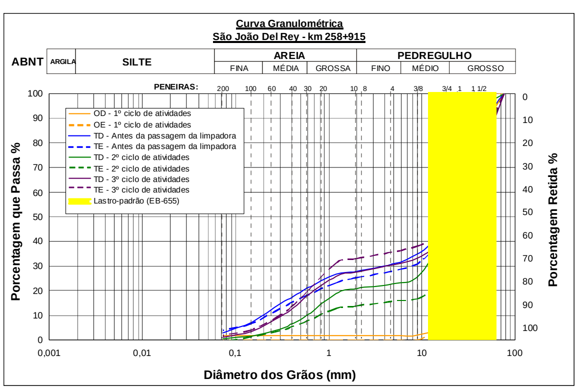


Fig. 5 (c). Compare grain curves from São João Del Rei - MG

Along with the collection of grain samples, the behavior of the modulus path was obtained by the use of DDL - Dynamic Deflectometre Laser. The track modulus, in turn, was obtained using a retro-analysis tool called FERROVIA 1.0.

The methodology for obtaining this parameter will not be addressed in this work; Silva and Paiva discuss a comprehensive approach on this issue [7].

The historical behavior data of the track modulus were used at certain points before the start of the shoulder ballast cleaning process, and then tracked over time, and again after the rain cycle at these same points.

## 8. BALLAST BEHAVIOR

At all measured points, the track modulus remained above the minimum parameters for an ideal route. The modulus values obtained soon after the passage of the equipment at the location Bon Jardin and Quatis were 73 MPa, and 165 MPa, respectively.

The modulus value via the São João Del Rei has not yet been completed.

From the data obtained from the granulometric curves, it was possible to generate a comparative chart of contamination of the shoulder (Fig. 6):

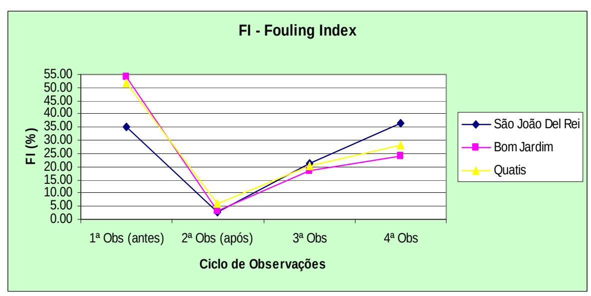


Fig. 6. Fouling Index (FI)

| Núcleo - São João Del Rei | | | |
|---|---|---|---|
| | FI (%) | Intervalo | Classificação |
| Apr-07 (antes) | 34.95 | FI > 40 | C |
| Apr-07 (após) | 2.76 | 1 < FI < 10 | ML |
| Fev-08 | 21.42 | 10 < FI < 20 | C |
| Jun-08 | 36.55 | 20 < FI < 40 | C |

According to the graph in Figure 6, the fouling index for ballast was very high before cleaning the shoulder, preventing the ballast from ensuring proper drainage. After cleaning and an ongoing cycle of rainfall, the water began to carry out the fine contaminated particles from the ballast, depositing them on to the shoulder.

This explains the increase in the fouling index of the shoulder ballast over the period of measurement.

Table 1 shows the classification suggested by Selig (1994) to the shoulder of the ballast during the observations:

Table 1 (a). Fouling Classification of Quatis-RJ

| Núcleo-Quatis | | | |
|---|---|---|---|
| | FI (%) | Intervalo | Classificação |
| Apr-07 (antes) | 51.75 | FI > 40 | AC |
| Apr-07 (após) | 6.00 | 1≤FI < 10 | ML |
| Fev-08 | 20.45 | 10≤FI < 20 | C |
| Jun-08 | 28.15 | 20≤FI < 40 | C |

Table1 (b). Fouling Classification of Bom Jardim - MG

| Núcleo-Bom Jardim | | | |
|---|---|---|---|
| | FI (%) | Intervalo | Classificação |
| Apr-07 (antes) | 53.99 | FI > 40 | AC |
| Apr-07 (após) | 3.17 | 1≤FI < 10 | ML |
| Fev-08 | 18.54 | 10≤FI < 20 | MC |
| Jun-08 | 23.95 | 20≤FI < 40 | C |

Table 1 (c). Fouling Classification São João Del Rei - MG

The photo shown in Figure 7 shows how fines are carried in ballast. When the shoulder is clear, it means the fouling index is low. The fines can then be carried out by rain water.

Fig. 7. Fine material carried down by rain water Bon Jardim – MG

Figure 8 shows the amount of contamination accumulated during the rainy season before and after cleaning. Before cleaning, the foul material would just build up in the track structure because the ends of the ties were sealed with mud, not allowing for the day to day contamination to escape the track structure during the wet season.

After shoulder ballast cleaning, contamination rates significantly dropped. This data is from greater cumulative rainfall intensity before (Dec. 06, Jan. 07, and Feb. 07) and after the passage of Shoulder Ballast Cleaning Machine (Dec. 07, Jan. 08, Feb. 08), time of tropical rains.

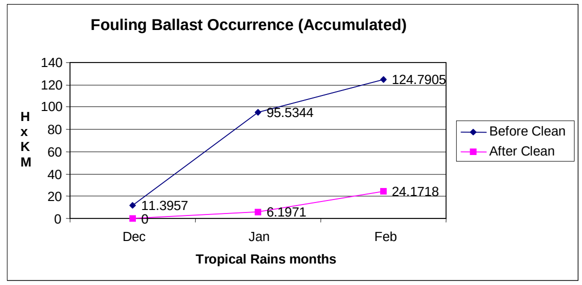


Fig. 8. Occupancy Occurrence for undue fouling ballast of MRS – Logistic

## 9. TRACK GEOMETRY CONDITIONS

To verify the behavior of the geometry of the track, an indicator was used that assessed the conditions of the track through geometrical parameters.

The TQI – Track Quality Index is the standard deviation of the appropriate parameters of the track, according to its class, and the parameters found by actual vehicle inspection [7].

The TQI should be used as a decision-making tool to determine the level and method of maintenance, according to the principles of LCC – Life Cycle Costs.

Guided by evolutionary behavior of the index, it is possible to associate the condition of track with the degree of maintenance.
For each of the vaious railways and demands for rail transport, TQI sets out appropriate standards of reliability and maintenance needed to ensure that reliability. Thus, it defines the action to be performed.

Table 2 shows the TQI avarage values from the Steel Line since 2005.

Table 2. Track Quality Index

| | Apr/05 | Apr/06 | Apr/07 | Apr/08 |
|---|---|---|---|---|
| São João Del | 9.2 | 9.0 | 9.1 | 5.9 |
| Bom | 7.8 | 8.7 | 11. | 7.2 |
| Quati | 10. | 9.2 | 10. | 5.9 |

Using the process of Shoulder Ballast Cleaning, since April 2007, MRS has reversed the loss of quality of track geometry parameters during a time of increasing traffic in demand for transport (see Figure 9).

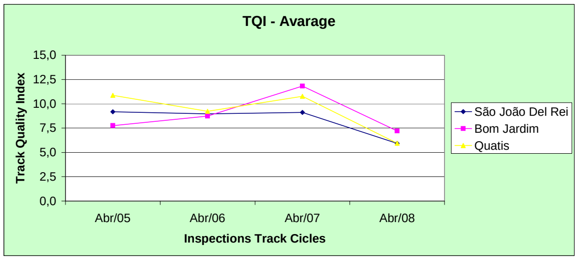


Fig. 9. Track Quality Index

## 10. CONCLUSIONS AND SUGGESTIONS

The superstructure has a critical influence on performance and maintenance of assets. The ballast receives the loads of the wheels and distributes to the lower layers of soil. Its stiffness and elastic behavior must be critically evaluated to avoid impairment of wheels and rails [10].

The establishment of and maintenance of geometric standards is essential to ensure trains can travel both securely and with appropriate speed.

It is essential that technology exists for maintaining the ballast, thus, ensuring the superstructure is able to efficiently perform its duties.

Shoulder ballast cleaning has proven to be a quick and efficient way to maintain the rail ballast, while ensuring a low track occupancy when compared to traditional undercutting methods. It appears to be the future of modern track maintenance, ensuring greater reliability and availability of assets.

The shoulder ballast maintenance process is a preventive technique, reducing costs by widening the interval between geometric corrections.

In regions of heavy tropical rains and a high density of traffic, this process is highly recommended. In places of very high fouling ballast, as well as in areas that have high shipments of ores and courtyard lines, undercutting may still be needed.

## 11. REFERENCES

[1] Ionescu, D. *Degradation Characteristics of Ballast in the Field and its Measurement,* Conference on Railway Engineering, May (2006), pages 174-179.

[2] Marconi, A. *Uma contribuição a metodologia de Recebimento, Manutenção e Desempenho de Lastro ,* IME – Instituto Militar de Engenharia Especialização de Engenharia de Transportes de Cargas Ferroviária, October (2006), pages 24-26.

[3] Suiker A. *The Mechanical Behavior of Ballasted Railway Tracks;* Delft University of Technology; January (2002), pages 2 – 4.

*[4]* Selig. E. T. , Waters J. M. Track *Geotechnology and Substructure Management*; Railway Geotechnical Consult; April (1994) pages 8.18 – 8.20.

[5] Hay, W. W. 1982. Railroad Engineering. 2nd Edtn

[6] Jancks, C. W. *Transit Cooperative Research Program,* Federal Transit Adminstration; October (2006); pages 5-8.

[7] J. Stasha *Railway Track Quality Assessment and Related Decision Making,* Faculty of Civil Engineering & Geosciences, October (2006); Pages 3-12.

[8] Silva. F.; Paiva. C. ; Aguiar. P. *Evaluation of Track / Ballast Behavior Under Increased Axle Load: Measuring Deflections on Track* ; IHHA – International Heavy-Haul Association (2007); pages 31 – 34.

[9] Zarembski A. *The Art and Science of Rail Grinding*; Simmons – Boardman Books (March 2005); pages 1-6.