DOES **MISSING BALLAST** RESULT IN DEVELOPMENT OF **TRACK GEOMETRY DEFECTS**?

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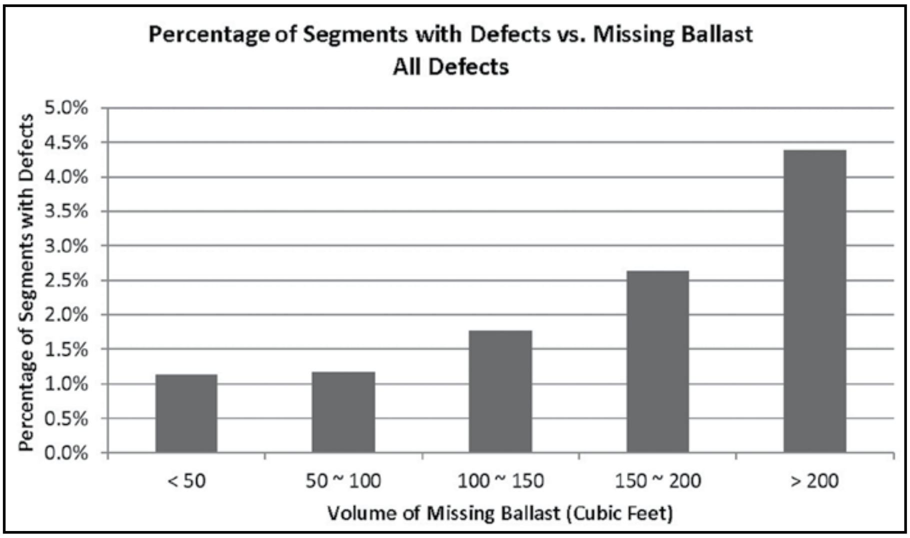
The correlation between missing ballast and the development of geometry defects is explored.



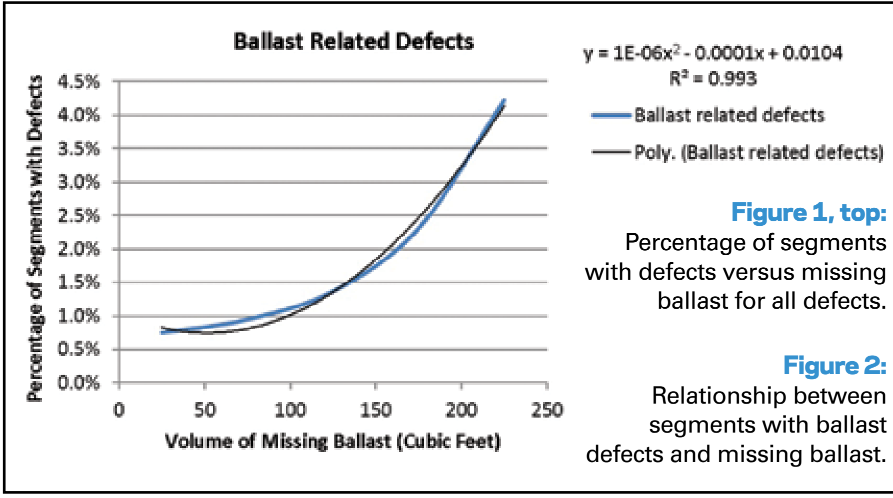


Figure 1, top: Percentage of segments with defects versus missing ballast for all defects.

Figure 2: Relationship between segments with ballast defects and missing ballast.

The presence of a full ballast section, to include full shoulders and cribs, has long been an important part of railroad maintenance. Past research has shown a relationship between inadequate ballast and lateral track resistance, to include resistance to track buckling and lateral track movement. Likewise, inadequate lateral resistance has been shown to result in the development of track geometry defects, such as alignment defects. Research on the relationship between shoulder size and lateral resistance has also shown the importance of the ballast lateral resistance. However, no formal relationship has been developed between missing volume of ballast and development of track geometry defects.

The recent introduction of ballast profile measurement technology, such as Laser Imaging Detection And Ranging (LIDAR) technology[1], allows for the measurement of the ballast profile at discrete intervals along the track. By overlaying digitized LIDAR data onto an idealized track structure representing the top of tie, the shoulders and the shoulder slope, it is possible to calculate the missing volume area in the ballast shoulders and cribs. This missing ballast can then be compared to the occurrence of track geometry defects as identified by a track geometry inspection car for the same track locations. In this study, the ballast deficiency data was obtained from Georgetown Rail Equipment Company's (GREX) BallastSaver system and the track geometry defects were received from the Class 1 railroad owner of the inspected tracks.

The data for the volume of missing ballast consisted of information regarding the location, volume of missing ballast, if it was on a curve or tangent, length of the segment and date of collection. The ballast data consisted of 187,025 segments, each approximately 50 feet in length, for a total length of approximately 1,798 miles of track[2]. The 50-foot segment length was selected after analysis of alternative segment lengths, based on the accuracy of location measurements so as to allow for best matching of geometry defect locations with ballast sections. The track geometry defect information consisted of the defect type, location, defect amplitude, defect length, date defect was identified, etc. A total of 5,440 geometry defects were reported (by the railroad) within that stretch of track, distributed over 2,278 segments, with many segments having multiple reported geometry defects.

In order to avoid issues of multiple geometry defects within a given segment, the analysis focused on the percentage of segments containing geometry defects ("defective segments") within a larger overall population of segments. Thus, the final results looked at the number of segments with geometry defects, irrespective of how many individual defects were within that segment, i.e., the percentage of segments with geometry defects as a function of total inspected segments ("percentage of segments with defects").

Once the initial matching was completed, a determination of the appropriate grouping size (based on cubic yards of missing ballast) was performed. Three higher-level groupings were examined; a 10-cubic-foot grouping, a 25-cubic-foot grouping and a 50-cubic-foot grouping. The 50-cubic-foot grouping provided the smoothest behavior and as such, was selected for use in the analysis.

Figure 1 presents the 50-cubic-foot grouping information as a bar chart. (Note, all the segments with volumes greater than 200 cubic feet were consolidated into a single ">200" category because of the relatively small number of segments in these categories). It should be noted that the majority of the missing ballast occurs in the shoulders with the balance in the cribs.

Analysis results

Figure 1 shows the total percentage of segments with defects for all defects. As can be seen from this figure, there is a well-defined trend of increasing percentage of segments with defects (i.e. increased number of segments where defects are present) as a function of increasing volume of missing ballast. As expected, this relationship between increasing segments with defects and increased volume of missing ballast result is primarily the result of the ballast-related defects which account for a majority of the defects present in the data. This data shows that the rate of development of ballast-

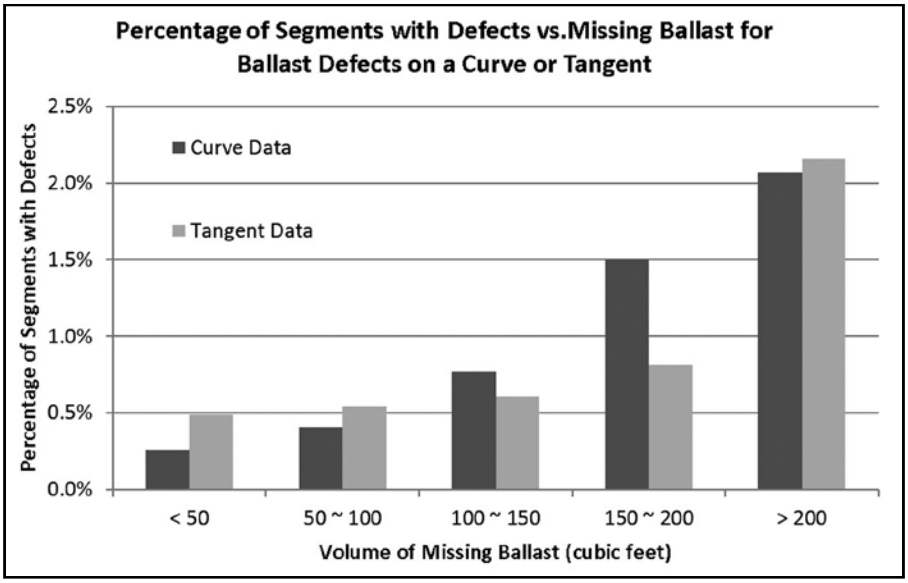


Figure 3, top: Effect of missing ballast on curve versus tangent track.

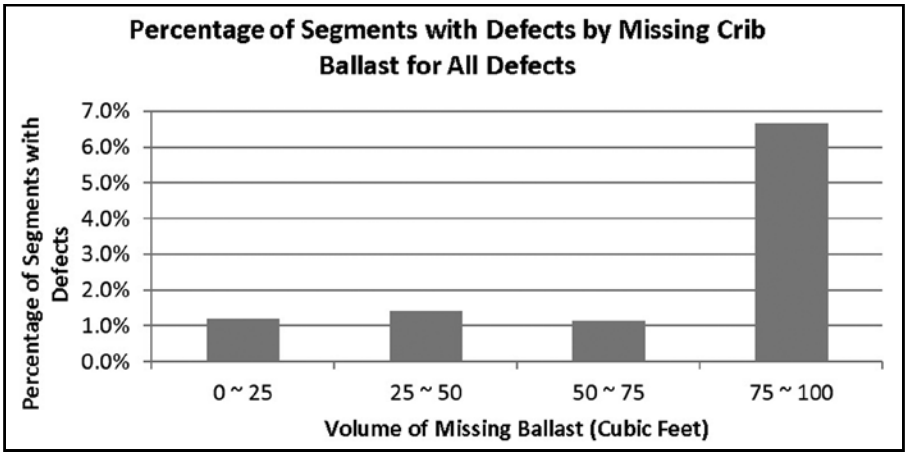


Figure 4: Effect of missing crib ballast.

related defects is positively correlated to the volume of missing ballast and that this relationship increases nonlinearly as shown in Figure 2. Note, the extremely good curve fit, as represented by the very high R^2 value (99 percent). Thus, this data strongly supports the idea that missing ballast section (specifically shoulder and crib ballast) will directly contribute to the development of ballast-related track geometry defects.

As a follow up analysis, the defect data was further separated by curve versus tangent track. These results are presented in Figure 3, which presents the rate of ballast-related defect occurrence (by segment) as a function of increased volume of missing ballast separately for curve and tangent track. As already noted, the segment defect rate on a curve follows a steady trend upward with increasing volumes of missing ballast. However, the rate of defects on a tangent follow a shallower curve, until a high volume of missing ballast is reached, which causes the rate to jump up to the same level as curve-based defects. This appears to suggest a threshold effect of tangent track, such that a small amount of missing ballast has only a modest effect on defect occurrence on tangents, but larger volumes of missing ballast can have a significant effect. This is similar to the behavior of missing ballast and track buckling for tangent track where a small amount of missing shoulder ballast has a minimal effect on lateral resistance, but a large amount of missing shoulder ballast can have a significant effect[3].

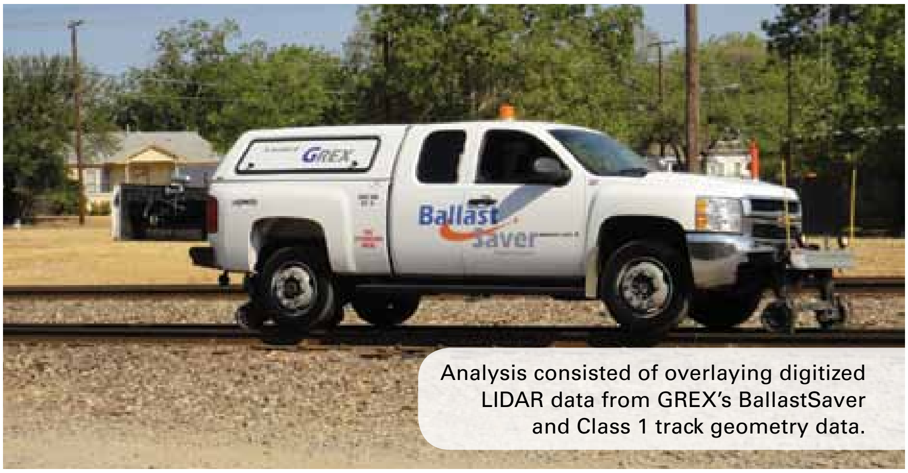
An additional set of analyses was performed looking at the difference between missing shoulder and crib ballast. A key aspect of this analysis is that the range of missing shoulder ballast was similar to the range of total missing ballast, while the range of volumes for missing crib ballast effectively was significantly less, with a maximum of 100 cubic feet of missing crib ballast (as opposed to more than 200 cubic feet for missing shoulder ballast). Thus, in order to plot the rates when looking at the volume of missing crib ballast, a grouping of 25 cubic feet was used as higher groupings prevented detailed analysis of the results. The behavior of the shoulder ballast analysis is basically the same as that shown in Figures 1 through 3, with an increasing percentage of segments with defects on curves and an apparent threshold effect on tangents. The analysis of the crib ballast effect, shown in Figure 4, also shows a potential threshold-type behavior, for all track, with a spike in the percentage of segments with defects in the 75- to 100-cubic-foot range[4].

Conclusions

The results of the study show that increasing volumes of missing ballast results in increases in the occurrence of track geometry defects and, in particular, the ballast-related track geometry defects, in those segments that have the missing ballast. This is consistent with basic industry practices and guidelines, which show a relationship between missing shoulder and/or crib ballast and reduced track strength. The results provide a quantifiable relationship, in form of a quadratic equation, between missing ballast and the rate of development of segments with geometry defects (defective segments). Examination of specific classes of geometry defects show a clear and well defined relationship between segments having ballast-related track geometry defects and missing ballast, which supports the previously held belief that these defects are related to the missing ballast.

4. The number of data points for this crib ballast analysis was very limited and as such needs to be used with caution until verified with a larger data set.

This relationship furthermore extends to analysis of curve versus tangent track, where curve track exhibits the same quadratic-type of relationship, while tangent track appears to have more of a threshold effect, where a small volume of missing ballast has a relatively mild effect, but a large volume of missing ballast has a significant effect on the rate of development of geometry defects. This curve versus tangent relationship is also evident based on the type of individual geometry defects. Analysis of missing shoulder ballast versus crib ballast provided further insight into the relationship between missing ballast and the occurrence of track geometry defects. Missing shoulder ballast exhibits behavior similar to the more general total missing ballast categories, while the missing crib ballast has a modest tangent track effect, but no well-defined curve track effect. This suggests that the lateral resistance of the shoulders is the dominant effect on curves, but on tangents, crib lateral resistance takes on increased importance.□



Analysis consisted of overlaying digitized LIDAR data from GREX's BallastSaver and Class 1 track geometry data.

References

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