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Soft Subgrade Support and Ballast Pocket Remediation on a Railway Embankment

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Summary

A 3-year research effort by Transportation Technology Center, Inc. (TTCI), Norfolk Southern Railway (NS), and Tensar Corporation identified and investigated ballast issues resulting from embankment deformation on a site in eastern Ohio, and concluded that the utilization of geogrid and ballast drains could reduce the track settlement and extend track maintenance cycles significantly in this type of environment.

Results of this work extended the maintenance of the track from weekly to a yearly timeframe, and the ballast drains continue to function after three years, although discharge may be slowing somewhat. The geogrid continues to contribute to track stability, although localized lower embankment issues may be causing deformation in a small zone about 60 to 80 feet long.

This line was constructed over 100 years ago, and a 700-foot long embankment on the line had undergone nearly continuous deformation for many years as a result of ballast pocket issues. During that time, weekly maintenance was needed in order to maintain track geometry. TTCI initiated an effort to characterize the engineering properties of the embankment fill using TTCI's Track Loading Vehicle (TLV) and ground penetrating radar (GPR), followed by the development of a work plan to stabilize the track. Ballast pockets over 7 feet deep were identified, in addition to soft soil embankment deformation.

Subsequent work involved removing the track and placing triaxial geogrid on the exposed sub-ballast, then covering and tamping it in order to stabilize the track. Installation of two ballast drains improved track drainage and contributed to stabilizing the mid-embankment shear deformation issues.

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INTRODUCTION

Transportation Technology Center, Inc. (TTCI) is investigating the effectiveness of the remedial methods used to address subgrade instability at a revenue service site in the eastern United States. TTCI focused on issues such as the presence of ballast pockets that have developed in the subgrade over time, moisture problems that are manifest because of water retention in ballast pockets, reduced shear strength in wet soils, and stabilization of these soils.

Over time, ballast in the track tends to undergo wear and degradation under heavy axle loads. Soft subgrade soils can also contribute to the problem, as dynamic loads produce a condition of vertical ballast migration into the subgrade, called ballast pockets. Once this occurs, remediation involves replacing degraded ballast with clean ballast and draining the moisture out of the ballast pockets, since a poorly drained track is prone to continued settlement and deformation, as well as developing other major repair issues if it goes unrepaired.

Figure 1 shows an approximately 100-year-old, 700-foot long section of clay fill embankment, which carried approximately 17 MGT per year. It had undergone continual deformation under increasing loading and frequency of use, and required weekly maintenance in recent years.

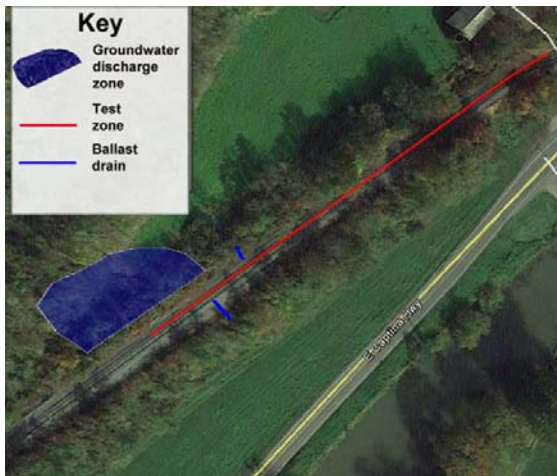


Figure 1. Eastern Ohio Study Area

INVESTIGATION

Ground penetrating radar (GPR) was used on the eastern Ohio section in October 2012 to characterize moisture and contrasting zones of reflectivity, and analysts were then able to identify zones with high moisture, low track stiffness, and ballast pockets. The TLV was also used to characterize subgrade stiffness and perform cone penetrometer tests. The results of the GPR and TLV testing shown in Figure 2 were combined in order to plan a remediation strategy.

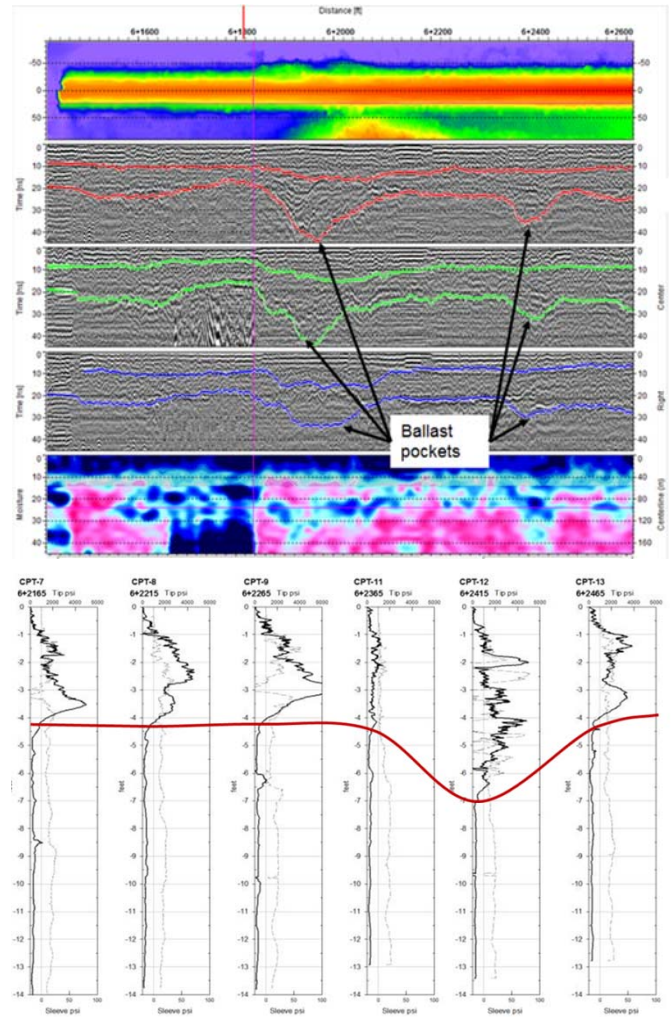


Figure 2. GPR and Cone Penetrometer Test Characterization Results

After the ballast pocket zones were identified, a remedial strategy was developed to address the high moisture issues shown in Figure 3 in the ballast pockets. Extensional cracking and deformation was also observed in the mid to upper embankment, which was addressed by dewatering the ballast pockets, and by placement of a geogrid, as it formed a mat type foundation and confined vertical ballast migration.

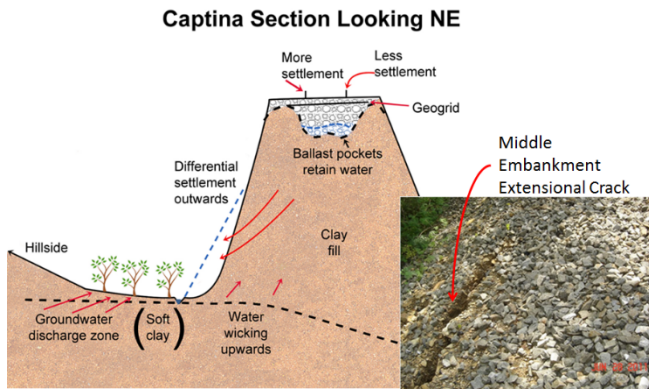


Figure 3. Dynamic Deformation of Embankment Fill

REMEDIATION INSTALLATION

The remediation system consisted of installation of two ballast drains located at OP6+ 2220 and 2420, and the placement of triaxial geogrid from OP6+2100 to 6+2600 (500 feet long). Triaxial geogrid was installed at a depth of 12 inches below bottom of tie, by 13 feet wide, by removing the track, placing the geogrid, replacing the track and ballast, and tamping the ballast (Figure 4).

Dynamic Forces Result in Lateral Ballast Migration

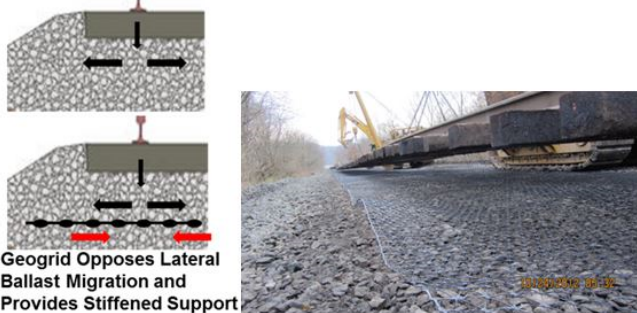


Figure 4. Conceptual Image of Geogrid and 2012 Installation

Although ballast drains have been used for many years in railway environments, modern GPR has enhanced the effectiveness of this method by being able to target ballast pocket position and depth, rather than guessing the optimal drain positioning. Ballast drains are relatively quick, inexpensive, and easy to install (Figure 5).



Figure 5. Ballast Drain Conceptual View and Installation

PERFORMANCE MONITORING

After the remedial systems were installed, the embankment was monitored for approximately 30 months, in order to document the performance of the systems for that period. A “telltale” system was installed in the upper ballast as the track was replaced in order to determine if any settlement was from above or from below the geogrid elevation. Settlement above the geogrid was determined by noting differential settlement between top of rail (TOR) and top of the nearby telltale (Figure 6), while settlement below the geogrid would log the settlement related to the two survey points as approximately equal. Most of the observed settlement was below the telltales.

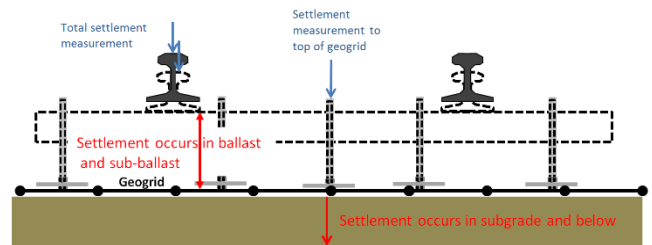


Figure 6. Telltale System used to Differentiate between Upper- and Mid-Embankment Settlement

The function of the ballast drains was assessed during site visits, and was found to be adequate by flow observation. However, flow appeared to be slowing somewhat in 2014, although precipitation was higher than in 2012 (Figure 7a). Another drainage method may need to be considered at some point.

The ballast covering the geogrid was also removed for observation in various locations during site assessments, and it was noted that the geogrid remained in good condition during the test, with one exception. After shoulder cleaning activities had taken place, a few small pieces of the geogrid along the perimeter became caught and torn loose by the equipment (Figure 7b). However, it did not appear to cause increased overall deformation of the embankment.



Figure 7a. Ballast drains still functioning in 2014, but appear to be slowing down



Figure 7b. Geogrid may be damaged during shoulder cleaning

GPR results also indicate that the geogrid was absent in the 2010 image (upper portion of Figure 9), but easily discerned in 2014 as shown in the lower portion of Figure 9. Although the geogrid polymers themselves do not produce a GPR response, the reflection does indicate a dielectric layer contrast along the geogrid and ballast interface. This is most likely caused by development of a “pavement” at the geogrid interface and differing moisture properties on either side of the interface.

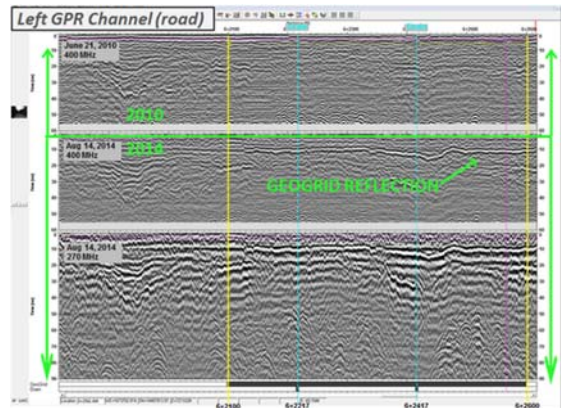


Figure 9. Geogrid Reflection Interface

RESULTS AND CONCLUSIONS

A site visit was conducted in fall 2014 in order to observe site conditions and systems. TTCI and HyGround Engineering performed an assessment of TOR and telltale elevations, drainage function, and a GPR survey of the embankment.

The GPR survey produced a comparison of 2010 and 2014 ballast moisture results, indicating that the ballast was retaining less moisture in 2014, although there was more precipitation in the weeks preceding the survey. This indicates continuing adequate function of the ballast drains, as Figure 8 shows.

It may be noted that the geogrid appears to be undergoing deformation near one of the ballast drains. Site observations indicate that this could result from deep embankment deformation. Future work will investigate the need for additional action at that location to arrest this deformation, in order to preserve the integrity of the geogrid.

TTCI plans to perform a summer 2015 site visit with the TLV to take final track stiffness and TOR measurements.

The positive effects of ballast drains and geogrid have worked together to preserve track geometry and to extend the maintenance cycle from a weekly schedule to a yearly timeframe.

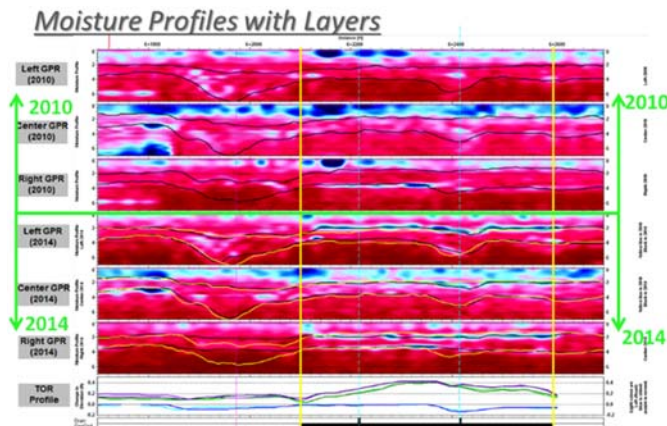


Figure 8. GPR Comparison of Ballast Moisture in 2010 and in 2014

ACKNOWLEDGEMENTS

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