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Stabilization of Ballast Pockets with Geogrid in a Railway Embankment

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Summary

A 5-year research effort by Transportation Technology Center, Inc. (TTCI), Norfolk Southern Railway (NS), and Tensar Corporation identified and investigated track substructure issues resulting from embankment deformation on a site in eastern Ohio, and it 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. However, it has also been observed that the effectiveness and useful life of the geogrid may be limited when clay embankments may exhibit deeper issues that require other remedial measures.

The presence and performance of geogrids in railway environments in shallow subsurface locations can offer increased resistance to ballast pocket development and higher load bearing strength of the upper embankment area. It is also resistant to degradation under dynamic loading. However, care must be taken in its application with respect to potential issues deeper in the embankment.

Stabilization measures for this site may include deepening the drainage ditch on the west side to reduce hydraulic head, and installing a retaining wall on the east side to stabilize embankment slopes. The test zone consists of a 500-foot-long embankment section on the line, which had undergone upper and mid-embankment deformation prior to remediation, resulting from the effects of ballast pocket and moisture retention issues. In October 2012, the track underwent remedial efforts consisting of installation of ballast drains and triaxial geogrid, which were designed to slow or stop the development of shallow to mid embankment ballast pockets, distribute live loads evenly over the embankment crest, and drain water out of the ballast pockets to increase soil shear strength in the mid to upper embankment area.

Weekly maintenance had previously been needed in this test section to maintain track geometry. Immediately after remediation, performance improvement was noted, as maintenance was reduced to once or twice yearly. Ballast pockets over 7 feet deep were stabilized, in addition to a reduction in mid embankment soft soil shearing. However, gradual loss of performance was noted in the section starting at ~12 to 24 months after remediation.

In 2017, although ballast drains are still functional, mid to lower embankment areas have undergone gradual deformation, which is affecting the stability, positioning, and performance of shallow geogrid and embankment profile. Ballast pockets, while not growing, may still be retaining water in some lower areas, contributing to soft soil shearing and mid embankment deformation.

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INTRODUCTION

Transportation Technology Center, Inc. (TTCI) has been investigating the use of geogrid and ballast drain combinations used to address subgrade instability at a revenue service site in the eastern United States. The original research focus was on addressing issues such as the presence of ballast pockets that have developed in the subgrade over time, moisture problems that are manifesting because of water retention in ballast pockets, reduced shear strength in wet fill materials, and stabilization of these fills.[1]

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 load pulsing can produce a condition of progressive vertical ballast migration into the subgrade, called ballast pockets. Once this process begins, subgrade depressions begin to form which retain water, lowering the soil shear strength more and inducing embankment deformation. The accepted and usual remedy is to replace degraded ballast with clean ballast and to drain the moisture out of the ballast pockets, since a poorly drained track is prone to continued settlement and deformation, as well as needing other major repair issues if it goes unrepaired.

Figure 1 shows an aerial view of the site, including a spring area (discharge zone), which correlates with and may exacerbate problems in the study area. Hydraulic head differences of at least 8 feet are present between each side of the embankment.

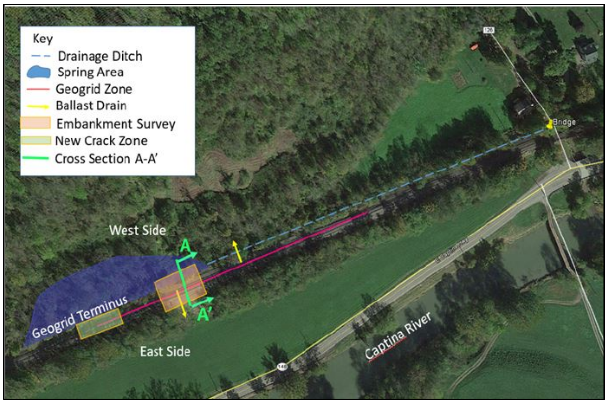

Figure 1: Test section overview

A conceptual cross section was developed of the area near the spring (Figure 2) to present and discuss mechanisms for observed embankment deformation. In 2012, the upper embankment area was stabilized by geogrid placement to test and observe geogrid longevity and stability in this environment. Initially, results were impressive, as ballast section maintenance was reduced from weekly to yearly. Approximately 1 to 2 years after installation, maintenance cycles began to increase again. By early 2017, track maintenance was needed 4 times in the first 5 months of the year.

The east side of the embankment has also become deformed since installation, as the original smooth profile has been altered to a hummocky configuration from 2012 to 2017 (Figure 3).

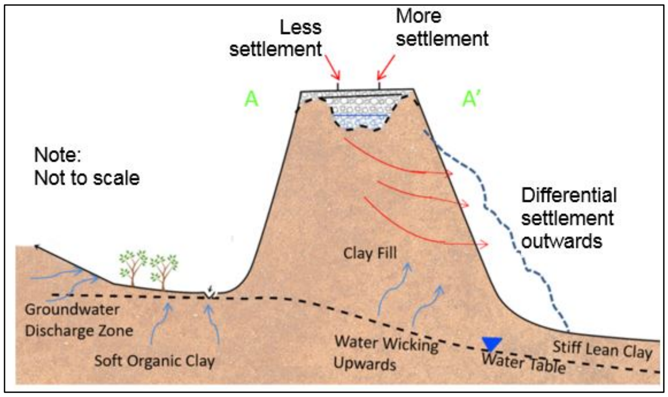

Figure 2: Clay embankment conceptual cross section

Figure 3: Comparison of planar embankment profile at installation and hummocky profile after 5 years

In late May 2017, a site visit was conducted to observe ballast drain function and geogrid condition at the site, and to perform top of rail (TOR) survey and other measurements.

Background

The remediation and research plan implemented in 2012 included installation of two ballast drains in the 500-foot-long embankment, to target optimal drainage points.[2] Geogrid (Figure 4) was also placed symmetrically under the track sections.

The geogrid was located 12 inches below the bottom of the ties during installation to allow ballast maintenance, provide stiffened support for the upper ballast section, and mitigate downward ballast migration into the ballast pocket areas.

Figure 5 illustrates a cross section of one of the ballast pockets that was targeted with ballast drains, using GPR, during the 2012 investigation. The ballast pocket development is asymmetrical in response to embankment deformation to the east (right), which the geogrid was designed to address with development of stiffened subballast support.

Figure 4: TX190L geogrid was symmetrically located under the ties during installation

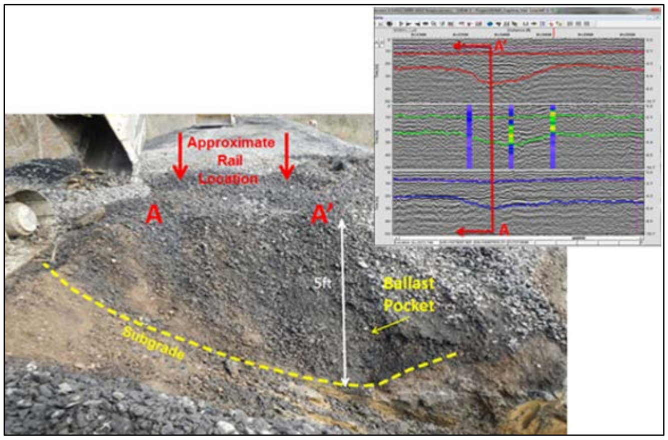

Figure 5: Original profile of ballast pocket area during ballast drain excavation. Location was identified using GPR (upper right insert).

Geogrid Performance

The 500-foot-long triaxial geogrid span performed well over most of the test area, but an 80-foot-long section spanning the east ballast drain encountered progressive deformation starting the year following installation (Figure 6) and evident in the 2015 TOR survey (Figure 7).

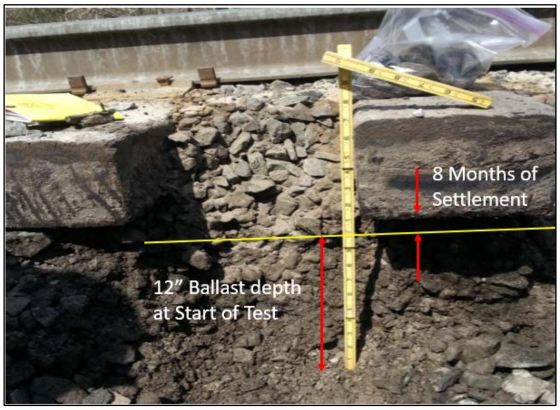

Figure 6: In early 2013, 0.10-foot of ballast settlement was already evident

In 2015, a 30- by 40-foot survey pin grid was installed to monitor embankment deformation. The grid, consisting of a series of 5-foot-long pins, was spaced 10 feet apart and driven 3 to 4 feet into the embankment. The grid indicated eastward deformation of the mid embankment over 3 years.

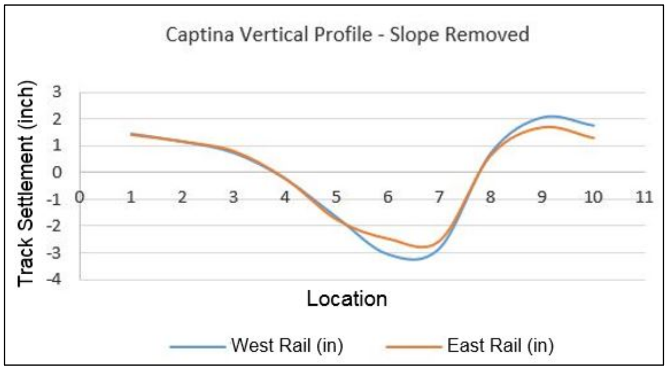

Figure 7: By 2015, TOR deformation was clearly evident before tamping and realignment

In spring 2017, a final site visit was conducted to expose the geogrid at eight locations, measure deformation, assess geogrid condition, and perform a TOR survey.

Although the geogrid was very effective in reducing ballast pocket development and in providing a stiff ballast foundation, deeper embankment shearing resulted in settlement and geogrid deformation (Figure 8).

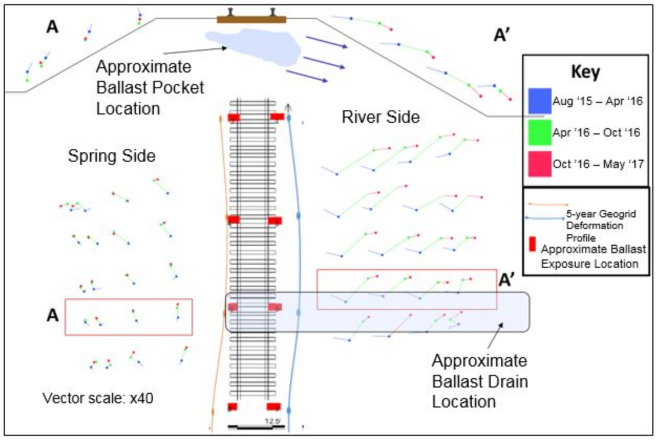

Figure 8: A 3-year embankment survey grid monitoring effort showed progressive mid-lower embankment deformation in spring 2017 along with geogrid translation. (Geogrid exposure locations are indicated in red)

Progressive loss of TOR profile resulted in eastward and downward migration of the geogrid relative to original positioning (Figures 9 and 10).

Figure 9: Exposed geogrid measurements showed migration downward and to the east

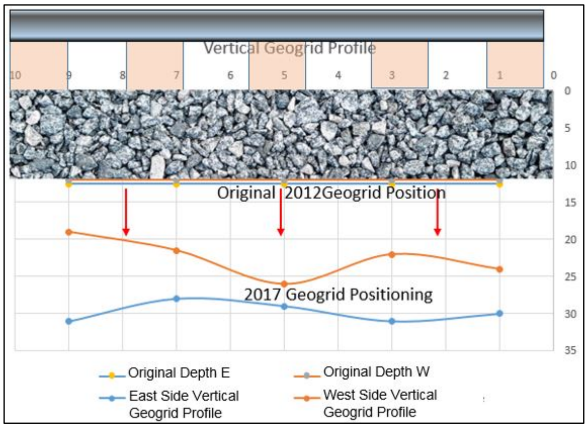

Figure 10: Mid embankment vertical deformation induced downward migration of geogrid from 7 to 19 inches over 5 years (2012 to 2017)

During the spring 2017 site visit, it was also observed that cracking of the east embankment had taken place (Figure 11). Embankment soils were water-saturated at this time, and the stiffness difference between unsupported and geogrid supported soils, along with ballast pocket influences, may have contributed to the 65-foot-long series of parallel cracks. Increased ballast pocket loading and moisture retention in unsupported zones resulted in development of failure planes (Figure 12).

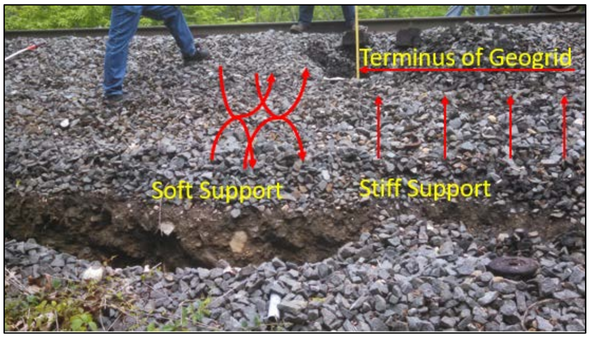

Figure 11: Cracking and translation of mid to lower embankment at geogrid termination point

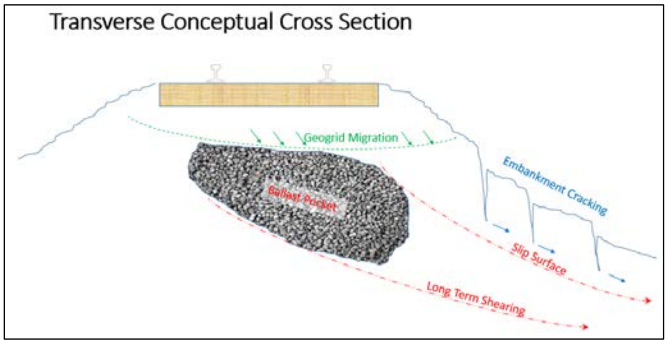

Figure 12: Development of slip failure planes in differentially loaded subgrade soils

Geogrid Stress Estimates

In addition to the eight geogrid exposure locations identified in Figure 8, two additional locations were exposed at the geogrid terminus (Figure 11). Measurements of the geogrid span at each location indicate that it is undergoing various amounts of transverse elongation in response to embankment and settlement influences (Figure 13). Accumulated strain is stretching the geogrid in a transverse manner, with over 6 percent strain evident at the terminus location. This may result in geogrid tearing and failure at some point.

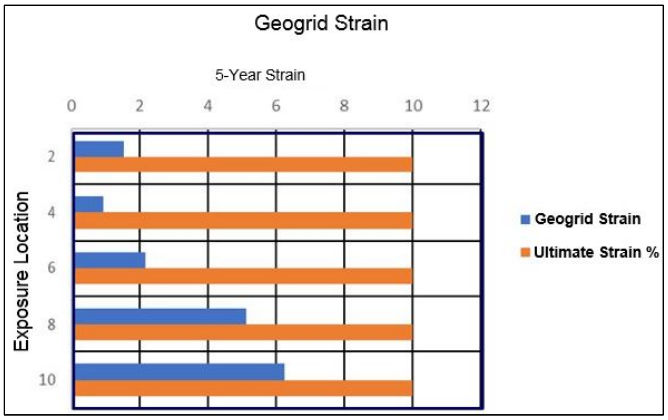

Figure 13: Transverse geogrid measurements indicate strain values from 0.94 to 6.25 percent

Conclusions and Next Steps

The presence and performance of geogrids in railway environments in shallow subsurface locations can offer increased resistance to ballast pocket development and higher load bearing strength of the upper embankment area. It is also resistant to degradation under dynamic loading. However, care must be taken in its application with respect to potential issues deeper in the embankment.

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Acknowledgements

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1. Hyslip, J. “Substructure Investigation – Captina Secondary.” HyGround Engineering report to Norfolk Southern Railway, Williamsburg, MA. Sep. 2010.
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