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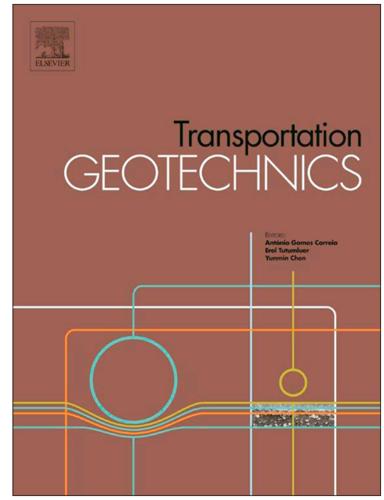

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Huseyin Boler, Debakanta Mishra, Wenting Hou, Erol Tutumluer

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Understanding Track Substructure Behavior: Field Instrumentation Data Analysis and Development of Numerical Models

Huseyin Boler[a], Debakanta Mishra[b,*,debmishra@boisestate.edu], Wenting Hou[a] , Erol Tutumluer[a]

[a]*University of Illinois, Urbana-Champaign, USA*
[b]*Boise State University, USA*

[*]Corresponding author at: 1910 University Drive, Mail Stop 2060, Boise, Idaho, 83725-2060

Abstract

Numerous studies have targeted using numerical modeling, field instrumentation, or combinations of both to gain insight into track substructure behavior under loading. In-depth understanding of track substructure behavior serving both passenger and freight trains is critical to developing suitable design and maintenance/rehabilitation methods to ensure adequate performance under loading. This manuscript presents findings from a recently completed study involving advanced instrumentation and numerical modeling to investigate track substructure-related issues at several problematic railroad bridge approaches in the United States. Multi-Depth Deflectometers (MDDs) were installed to measure transient as well as plastic deformations experienced by track substructure layers under loading. Strain gauges were installed on the rail web to measure the vertical wheel loads applied during train passage. Data from the field instrumentation was used to make inferences regarding the relative contributions of different substructure layers towards the differential movement problem. A 3-D Finite Element (FE) model was developed to further understand the behavior of the instrumented locations, and was calibrated using the field instrumentation data. An elastic layered track analysis program, GEOTRACK, was first used to iteratively backcalculate individual track substructure layer moduli from the field measurements; these backcalculated modulus values were subsequently used in the FE model to predict track response under transient loading conditions. Modulus values estimated for the ballast layer were found to be significantly affected by the presence of gaps at the tie-ballast interface at track transitions. Once validated, the model was further modified to match transient displacement results acquired in the field using a quasi-static moving load approach. Good agreement was found between the model predictions and field instrumentation results. Development of advanced numerical models augmented by field instrumentation data can facilitate the design and maintenance of well-performing track structures.

Keywords: Field Instrumentation, Multidepth Deflectometers (MDDs); GEOTRACK; Railroad Track Substructure; Finite Element Method

Introduction

In-depth understanding of railroad track behavior under train loading can be achieved through the development and adoption of state-of-the-art modeling and analysis methods. Numerous research studies over the years have focused on the development of advanced layered track analysis models. Traditional analysis and design methods generally utilize concepts such as Beam on Elastic Foundation (BOEF), and Elastic Layered Theory (ELT), whereas modern analysis approaches often take advantage of advanced numerical methods such as the Finite Element Methods (FEMs). Although track analysis models based on the concept of FEM are often capable of analyzing complex geometries and material properties, they must still be