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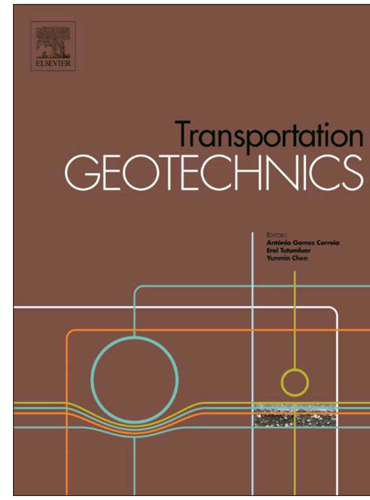

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Laboratory Evaluation of Railroad Ballast Behavior under Heavy Axle Load and High Traffic Conditions

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Abstract

Repeated loading of railroad track results in deformation of the track foundation materials. The degree of ballast fouling and the amount of moisture affect the rate and magnitude of both elastic and plastic deformation of the track. As train traffic accumulates, the track deforms to a point where maintenance is required. Studying the effects of fouled ballast in different moisture conditions under different loads leads to a better understanding of the risk factors and maintenance needs of the track.

In this study, a large ballast testing box was used to simulate the degradation of fouled ballast at different moisture conditions under heavy axle loading and high traffic conditions. The ballast compression tests were conducted on ballast with different fouling and moisture conditions up to 2,500,000 cycles of repeated heavy loading. The ballast was also tested in saturated conditions that simulated heavy rainfall events. The laboratory results have been compared with an accepted settlement model and different measured field settlements. The ballast box test results show comparable results with field measurements and analytical modeling. This paper presents conclusions regarding the effects of various factors on the rate and magnitude of the plastic and elastic settlement.

Keywords: Railroad, Track, Ballast, Fouling, Settlement, Heavy Axle Load

1. Introduction

Under good track conditions, where there is a supportive subballast and a stable subgrade, the ballast is the main source of traffic-induced track settlement (Selig and Waters, 1994). The most common source of ballast fouling is from in-service abrasion and breakage, often referred to as breakdown fouling (Selig et al., 1992). Fouling also contributes to water retention within the ballast layer. The increase in fouling and moisture within the ballast layer reduces the ability of the ballast to adequately support the track and leads to increased track geometry deterioration (Selig and Waters, 1994; Li et al, 2016). Rough track geometry increases track and rolling-stock deterioration, decreases ride quality and can lead to safety problems: Regarding to the Rail Equipment Accident (REA) databases recorded by Federal Railroad Administration (FRA) from 2001 to 2010 and analysis performed at the University of Illinois Urbana-Champaign, track geometry problems cause 7.3%, 7.2% and 3.6% of the freight train derailments in main, siding and yard types of track, respectively. This represents the second top main cause of freight train derailment in the main lines (Liu et al., 2012).

To keep the track geometry in a good condition, track maintenance such as surfacing, ballast cleaning and ditching are performed. This maintenance work is often performed by railroad personnel who usually don't have defined criteria for critical fouling and moisture conditions.

Railroad track elastically settles under each application of a wheel load. Track also settles due to accumulated plastic deformation in the ballast, subballast and subgrade from many cycles of loading. The plastic settlement from repeated cyclic loading causes deterioration of track geometry and results in the need for maintenance (Selig and Alva-Hurtado, 1982). Many numerical and experimental studies have been performed to evaluate the resilient and permanent deformation behavior of ballast under repeated loading and effective parameters (Brown, 1974; Gräbe and Clayton, 2009; Huang and Tutumluer, 2011; Han and Selig, 1997; Indraratna et al., 2007; Mishra et al., 2013;