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Behavior of geogrid-reinforced ballast under various levels of fouling

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ABSTRACT

This paper presents a study of how the interface between ballast and geogrid copes with fouling by coal fines. The stress-displacement behavior of fresh and fouled ballast, and geogrid reinforced ballast was investigated through a series of large-scale direct shear tests where the levels of fouling ranged from 0% to 95% Void Contamination Index (VCI), at relatively low normal stresses varying from 15 kPa to 75 kPa. The results indicated that geogrid increases the shear strength and apparent angle of shearing resistance, while only slightly reducing the vertical displacement of the composite geogrid-ballast system. However, when ballast was fouled by coal fines, the benefits of geogrid reinforcement decreased in proportion to the increasing level of fouling. A conceptual normalized shear strength model was proposed to predict this decrease in peak shear stress and peak angle of shearing resistance caused by coal fines at a given normal stress.

1. Introduction

Ballast is a free draining granular material used as a load bearing platform in railway tracks (Selig and Waters, 1994). It is normally composed of medium to coarse gravel sized particles (10–60 mm) and a small percentage of cobber size aggregates. Its main functions are to (1) transfer train load from sleepers to the sub-ballast layer at a reduced and acceptable level, (2) provide lateral resistance and (3) facilitate free drainage conditions. As trains pass over the track, ballast material is free to spread laterally due to the inadequate confining pressure provided by the shoulder ballast (Indraratna et al., 2005). A layer of geogrid between the ballast aggregate acts as a boundary which inhibits lateral spreading. Fig. 1 shows the main components of ballasted track structures reinforced with geogrid.

During operation, ballast deteriorates due to the breakage of angular corners and sharp edges, infiltration of fines from the surface, and mud pumping from the subgrade under train loading. As a result of these actions ballast becomes fouled, less angular, and its shear strength is reduced (Indraratna et al., 2005). Fouling materials have traditionally been considered as unfavorable to track structure. According to Selig and Waters (1994), ballast breakdown, on average, accounts for up to 76% of fouling, followed by 13% of infiltration from sub-ballast, 7% infiltration from surface ballast, 3% from subgrade intrusion, and 1% from sleeper wear. However, Feldman and Nissen (2002) reported that for tracks in Australia used predominantly for coal transport, coal dust accounts for 70%–95% of contaminants and ballast breakdown contributes from 5% to 30%.

The effectiveness of geogrid has been the subject of numerous experimental investigations conducted by Bathurst and Raymond (1987); Webster (1991); Shin et al. (2002); Indraratna et al. (2004, 2007, 2006); McDowell and Stickley (2006); Brown et al. (2007); Fernandes et al. (2008); Raymond and Ismail (2002); Raymond (2002); Gobel and Weisemann (1994); Palmeira (2009). The ability of geogrid reinforcement to provide lateral and vertical constraint to ballast has been emphasized, as has the subsequent reduction in ballast settlement. Indeed this interaction between ballast and geogrid significantly affects the overall performance of ballasted rail track because geogrid acts as a non-horizontal displacement boundary that confines the surrounding ballast particles via the frictional resistance between itself and the ballast aggregates. Shearing resistance is induced by the ballast interlocking through the apertures, while enhancing a bearing resistance against the ribs of the geogrid (Coleman, 1990; Shukla and Yin, 2006). Konietzky (2004) and McDowell et al. (2006) applied the discrete element method to model this action between ballast and geogrid, and they concluded that due to this interlocking, the geogrid provides additional confinement and increases the stiffness of surrounding particles.

When ballast is fouled by breakage or infiltration of fine particles (Selig and Waters, 1994), the interaction between them may

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