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Full Length Article

Compaction-induced stress in geosynthetic-reinforced granular base course – A discrete element model

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A R T I C L E I N F O

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A B S T R A C T

A discrete element method (DEM) model was used to simulate the development of compaction-induced stress in a granular base course, with and without geogrid reinforcement. The granular base course was modeled as a mixture of uniformly sized triangular particles. The geogrid was modeled as a series of equally spaced balls that interact with each other through long-range interaction contacts. The long-range interaction contact was also used to simulate a deformable subgrade. The compactor was modeled as a solid cylinder rolling at a constant speed. The DEM model shows that the geogrid-reinforced granular base course gains additional compaction-induced stress due to the residual tensile stress developed in the geogrid. The residual tensile stress in the geogrid increases with the number of compaction passes. Parametric analyses were also conducted to assess the effects of geogrid stiffness and subgrade modulus on the compaction-induced stress.

1. Introduction

Compaction is an important earthwork procedure during the construction of civil engineering structures such as pavements, embankments, retaining walls, and foundations. The compaction of granular soils is usually achieved by a few passes of a roller compactor until the desired dry density is reached. It is well known that compacted granular soils exhibit improved engineering properties such as increased stiffness and shear strength, and reduced permeability. In addition to the improved engineering properties, compaction also produces an increased lateral earth pressure in granular soils compared to the lateral earth pressure at rest. The increased lateral earth pressure is often referred to as the compaction-induced stress or the “locked-in” stress (Duncan and Seed, 1986; Seed and Duncan, 1986). The compaction-induced stress helps compacted soils gain additional strength and stiffness due to the stress-dependency of granular materials.

The development of compaction-induced stress is particularly important for roadway pavements with a granular base course, because the stiffness of the base course significantly affects the performance of the pavement structure. When a granular soil is reinforced by geosynthetic products such as geogrids, it usually suggests that a larger compaction-induced stress will be developed in the reinforced soil due to the interlocking effect between the geogrid and the soil. This phenomenon may have contributed to the increased stiffness of geosynthetic-reinforced granular base in the early stage. Although limited experimental data are available, partially due to the technical difficulty in the lateral earth pressure measurement in granular soils, a small number of published researches have supported the above hypothesis. For example, Kwon and Tutumluer (2009) compared dynamic cone penetrometer (DCP) test results in an unreinforced base course and a geosynthetic-reinforced base course and found that the reinforced base course showed a higher as-built stiffness. Another field study of intelligent compaction (Chang et al., 2011) also showed that the geogrid-reinforced base course showed an overall higher and more uniform stiffness than the control case after the same number of compaction passes.

The as-built stiffness of the granular base course is an important parameter in the roadway pavement design. Ideally, the increased stiffness of the reinforced base course layer due to the compaction-induced stress should be estimated and reflected in the pavement design. In the past, several design models (Perkins, 2001; Kwon et al., 2009; Wu and Pham, 2010; Yang et al., 2013) have been proposed to predict the compaction-induced stress in the design of reinforced flexible pavements. For example, Perkins (2001) suggested a residual tensile strain of 1% in the geosynthetic due to the effect of construction. Yang et al. (2013) proposed to modify the Duncan and Seed

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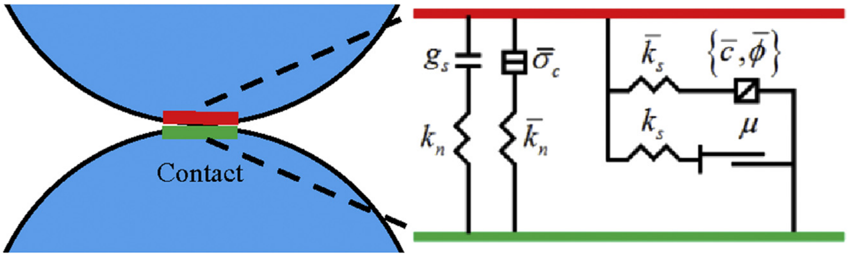
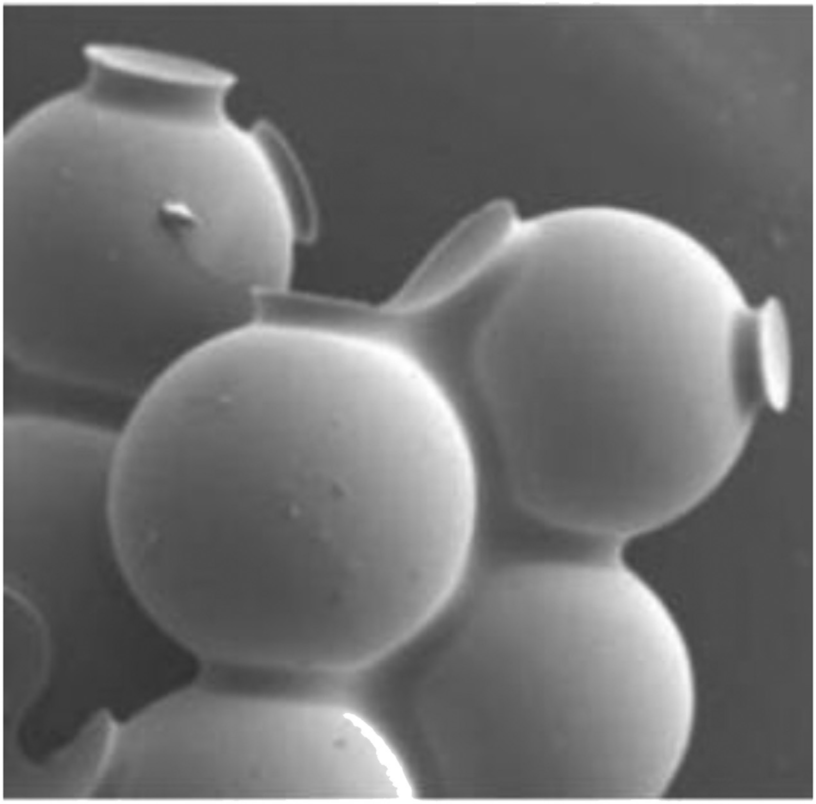


(a) Linear parallel bond model.



(b) Example of glass beads cemented with epoxy.

Fig. 1. Linear parallel bond model (Itasca, 2017) and an example.

(1986) model to consider the confinement effect of geosynthetics. However, none of the previous studies has well established the relationship between the compaction-induced stress and the material properties of geosynthetic, granular soil and subgrade.

This paper presents a two-dimensional (2D) discrete element method (DEM) model for the compaction process on a granular base course layer underlain by a deformable subgrade. The objective of the study is to build a numerical simulation tool to qualitatively investigate the phenomenon of compaction-induced stress in a layer of coarse-grained soil with and without geogrid reinforcement. The DEM model was developed with the computer program PFC™ 5.0 developed by Itasca (2017).

Table 1
Linear parallel bond model parameters.

Material	Linear group			Parallel-bond group					
	Friction coefficient, *fric*	Effective modulus, *emod* (MPa)	Normal-to-shear stiffness ratio, *kratio*	Tensile strength, *pb_ten* (MPa)	Cohesion, *pb_coh* (MPa)	Friction angle, *pb_fa* (°)	Bond effective modulus, *emod* (MPa)	Bond normal-to-shear stiffness ratio, *kratio*	Bond gap, *gap* (m)
Aggregate	0.6	100	1	0	0.02	35	5	2	0.0015
Geogrid	1	10	1	4.78	4.78	–	11.3	50	0.034
Subgrade	1	10	1	10	10	–	0.34	100	0.125

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