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EFFECT OF COMPACTION ON THE RESILIENT BEHAVIOUR OF GRANULAR MATERIALS: AN ANALYTICAL STUDY

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Abstract

The new 2002 AASHTO Guide for Pavement Design advocates the use of the resilient modulus parameter for the characterization of granular materials used as base and sub-base layers in flexible pavements. This mechanistic parameter is known to be influenced by the material physical conditions and the state of stress the material is subjected to. The research work reported herein examines the effect of one of the construction variables, namely compaction, on the resilient modulus. The study involves an analytical simulation, using the Discrete Element Method (DEM), to quantify the effect of compaction, as measured by relative density, on the resilient modulus. It consists in performing analytical simulations on an assembly of particles compacted to three degrees of compaction and subjected to the same state of stress usually used in laboratory testing. Results confirmed the major role that density plays in defining the resilient behaviour of granular materials. Findings consolidated the potential of the DEM technique for modeling the resilient behaviour of these materials.

Introduction

The resilient modulus is a key element in the design and rehabilitation of pavement structures. It was introduced by the American Association of State Highway and Transportation Officials (AASHTO) in the design of pavements in 1986. It closely simulates the in-situ conditions in terms of traffic and environmental loading (Brown, 1977). The resilient modulus, M_r, is a mechanical property of the material. It describes its stress-strain relationship under dynamic loading and specified physical conditions. In repeated triaxial load tests, M_r is defined as the ratio of the peak deviator stress (σ_d) to the recoverable axial strain (ε_r):

$$M_r = \sigma_d / \varepsilon_r \tag{1}$$

This paper presents analytical simulations of the resilient modulus test using the discrete element method (DEM). This work aimed at delineating the effect of compaction on this modulus.

Numerical Investigation

Resilient Modulus Test Simulation

Simulation of the resilient modulus test using DEM required preparation of a sample and application of a repetitive load. Particles were randomly generated during sample preparation and they did not touch one another. The particles were then compacted by moving the lateral rigid boundaries inwards. When proper compaction was achieved, the lateral boundary velocities were set to zero and iterations were continued until particle velocities converged to zero (Equilibrium State). Boundary particles of the compacted sample were identified and used to form flexible boundaries and apply confining pressure to the sample. The configuration of these flexible simulated membranes changed during the test and was updated at regular intervals. A prepared sample for which the flexible boundaries are shown in black is presented in Figure 1. The lines between particles represent interparticle forces and the width of each line is proportional to the magnitude of the force. The lateral, rigid boundaries used for sample compaction were retracted (see Figure 1) and served no function during further testing.

The loading stage subjected the compacted and confined samples to a repetitive deviator stress at the top boundary.

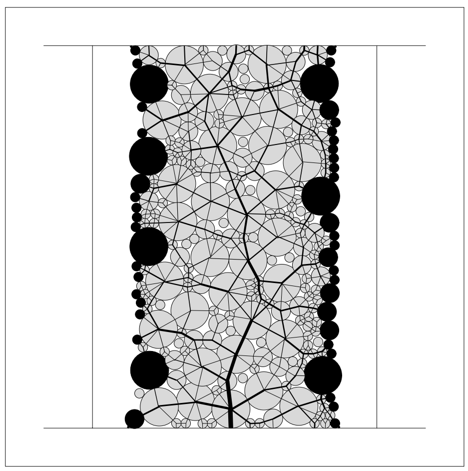

Figure 1: Confined sample

Testing Program

To study the effect of compaction (density) on the resilient behaviour of aggregate materials, three samples were fabricated and loaded, and their resilient modulus determined. The three samples represent loose, medium and dense states of the material. The sample contained three different particle sizes, which were proportioned as designated in Table 1. The physical properties of the particles used in the simulations are listed in Table 2. The three samples were tested under a confining pressure of 35 kPa and a deviator stress of 70 kPa.

Table 1. Particle size distribution

Particle Size (mm)	Percentage (%)
10	15
5	20
2.5	65

Table 2. Particle physical properties

Physical Property	Sample #1
Normal Stiffness (kPa)	0.5e5
Shear Stiffness (kPa)	0.5e5
Density (g/cm^3)	2.70
Friction	0.5

Results

During each loading cycle, the maximum deviator stress at the end of the loading phase was noted and the total corresponding strains were calculated. Further, the residual (plastic) strains were evaluated at the end of the unloading phase. The resilient modulus was then calculated as the ratio of the maximum deviator stress to the elastic strains (total strains minus plastic strains). Table 3 presents the resilient modulus results for the three samples studied. It shows that increasing the density of aggregates results in higher resilient moduli.

Table 3. Resilient modulus results

Sample State	Loose	Medium	Dense
Resilient Modulus (MPa)	150	215	320

Conclusions

Numerical simulations of the resilient modulus test showed that DEM is capable of reproducing the resilient behaviour of aggregate materials under cyclic loading. Simulations at three different states confirmed the effect of density on the resilient modulus and the need to have a good control on compaction in the field.

References

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