Evaluation of dilatancy during pullout test by DEM

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1 Introduction

The pullout test was probably the most commonly used in the reinforced soil practice and study. It was believed to be able to evaluate the reinforced mechanism in more detail. On the other hand, numerical analysis such as FEM was effectively used for the prediction of displacements, strains, and forces generated in the reinforcement. Although soil was a kind of discrete material, it had been traditionally treated as continuum material. However, the discrete element method (DEM) was based on discrete feature of soils. The DEM analyzed complex response of an assembly of discrete soil particles from essential contact laws between soil particles. The DEM held much promise as a tool for investigating aggregate-geogrid composite systems. And due to the advantage of DEM that it could provide micro scale information which was difficult to be obtain through experiments. This paper presented DEM simulation of geogrid pullout behavior and evaluated the dilatancy behavior during pullout test.

2 Implementation of the pullout test environment

Two-dimensional DEM model of the pullout test using PFC^{2D} was shown in Fig.1, displaying a soil sample of disks and embedded geogrid in the middle of the pullout box. The dimensions of DEM pullout test model was 300mm in width and 370mm in height, corresponding to real tested pullout apparatus. Using servo-control, the velocity of top wall was adjusted in a feedback loop to achieve a target vertical stress σ_v. The DEM soil sample used in this study differed from tested soil; however their grading distributions were similar.

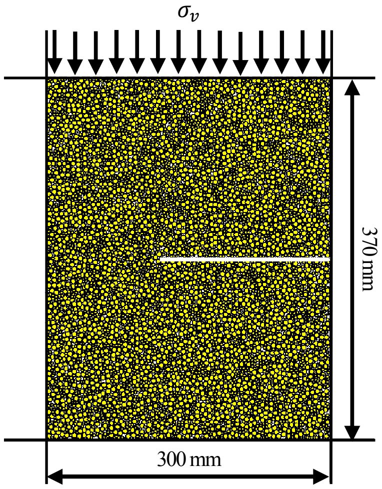


Fig.1. DEM model of pullout test

A Mohr-Coulomb liked slip contact model of DEM was applied to enable close coupling of the simulation and soil physical behavior, Microscopic parameters of DEM soil sample were adjusted by numerical biaxial tests. Geogrid was modeled as bonded particle chain. Because the geogrid pullout resistance was made up of frictional resistance and bearing resistance of transverse ribs. Therefore to take into account the influence of geogrid shape, the junction of geogrid was simulated using a cluster of bonded particles to reflect the influence of bearing resistance (shown in Fig.2). Microscopic parameters of DEM pullout model were given in Table 1.

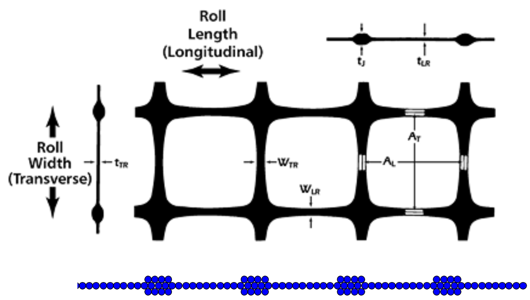


Fig.2. General dimensions and DEM model of geogrid

The simulation result was compared with the experimental pullout test in Fig.3. The pullout simulated result was close to the experiment results when displacement was small. They were different when pullout displacement increased. This difference might due to that the boundary condition of the front wall was hard to be simulated accurately when junction unit was pulled out. The DEM pullout model was reasonable when pullout displacement was small.

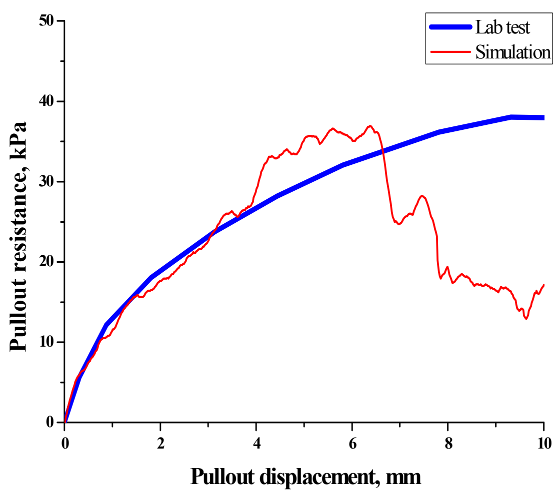


Fig.3 Pullout resistance as a function of displacement

Table 1 Microscopic parameters for DEM model of soil and geogrid

Parameter for soil assembly	Value	Parameter for geogrid	Value
Density, g/m^3	2.63	Density, g/m^3	0.191
Contact normal stiffness, kN/m	2.0×10^5	Radius, mm	1.0
Contact shear stiffness, kN/m	2.0×10^5	Contact normal stiffness, kN/m	2.36×10^5
Interparticle friction angle	40.1°	Contact shear stiffness, kN/m	2.36×10^5
		Contact bond normal strength, kN	1.0×10^3
		Contact bond shear strength, kN	1.0×10^3
		Geogrid interface friction coefficient	0.843

3 Results and Discussions on DEM analysis

Due to dilatancy during pullout test was an important behavior in reinforced soil practice. It linked with the mechanical behavior of reinforce soil structures such as confining effect of reinforcement and compaction effect of soil material. Therefore the dilatancy behavior during pullout test was analyzed by DEM here.

The recorded dilatancy in DEM pullout test analysis associated with porosities was shown in Fig.4. The vertical displacement was taken as the wall displacement of the top wall maintaining vertical stress in pullout test. Vertical displacement was found to be smaller at loose soil sample, consistent with the widely known phenomenon in which soil dilatancy increased with an increase of soil density. In field condition, this meant that compaction effect obviously influenced the dilatancy behavior and the performance of reinforced soil structure.

In more details Fig.5 illustrated the vertical displacement field for different density. The porosities were 0.17 and 0.19 respectively. It was shown that great vertical displacement of soil particles occurred in a comparatively small zone in the vicinity of reinforcement in the middle of pullout box. And the magnitude of dilatancy was greater in denser soil sample.

And to investigate the influence of geogrid on dilatancy during pullout test, two different geogrid shapes were investigated in the DEM analysis. One DEM geogrid model had five junction units and five rib units, corresponding to the real geometry of tested geogrid, and the other only had one junction unit (shown in Fig.6). The analysis was performed under the same porosity 0.18. When only one junction unit existed, great dilatancy occurred around the unique junction unit in the center of the pullout box. And the dilatancy accumulated when junction unit increased. It was shown in Fig.6 that bearing force of transverse ribs was an more important factor influencing the dilatancy behavior comparing with friction forces.

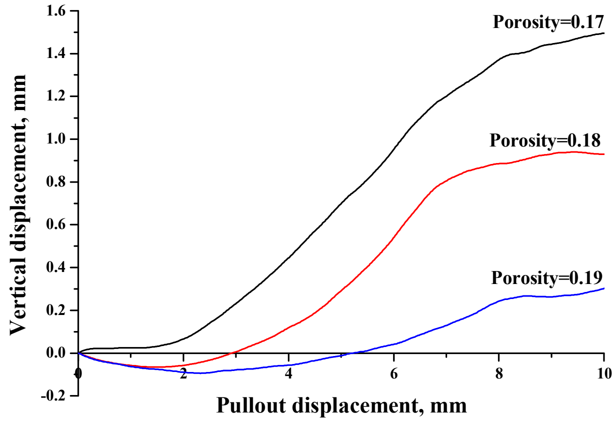
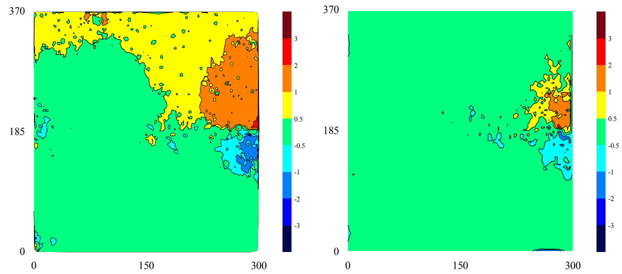


Fig.4 Vertical displacement of top wall for different porosities



Porosity=0.17 Porosity=0.19

Fig.5 Vertical displacement field for different porosity

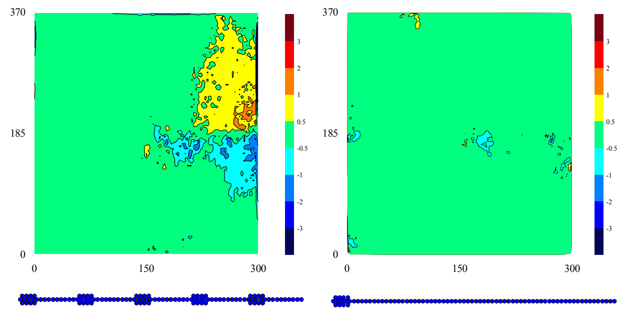


Fig.6 Vertical displacement field for different geogrid shape

4 Conclusions

Here presented a DEM pullout model to evaluate the dilatancy behavior during pullout test. The DEM pullout test model was demonstrated reasonable and helpful. The DEM pullout model could reasonably reflect the influence of density and geogrid shape on the dilatancy behavior during pullout test. The DEM pullout model reflected that the dilatancy was clear in vicinity of geogrid and the dilatancy mainly caused by the bearing force of transverse ribs of geogrid. Further investigations were needed to approximate the dilatancy behavior linked with confining effect of reinforcement and compaction effect of soil by DEM quantificationally.

Reference

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