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Reverse Extrusion Test for Fine-grained Soil Characterisation: Internal Flow Pattern with ANN-Enhanced Particle Tracking

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1 INTRODUCTION

The reverse extrusion test involves one-dimensionally (1D) compressing a fine-grained soil sample contained in a cup container of cross-sectional area A. The force F_e applied by the loading platen causes extrusion of the soil to occur via a small and centrally located orifice on the platen. The applied force is continuously monitored during the test, with the pressure value causing extrusion (i.e., $p_e = F_e/A$) proposed as a means of quantifying the undrained shear strength and consistency limits of fine-grained soils [1]. Previous experimental results showed that the p_e value correlates well with undrained shear strength at various water content for a specific soil type [2]. However, their relationship varies between soils and also depends on the compression velocity. Gas bubbles entrained during sample preparation and the complex internal flow pattern and possible localized sample consolidation that occur during the extrusion test [2] hinder understanding of the mechanism of the extrusion test. Thus, we adopted X-ray computed tomography (CT) combined with a recently developed marker-based tracking algorithm [3,4] to quantify the internal flow pattern of saturated kaolinite during extrusion tests.

2 METHODOLOGY

We developed a reverse extrusion apparatus manufactured from nylon plastic, which was transparent to X-ray. The internal dimensions of the sample container were 38 mm in diameter and 40 mm deep. The extrusion apparatus was fitted into an axial loading frame with detachable loading platen that included a central 6 mm diameter orifice. A stepping motor vertically displaced the loading platen, inducing a build-up in the platen axial force and causing extrusion to occur on reaching the p_e value. A load cell and displacement transducer recorded the axial force and platen displacement throughout the test.

We prepared the test sample by mixing kaolinite (IMERYS, Speswhite) with deionised water to produce a water content of 57% (i.e., lower than its liquid limit of 67%). Some sand particles (300–600 μm size range) were added to the kaolinite paste as markers for particle tracking. The kaolinite sample within the extrusion apparatus was compressed at a platen axial displacement rate of 1 mm/min. Once the p_e value was reached, we stopped the loading, fixed the detachable loading platen to the extrusion apparatus, and then carefully removed them from the loading frame.

The extrusion apparatus and the kaolinite sample therein were scanned using an X-ray CT scanner at a spatial resolution of 28 μm. Then we carefully put the extrusion apparatus back into the loading frame and recommenced the sample loading, this time to achieve a 2.13 mm platen axial displacement, before running a second X-ray CT scan of the compressed kaolinite sample. The sand particles embedded within the kaolinite were tracked between the first and second scans to measure their displacement using particle morphology and location information. Artificial Neural Network (ANN) was used to optimize the tracking algorithm [3,4].

3 RESULTS & DISCUSSIONS

Preliminary results are shown in Fig. 1 to demonstrate the internal soil flow pattern measured from particle tracking. Here, the arrows represent the projection of displacement vectors for individual sand particles (markers) on the vertical (*x*–*z*) plane between the two X-ray scans. Note that the sample container (i.e., rather than the loading platen) was selected as the reference to calculate displacement. As expected, the soil remote from the orifice experienced significantly less disturbance and showed negligible displacement (region P1 in Fig. 1). The soil close to the loading platen, indicated by the horizontal line at 'Orifice', moved upwards and resulted in an arch-shaped flow pattern (region P2 in Fig. 1) towards the central orifice through the loading platen.

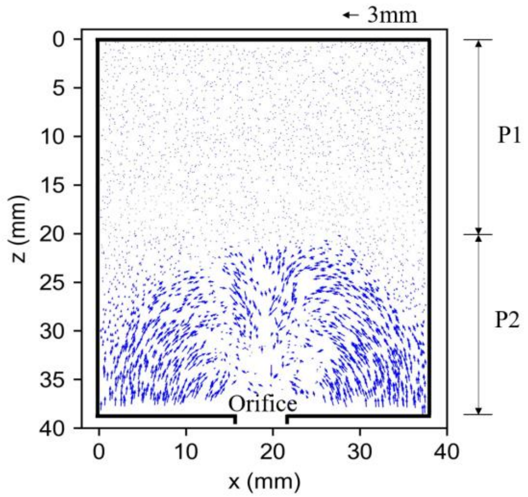

Figure 1: Soil flow pattern of partial slice projections for reverse-extrusion test

4 CONCLUSIONS

An ANN-enhanced particle tracking method was employed to measure the internal soil flow patterns during a reverse extrusion test. Results show two sample regions having distinctly different displacement patterns. The region close to the loading platen with a central orifice opening showed an arch-shaped flow pattern of the soil extrusion through the orifice, while the soil remote from the loading platen at the closed end of the sample container experienced negligible displacement. The internal flow patterns demonstrated that the image processing technique, enhanced by machine learning, can facilitate further analysis on the mechanism of the reverse extrusion test.

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