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Early detection of seepage-induced internal erosion using acoustic emission monitoring

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Abstract

Techniques for monitoring water-retaining earth structures are currently limited in their capacity to detect seepage-induced internal erosion (e.g. suffusion) in its early stages, or before serious damage has occurred. Acoustic emission (AE) is widely used in many industries for non-destructive assessment of materials and systems, but despite its advantages it is seldom used in geotechnical engineering as the AE generated by particulate materials is highly complex and difficult to measure and interpret. This project aims to develop the interpretation of AE generated by seepage-induced internal instability phenomena. A continuous, real-time AE early warning system for detecting seepage erosion mechanisms and processes will enable safety-critical decisions to be made. Laboratory testing with a large permeameter apparatus is being used to characterise and quantify the AE generated by the hydromechanical behaviour of a range of internally unstable soils. Initial results show that key processes such as the internal movement of particles can be measured and interpreted using AE.

Introduction

A long-standing problem with the longevity of water-retaining earth structures is their vulnerability to seepage-induced internal erosion – in the United Kingdom alone millions of people rely on ca. 2200 large embankment dams and 7500km of levees for flood protection, clean water supply and renewable energy (ICOLD, 2014), with internal erosion and piping being their main cause of failure (Fell and Fry, 2007). Current monitoring techniques have technological or financial limitations for the deployment of reliable early

high frequency stress waves (> 10kHz) generated by mechanisms and processes occurring inside a material. AE from particulate materials is highly complex and difficult to measure and interpret, thus being seldom used in geotechnical engineering. However, a body of research has demonstrated its significant potential for use in the monitoring of soil behaviour (Koerner et al., 1981; Smith et al., 2017; Smith and Dixon, 2014). This project aims to develop methodologies to interpret the AE generated by seepage-induced internal instability, the basis for a real-time early warning system enabling safety-critical decisions to be made (e.g. evacuation of vulnerable people, timely and targeted interventions).

Methodology

Element testing with a large permeameter apparatus (Figure 1) is being used to analyse the AE generated from internally unstable soils subjected to a range of hydraulic regimes. Parameters of AE are being quantified in both time and frequency domains for comparison hydromechanical behaviour. This paper presents results from testing the material in Figure 2, which was homogenized and subjected to horizontal water flow.

Results and Discussion

Migration of finer particles through voids in the soil skeleton was observed in the direction of seepage flow throughout the test. Figure 3 shows the amplitude ratio frequency spectrum for this test, showing significant AE in the 20-

45kHz range. Seepage erosion generates AE through several mechanisms, including particle collisions and frictional interactions (Koerner et al., 1981; Ferdos et al., 2018).

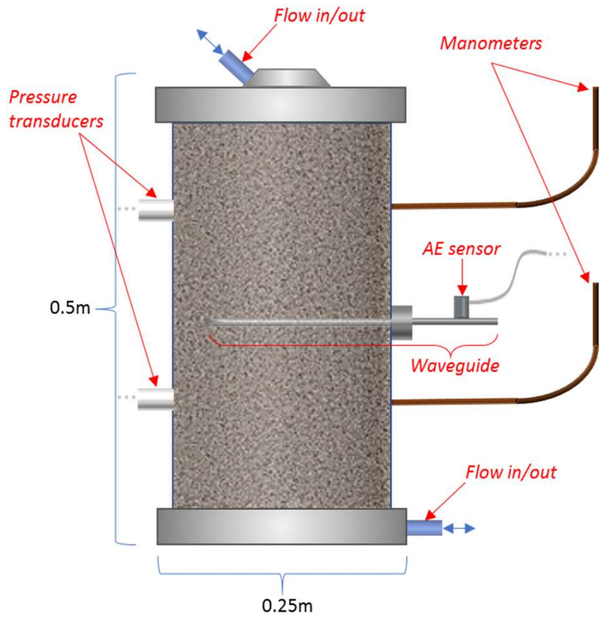

Figure 1. Permeameter schematic.

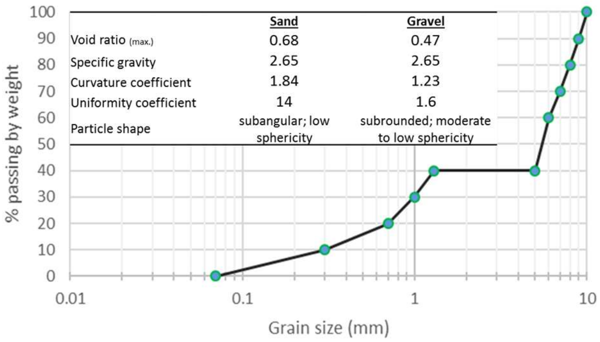

Figure 2. Grain size distribution and properties of the tested specimen.

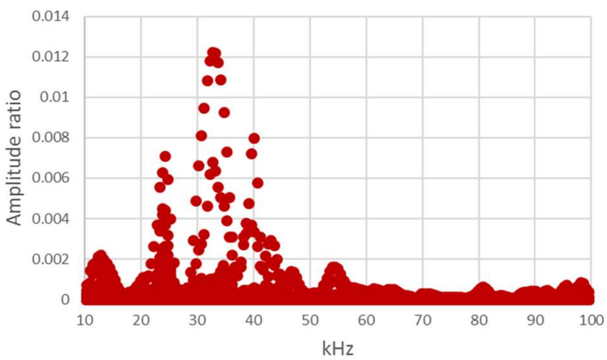

Figure 3. Scatter plot of amplitude ratio and AE frequency from experiment.

Conclusions and Future Work

This paper has introduced the use of AE to detect and interpret seepage-induced internal instability, which was demonstrated by preliminary results from permeameter tests. An on-going experimental programme aims to characterise the AE signatures generated by different mechanisms and behaviours in internally unstable soils under varied hydraulic regimes, aiming to develop methodologies to interpret the AE for early detection of seepage erosion. A new permeameter is in development to enable control of effective stress and measurement of volume change. Field trials are also planned to assess performance of the approach in the field environment.

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