Ground characterization using cross-hole radar: ZOP configuration in weathered limestone

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ABSTRACT

A borehole transillumination GPR survey conducted using zero offset profiling was performed at a geotechnical test site in central Florida to characterize subsurface conditions. These conditions consist of approximately 6 meters of clayey/sandy-clay soil overlying variably and highly weathered limestone. The test site has five PVC cased boreholes arranged in a “plus sign” (+) pattern aligned roughly in an east-west and north-south direction with each borehole spaced approximately 3 meters apart. The depth of each borehole is approximately 18 meters. The GPR survey was conducted along the east-west direction. The radar velocity results from the GPR survey clearly show a transition between soil and weathered bedrock and the effect of the water table on radar velocities. The radar velocities within the limestone clearly show two distinct limestone zones; an upper highly weathered zone with relatively low radar velocities and a lower less weathered zone with relatively high radar velocities. The interface between the two distinct zones occurs at different depths within the boreholes. The radar velocities recorded in the limestone are much lower than typical published values for limestone but are the very similar to radar velocities from other studies in highly weathered limestone.

INTRODUCTION

Ground penetrating radar (GPR) is a non-intrusive geophysical characterization tool which uses electromagnetic (EM) waves to image the subsurface. GPR is used in a variety of scientific fields such as archeology, forensics, geology, and geotechnical engineering. Within the realm of geotechnical engineering, GPR is often used for infrastructure assessment, cavity detection, and determining stratigraphy. For most geotechnical applications GPR surveys are conducted in reflection mode; a transmitter on the ground surface sends EM waves into the subsurface and the waves are reflected back to a receiver when they encounter a material of a different dielectric constant. The depth of penetration of the EM waves is a function of soil type and frequency of the transmitter. In general, the smaller the EM wave frequency the deeper the penetration but the lower the resolution. When a very detailed and deep survey is required, it is often advantageous to use a borehole radar system to conduct cross-hole surveys (for example Rucker and Ferré, 2004).

Borehole ground penetrating radar surveys have been used for numerous geotechnical, geological, and hydrogeological investigations. Examples of such investigations include dielectric properties of frozen soils and permafrost (Hunter and others, 2003), liquefaction
Unconfined compressive strength of 4-inch plaster cubes containing large voids

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ABSTRACT

The presence of large voids ("macroporosity") can have a large influence on the engineering properties of materials, but quantifying this influence is not a simple undertaking due to the variation in void size, shape, and spacing. In a recent Montana Tech master's thesis, the influence of void spacing was investigated using 4" cubic specimens containing seven 0.5" diameter cylindrical voids oriented in a cluster around the center of the specimens. Numerical and experimental results suggest that void spacing has significant influence on unconfined compressive strength (UCS); the controlling factor appears to be the width of the solid "pillars" that are able to carry load. The work described in this paper is an expansion of the earlier study, in which some of the voids in the cluster are not present. Sixty-two-dimensional FLAC numerical models containing three and five 0.5" diameter voids produced evidence supporting the interpretation that "pillar" size controls the specimen UCS: in all cases except one, the UCS values of the three and five void configurations were moderately to significantly different from those with the seven-void cluster only when the pillar size was substantially increased. Twenty-five specimens were tested in the laboratory to verify the results of the numerical models.

INTRODUCTION

The presence of large voids, known as "macroporosity," can have a substantial influence on the engineering properties of macroporous rocks such as lithophysal tuff, vesicular basalt, and vuggy limestone. Researchers at Montana Tech and the University of North Florida have recently been collaborating on this topic, using an integrated approach combining experimental work with numerical modeling to investigate and quantify the influence of the macropores.

In a recent Montana Tech master's thesis, the effect of macropore spacing and orientation on unconfined compressive strength, stiffness and failure mode was investigated using laboratory testing and 2D and 3D numerical models (Jespersen and others, 2008a, 2008b, 2009, 2010). A total of 72 plaster cubes were prepared and tested, 56 of which contained seven equally spaced 0.5" diameter circular macropores, in a cluster configuration with six macropores surrounding one central macropore. All macroporous cube specimens had a total macroporosity of 8.6 percent. The specimens were created with four different center-to-center macropore spacings in order to investigate the influence of distance between macropores. The bulk of the numerical analyses consisted of two-dimensional plane strain unconfined compression testing of square specimens with circular voids using Itasca's FLAC software. The numerical results, verified
Influence of spherical voids on the unconfined compressive strength of plaster cylinders: preliminary results

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ABSTRACT

In order to quantify the influence of large voids on the unconfined compressive strength (UCS) of macroporous materials, fifty-four 3”x6” plaster cylinders have been created, containing up to twenty-four 1” diameter spheres representing large voids. The UCS of each specimen is being determined in the laboratory, after which the specific location of each of the spheres is found. A FLAC3D numerical model is then created for each specimen, and the UCS determined via numerical simulation of the laboratory test. To date, 17 specimens have been tested in the laboratory, and three numerical models have been completed. Although the numerical and experimental results do not agree perfectly, the UCS values determined in the laboratory are lower than the numerically determined UCS values, as expected. The new results, both numerical and experimental, are within the range of data previously collected.

INTRODUCTION

Researchers at Montana Tech and the University of North Florida are collaborating to investigate the influence of large voids on engineering properties of macroporous materials. A previous component of the study (Erfourth, 2006; Morrison and others, 2007) focused on quantifying the decrease in unconfined compressive strength (UCS) and elastic deformation modulus (E) due to the presence of spherical voids of different sizes. The research consisted of both laboratory testing and numerical modeling, and showed good comparison between the two methodologies.

Figure 1 (Erfourth, 2006) shows a graph of the unconfined compressive strength of the laboratory and FLAC3D numerical specimens containing 1” diameter spherical voids, normalized by dividing the macroporous UCS by the UCS of a solid specimen to highlight the deleterious effect of the large voids. The two sets of data overlap significantly, with the laboratory data displaying slightly lower UCS values, presumably due to material flaws that are not present in the numerical models. The macroporosity of the specimens ranges from 0-46%, corresponding to the presence of zero to 36 spherical voids in the 3”x6” cylindrical specimens. While many of the laboratory and numerical specimens contained the same number of voids, and hence the same macroporosity value, the positions of the voids within the specimens were different. Since the engineering properties are influenced by not only the number of voids, but also their relative locations, the data are not expected to be identical.
Interfacing a rotary stage and DSLR camera for an automated core photography system

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ABSTRACT

When a cylindrical object, such as a core specimen is photographed there is significant distortion of surface features at the edges of the image. The resulting image is unusable for analyzing any surface features and can only be used as a specimen identification tool. A laboratory specimen photography system code named GeoTable has been developed to overcome these limitations. The system consists of a retrofitted manual rotary stage interfaced with a DSLR camera and a laptop computer. The GeoTable is able to automatically capture images of the complete specimen surface in an integer number of degrees specified by the user. A full description of the GeoTable system is described in the paper.

INTRODUCTION

A comprehensive investigation of laboratory rock properties should include, at a minimum, surface photographs of each specimen to be tested. A single photographic image can only capture less than 180 degrees of a cylindrical specimen surface. Since the specimens are cylindrical, the shape and orientations of surface features are distorted in photographs. As a result, most specimen photographs are only used to identify specimens and qualitatively describe surface features such as layering and orientation of discontinuities.

To overcome these limitations an automated laboratory core specimen photography system named GeoTable has been developed. The system consists of both hardware and software components; a custom computer controlled rotary stage and digital camera. A manual rotary stage was retrofitted with a stepper motor and gearing system and specific software was written to control the stepper motor. The same software also controls a digital camera. The stepper motor and digital camera are interfaced with a laptop PC via USB ports. This paper describes the hardware, software, and set-up of the GeoTable system for imaging prepared core specimens.

HARDWARE COMPONENTS

The hardware components of the GeoTable system consist of a manual rotary stage that has been retrofitted in order to be rotated using a microcontroller-controlled stepper motor. The
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