Engineering Geology 220 (2017) 52–64

Contents lists available at ScienceDirect

Engineering Geology

journal homepage: www.elsevier.com/locate/enggeo

Field scale hydraulic conductivity and compressibility of organic clays

Navid H. Jafari [a,*], Timothy D. Stark [b]

[a] Dept. of Civil and Environmental Engineering, Louisiana State University, 3504 Patrick Taylor Hall, Baton Rouge, LA 70803, United States
[b] Dept. of Civil and Environmental Engineering, Univ. of Illinois, 205 N. Mathews Ave., Urbana, IL 61801-2352, United States

ARTICLE INFO

Article history:
Received 3 August 2016
Received in revised form 30 December 2016
Accepted 14 January 2017
Available online 20 January 2017

Keywords:
Hydraulic conductivity
Soil compressibility
Scale effect
Transient seepage
Consolidation
Organics

ABSTRACT

This paper uses the results of an extensive subsurface investigation performed along the Inner Harbor Navigational Canal in New Orleans, Louisiana to identify the scale effect of soil hydraulic conductivity (K) and compressibility (m_v) for geotechnical and geoenvironmental analyses. The magnitude and variability of soil hydraulic conductivity and compressibility parameters were obtained from laboratory 1-D consolidation and permeameter tests, CPTu dissipation tests, field piezometer slug tests, and multiple well pump tests. The geometric means of horizontal hydraulic conductivity (K_h) measured by the laboratory permeameter, slug, and field pump tests are 2.5×10^{-7}, 1.6×10^{-6}, and 1.3×10^{-5} cm/s, respectively. This represents a scale effect of about 50 times when increasing the sample volume tested from the laboratory to field scale. The uncertainty in vertical hydraulic conductivity (K_v), K_h, and m_v values was determined using a coefficient of variation, which ranges from 0.34 to 0.73. While K_h is scale dependent, a comparison of m_v evaluated from field pump and 1-D consolidation tests indicates that sample volume does not significantly impact measured values of m_v, which signifies that laboratory consolidation tests can be used to predict field scale compressibility.

© 2017 Elsevier B.V. All rights reserved.

1. Introduction

Evaluating the field-scale hydraulic conductivity and compressibility of soft organic clays that dominate fluvial-deltaic deposits, e.g., the Mississippi River Delta and Sacramento-San Joaquin River Delta, is important for geotechnical and geoenvironmental analyses, such as, seepage, stability, consolidation, and contaminant transport. In particular, increasing concentration of industry and population can lead to these fluvial-deltaic clays hosting a large number of chemical spills, superfund sites, and waste disposal facilities (Flawn et al., 1970; Taylor, 1993; Hanor, 1993). Because organic clays also overlie coastal aquifer systems, long-term groundwater withdrawals can result in significant consolidation of these aquitards and ultimately manifest as land subsidence at the ground surface. Examples of urban and agricultural regions affected by groundwater-induced subsidence of thick normally consolidated organic layers include the San Jacinto Basin and San Joaquin Valley in California; Houston-Galveston, Texas; and coastal Louisiana. For example, Smith and Kazmann (1978) estimate approximately 0.4 m of local subsidence in Baton Rouge, Louisiana from 1935 to 1976 due to groundwater withdrawal.

In addition, deltas in Louisiana and California are protected against flooding and storm surges with earthen levees and floodwalls. This infrastructure is prone to long-term settlement due to underlying organic soils and areal subsidence, which results in expensive maintenance costs to periodically raise levee and floodwall crest elevations to maintain flood design. For example, Stark and Jafari (2015) show that the floodwall along the eastern side of the Inner Harbor Navigational Canal (IHNC) had settled 0.46 to 0.61 m (1.5 to 2.0 ft) prior to Hurricane Katrina due to areal subsidence. To predict the time-dependent contaminant migration and rate of consolidation of aquitards and levee foundation soils, the underlying soil hydraulic conductivity and compressibility estimated from laboratory or field measurements are necessary to represent the scale effects of larger geologic formations.

Hydraulic conductivity can be scale-dependent, and it is difficult to represent all in situ features, e.g., fissures, organics, bedding planes, sand/silt seams, among others, in a flexible wall permeameter given the small specimen diameter (Tavenas et al., 1983; Chapuis, 1990, 2004, 2012; Benson et al., 1994). Flexible wall permeameters are suited for testing relatively homogeneous natural deposits and engineered soils to assess the influence of effective stress changes. However, a drawback to laboratory testing is the tendency to select the most uniform or clayey samples because they are easier to trim and require less support (Olson and Daniel, 1981). The advantage of in situ testing is the potential for testing a representative volume of soil, with all in situ features, at the in situ stress state. Typical in situ tests can be conducted by driving a device into the ground (driven piezometer, cone penetrometer, and/or self-boring pressuremeter) or by drilling a borehole (standpipe piezometer slug, field pump, and/or borehole packer tests). These tests can directly or indirectly measure the in situ hydraulic conductivity. Slug tests and multiple well pump tests permeate fluid into the surrounding soil (Chapuis, 1998; Chapuis and Chenaf, 2002;

---

[*] Corresponding author.
E-mail addresses: njafari@lsu.edu (N.H. Jafari), tstark@illinois.edu (T.D. Stark).

http://dx.doi.org/10.1016/j.enggeo.2017.01.015
0013-7952/© 2017 Elsevier B.V. All rights reserved.

Chapuis et al., 2005), while indirect techniques (cone dissipation test) monitor the dissipation of excess pore-water pressure in the ground after expanding a cavity (Burns and Mayne, 1998).

The test interpretation used in the field assumes that the medium has uniform hydraulic conductivity. However, the subsurface is usually heterogeneous and variable, and may include features, such as fissures, sand/silt laminae, and/or organics. As a larger volume of the subsurface is tested, preferred flow pathways are encountered which leads to varying values of hydraulic conductivity at different scales. Available literature indicates an increase in hydraulic conductivity with specimen volume for geologic materials ranging from clay-rich glacial tills to alluvium to fractured rocks (Rovey and Cherkauer, 1995; Schulze-Makuch et al., 1999; Jones, 1993). Most of these data were obtained by comparing laboratory tests, field slug tests (piezometers and packer tests), and large pumping tests. In general, there is an overall increase in hydraulic conductivity as testing moves from laboratory scale (tested volume is 10^{-5} to 10^{-3} m^3), to borehole test scale (10^{-3} to 10^1 m^3), and to large field pump test scale (10^1 m^3 or more) (Ratnam et al., 2005).

Neuzil (1986) describes the many challenges faced to obtain estimates of hydraulic conductivity in low hydraulic conductivity formations, e.g., extrapolating small-scale and short-duration tests to larger scale and durations. As a result, limited data is available on the field-scale hydraulic conductivity and compressibility of organic clay layers. To quantify the scale effects of hydraulic conductivity, this paper uses the results of the field and laboratory testing program performed along the eastern side of the IHNC floodwall in New Orleans, Louisiana. The purpose of this testing program was to obtain estimates of in situ hydraulic conductivity and compressibility for floodwall seepage and stability analyses in organic clay and organic-rich layers that were found intermittently in the thicker marsh clay deposits underlying the IHNC floodwall. Because field pump tests are rarely performed in fine-grained strata, this paper also describes the equipment and analysis procedures of four field pump tests conducted during this study, provides a comparison between field and laboratory hydraulic conductivity and compressibility of organic clays, and discusses the variability of hydraulic conductivity along the IHNC.

2. Characterization of IHNC subsurface

The IHNC is located just west of the Lower Ninth Ward (LNW) in Saint Bernard Parish, Louisiana. The IHNC in Fig. 1 runs essentially north-south with the southern end connecting to the Mississippi River

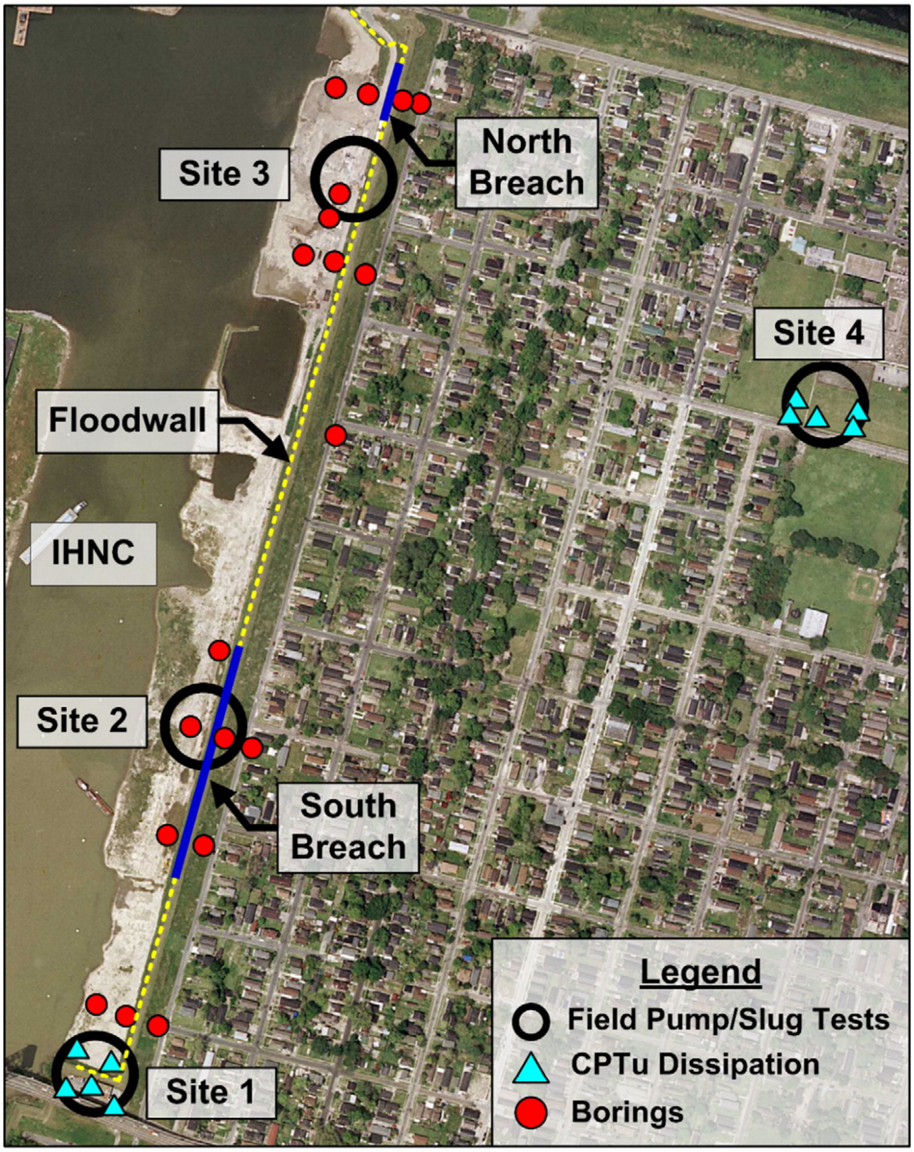

Fig. 1. Overview of IHNC and location of floodwall breaches, field tests, and borings used to obtain high-quality laboratory samples [background image courtesy of Gulf Coast Aerial Mapping (GCAM), with permission].

Download English Version:

https://daneshyari.com/en/article/5787589

Download Persian Version:

https://daneshyari.com/article/5787589

Daneshyari.com