Matric Suction Measurements in Soils

Mike Greenough
Community College of Vermont
Dr. Mandar Dewoolkar and Dr. Donna Rizzo
The University of Vermont

Abstract

Negative porewater pressures or matric suction in soils affect their transport, shear strength and compressibility properties. The presence of matric suction in streambank soils generate apparent cohesion (shear strength) and help keep streambanks stable. When the matric suction is lost with precipitation or rising stream levels, the bank soils may lose some of this apparent shear strength and collapse. Measurement of matric suction in situ are therefore very useful in understanding mechanisms involved in streambank failures. It is preferable to measure the matric suction in soils in situ in a borehole; however, this type of measurement is often difficult to make. An alternative is to make the matric suction measurement in a soil core removed from the ground, which is much easier to accomplish, but the relief of in situ stresses may alter the matric suction in the core altering the matric suction. Therefore, it was desirable to evaluate if the two methods yield same measurements, particularly because no study examining this aspect of the matric suction measurement was found in the literature. As part of this project, we made and compared matric suction measurements with a T5 Decagon tensiometer of soils of varied but known water contents in soil specimens prepared in a laboratory as well as in unknown field specimens.

Introduction

Matric suction is the pressure dry soil exerts on the surrounding soils to equalize the moisture content in the overall block of soil. In the unsaturated zone, or vadose zone, this pore pressure is determined by capillarity and is also referred to as soil tension, soil suction, or matric suction. Recent advances in the technology for measuring matric suction have permitted the direct measurement of gauge porewater pressures lower than –100 kPa (Take and Bolton 2003) with tensiometers. The tensiometers operate by allowing the pore water to come into equilibrium with a reference pressure indicator through a permeable ceramic cup placed in contact with the soil (pore water pressure). Quantitatively, the soil moisture suction is represented by the difference between the ambient air pressure and the soil pore water pressure (Ridley and Burland 1994). Soil suction and soil moisture content may be related to stream bank erosion rates, which is a driver of sediment and nutrient transport throughout a watershed. As soils become increasingly saturated they become heavier and more likely to fail and fall into the body of water eroding them. Also, as saturation increases, matric suction decreases, allowing the weight of the soil to overcome the cohesive strength of the soil, resulting in stream bank failure.

As part of this project, we compared matric suction measurements with a T5 Decagon tensiometer of soils of varied but known water contents in soil specimens prepared in a laboratory as well as in unknown field specimens. Measurements were made in situ inside a shallow borehole and in the core removed from the laboratory specimen or the ground at sites.

Materials

- Infield T5 laboratory tensiometer and compatible data logger (Figure 1).
- Laboratory scale
- Laboratory oven and pans
- Deionized water
- Soil sampler (Shelby tube)
- Agricultural soil for laboratory testing
- Large wooden container (inside dimensions of 80 cm x 80 cm x 90 cm high) for preparing laboratory specimens

Figure 1. T5 tensiometer and data logger

Procedures

1. Prepare soil samples of 80 cm x 80 cm x 90 cm with a target moisture content of 3%, 6%, 9%, 12%, 15%, 18%, 21%.
2. Core three soil specimens from each of the soil samples mentioned above.
3. Insert the T5 tensiometer approximately 6-8 inches below the soil surface and begin data monitoring (figure 2).
4. Allow the tensiometer to display matric suction until the reading plateaus and no longer changes, record the number shown on the INFIELD7 data logger.
5. Repeat steps 3 and 4 by inserting the tensiometer in the core removed from the soil specimen.
6. Collect approximately 20 grams from each sample and allow to dry in oven overnight to determine actual moisture content.
7. For the field study(Figure 3), use procedures outlined in steps three and four above.

Figure 2. Laboratory tensiometer measurements, July 2016

Figure 3. Recording matric suction readings from a "hole" sample at Lareau Farm, July 2016.

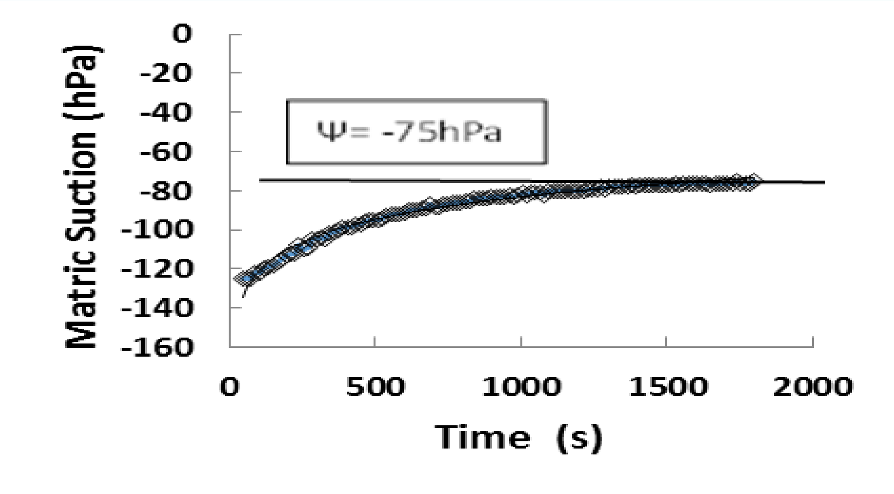

Figure 4. Typical matric suction (Ψ) measurement.

Results

Matric Suction in Laboratory Specimens

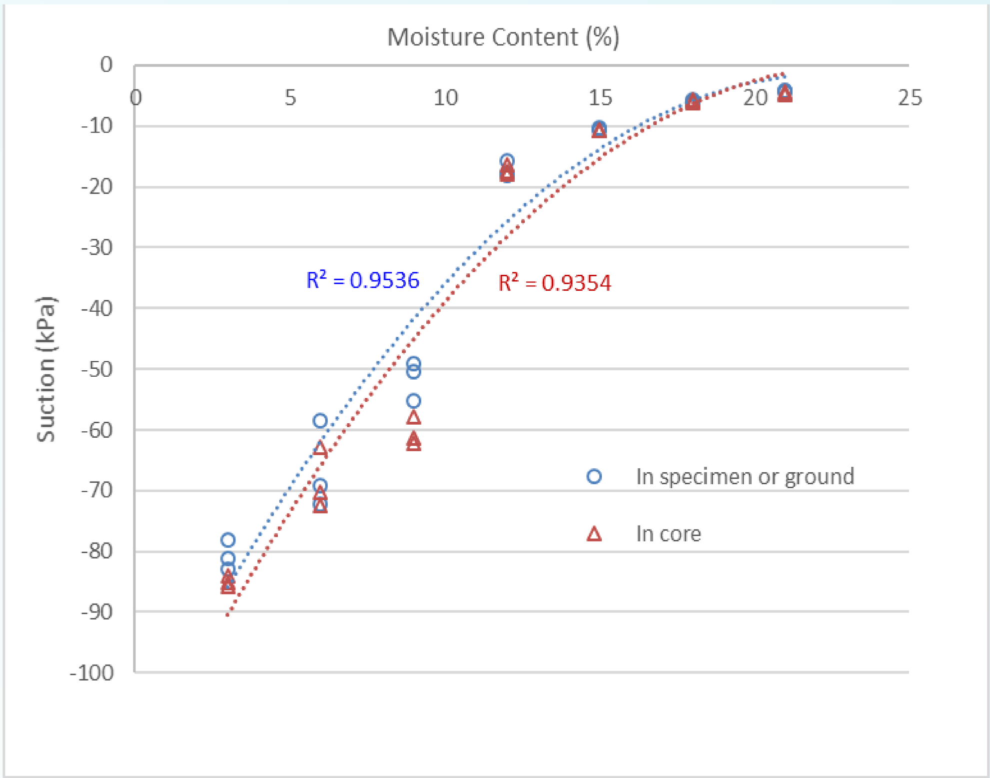

Figure 5. Matric suction decreases as moisture content increases, nonlinearly.

Correlation of Suction Measurements at all Moisture Contents

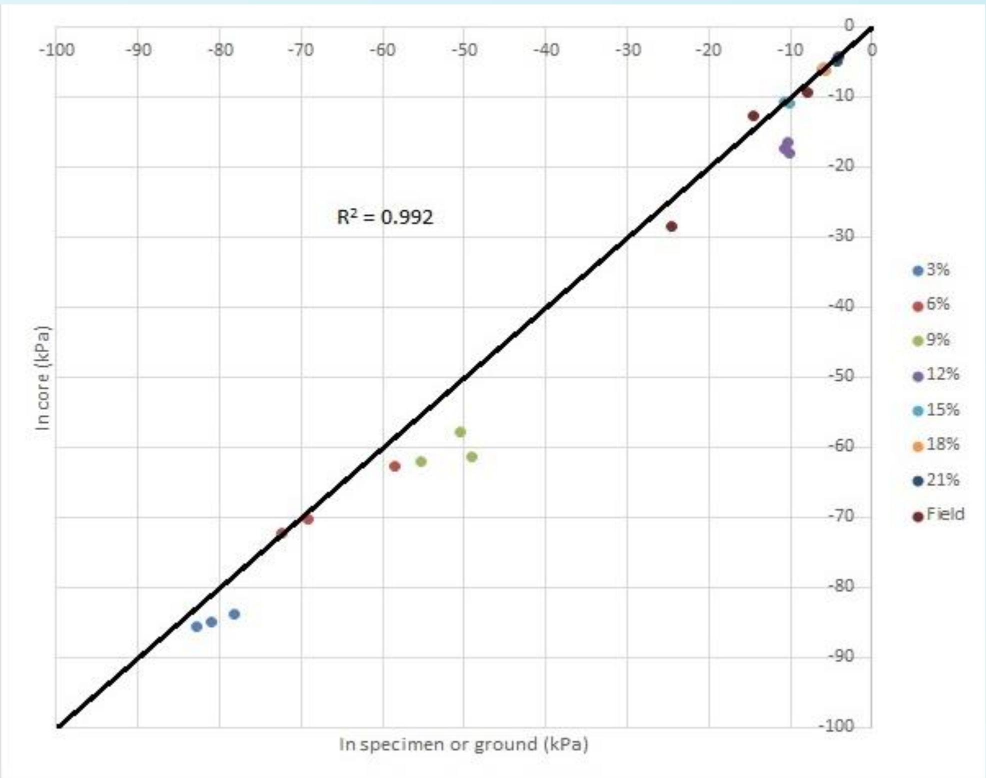

Figure 6. Matric suction measurements made "in situ" correlated well with both lab and field specimens.

Conclusion

Matric suction is displayed as a negative number in units of kilo-pascals (kPa), although it is customary to use the absolute value of these pressure readings (Figure 4). The matric suction decreased with increasing moisture content nonlinearly (Figure 5), which was an expected trend.

Figures 5 and 6 show that matric suction measurements made "in situ" in general compared well with those measured in the cores. This was observed for both the laboratory and field specimens. Any small differences observed were more pronounced at smaller moisture contents (<10%).

The results indicate that it is acceptable to measure soil matric suction in cores immediately following their removal from the ground instead of making matric suction measurements in situ in small boreholes.

Acknowledgments

First, I would like to acknowledge my fellow Q2 team members, Carly, Christina, and Joanne. Thank you for all your help and hard work. You made this an amazing internship experience. To the outreach team members of Baxter and Rachel, thank you for being there to answer our questions, give us guidance, and for the keys to the soils lab. Thanks to Jeff Frolik and Blake Hewgill for fixing our VNA's on multiple occasions. Thank you to the Q2 mentors, Mandar Dewoolkar, Donna Rizzo, Jodi Stryker, Kristen Underwood, Justin Guilbert, John Lens, and Scott Hamshaw for putting your trust in our abilities, having faith that we will get the job done, and for the advice and motivation you have given me to be successful. Finally, I would like to thank Vermont EPSCoR and CWDD for selecting me for this internship and giving me the opportunity to participate in this wonderful program.

The Q2 Team (from left to right), Mandar, Rachel, Mike, Carly, Joanne, Christina, Baxter, and Donna.

References

Ridley, A. M., & Burland, J. B. (1994). A new instrument for the measurement of soil moisture suction. *Geotechnique 43,* 321-324.

Take, W. A., & Bolton, M.D. (2003). Tensiometer saturation and the reliable measurement of soil suction. *Geotechnique* 53, No. 2, 159–172.

Funding provided by NSF EPS Grant #1101317

T5 Schematic