Development of a Dimension Reference Tool for Field Estimation of Soil Plasticity

Mike Krcmarik, EIT, SoiloftheMonth.com
3/13/2016

Soil plasticity and methods of estimation are discussed. A dimension reference tool for estimation of soil plasticity in the field is proposed.

1. Introduction

Plasticity describes the ability of a soil "to be shaped into different configurations without cracking and to hold a shape unsupported after reshaping" (USDA SCS 1987) (Figure 1). Plasticity aids in prediction of a soils engineering behaviors such as permeability, compaction, volume change, and strength. Prediction of soil behavior is required for successful geotechnical engineering.

Figure 1. High plasticity soil (top) and low plasticity soil (bottom) Photo@soilofthemonth

All soils exhibit plasticity however the range of water content over which they exhibit plasticity is unique. This water content range is termed the plasticity index (PI). Laboratory measurement of the upper bound of the PI, the liquid limit, is determined by measuring the moisture content at which a standard groove formed in soil closes after a standard number of blows. The lower bound of the PI, the plastic limit, is determined by measuring the moisture content at which a standard thread can be rolled before it begins to crumble (ASTM D4318). A private testing lab in the vicinity of the author charges $75 to measure PI and requires 3 days to complete testing.

Estimation of soil plasticity is useful when immediate results are desirable and laboratory precision is not warranted or feasible such as during field work, initial site characterization, estimating, and construction inspection. Estimation of any soil property is, at its most basic, finding behaviors unique to a given property that can be repeatedly observed in the field. Numerous frameworks, methodologies, and rules of thumb exist to codify and quantify learning estimation. However it is in this author's opinion that the only guaranteed method to accurately classify soil or estimate any property is significant calibration of one's self with known samples.

2. Methods of Plasticity Estimation

Frameworks for plasticity estimation are typically part of a soil classification system, such as the Unified Soil Classification System (USCS). Estimation of plasticity is therefore also useful as a means to predict a USCS Group which have unique index properties useful to designers. Estimation of plasticity is done on a qualitative basis, such as none, low, medium, or high plasticity. Conversion of these qualitative descriptors to quantitative values is available in the literature (Burmister 1949, Sowers 1979) or can be approximated with Casagrande's Plasticity Chart containing USCS Group Symbols.

ASTM D2488 (Visual-Manual Procedure)

Similar to the laboratory plastic limit test, the user attempts to roll a standard diameter thread. If the user is able to form the thread they will then fold the thread up and repeat until the thread crumbles when rolling is attempted. Based on the ease of rolling and time required to reach the plastic limit the sample is placed into one of four plasticity categories, nonplastic, low, medium, and high (ASTM D2488) (Figure 2). The requirement that material finer than the #40 should be removed from the sample is impractical in the field, however rolling small diameter threads can be difficult as gravel and sand particles serve as premature breaking points along the thread. Users have to calibrate themselves to the appropriate starting water content for rolling and the definition of ease of rolling and toughness.

Figure 2. Thread rolling to estimate plastic limit in the laboratory. Photo: Braja M. Das, Geotechnical Engineering 8th Edition

USDA-NRCS Soil Survey (NCSS)

The user attempts to roll a standard length thread to as small a diameter as possible at a water content where the maximum plasticity is expressed. Depending on the diameter obtained and if the roll can support itself plasticity is then defined as nonplastic, slightly plastic, moderately plastic, or very plastic. Slightly larger diameter threads in this method decrease breaking due to large particles and water content water content is not a variable. Users have to calibrate on how to support the thread each time and the definition of self-supporting.

2.2 Supplemental Tests

A number of additional tests exists to aid the user in determining plasticity. These tests are primarily used in conjunction with USCS classification, but are also useful outside the USCS framework to determine between two close plasticity groups such as low and medium.

Dry Strength Test

A half inch diameter ball is formed and left to dry overnight. The strength with which it takes to crush the dried ball between the thumb and forefingers is evaluated and an indication of plasticity. High dry strength is typical of high plasticity and low dry strength is typical of low plasticity. This test is simple and eliminates the variable of water content. However results are not immediate and cementing agents in the soil can influence results. The user must calibrate themselves on considerable pressure and low pressure terminology.

Ribbon Test

Soil is ribboned out between the thumb and forefinger until it breaks. A long ribbon is generally indicative of high plasticity. Calibration is needed to determine how thickness and length correlate to each plasticity grouping.

Shine Test

Soil is scraped with a knife and then examined for a shine. Shiny soils are indicative of high plasticity. Dull shines are generally indicative of low plasticity soils.

Dilatancy

A pat of soil is forcefully struck and then examined for free water appearing on the surface. The dilatancy phenomena is generally indicative of low plasticity (ML) and not a property of high plasticity. This test is difficult to pull off for the author.

Toughness

Soil in the plastic state is evaluated for ease at which thread rolling and kneading occurs. High toughness (considerable pressure) is indicative of high plasticity soil.

3. Measuring Devices

The plasticity frameworks and supplemental tests require the user to know quantitative dimensions, such as the thread diameter and length, in order to estimate plasticity. Typically rulers and other objects of known dimensions are used (Figure 3).

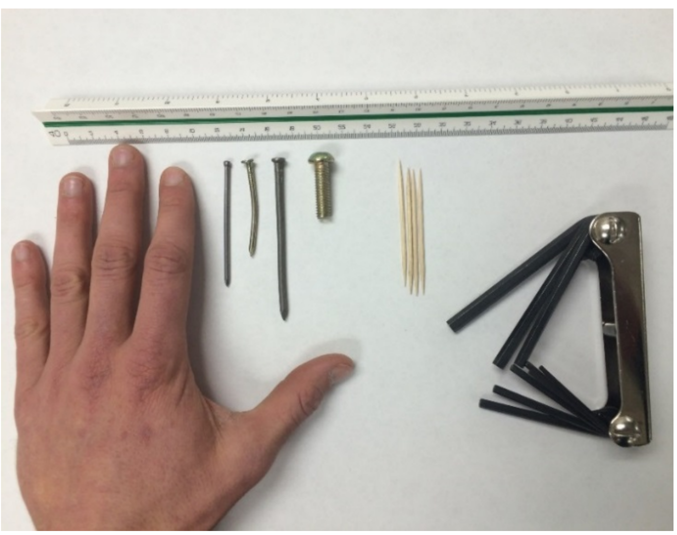

Figure 3. Typical objects of known dimensions used for plasticity estimation. Photo @SoiloftheMonth

A small tool consisting of only pertinent dimensions for plasticity estimation is proposed (Figure 4). The tool, in the shape of a key, is a dimension reference tool allowing the user to compare threads to the standard 1/8", 6mm, 4mm, and 2mm diameters and 4mm length that comprise the frameworks discussed in Section 2. The tool has a bevel and #40 holes on the face to facilitate the shine test and removal of large particles not permitted by ASTM D2488. The tool eliminates the need for large multiple reference devices in the field while providing only the necessary dimensions needed (Figure 5).

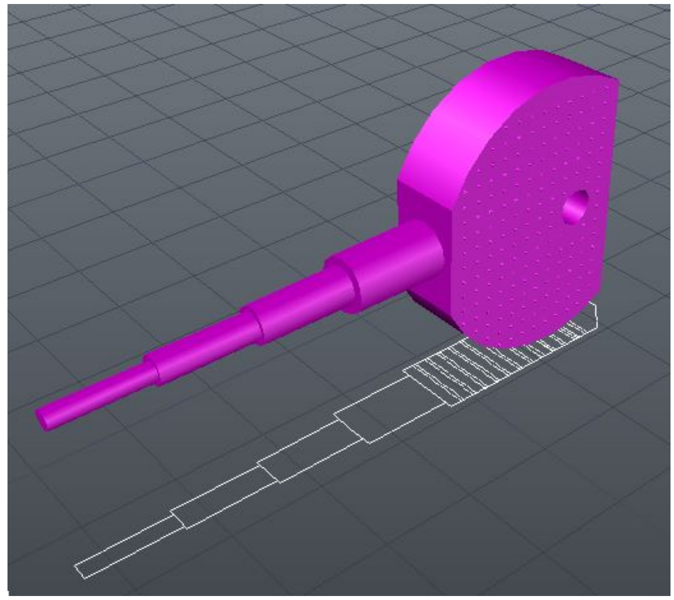

Figure 4. 3D model of plasticity key Photo @SoiloftheMonth

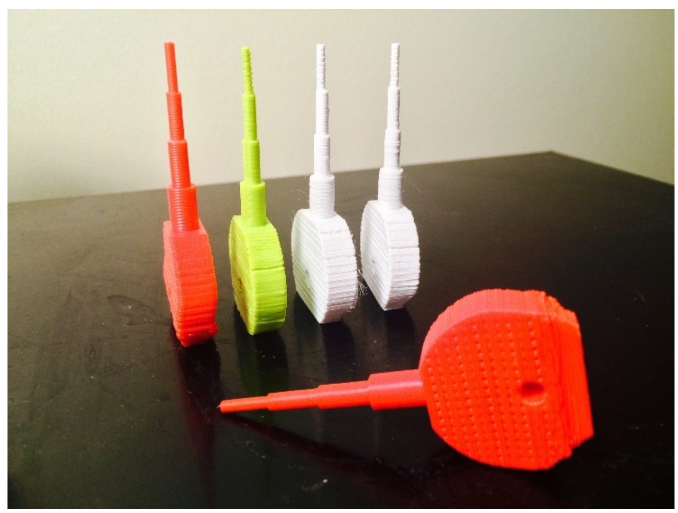

Figure 5. 3D printed soils plasticity key@SoiloftheMonth

4. Summary

Plasticity is an important property useful for the prediction of a soils engineering behavior. Estimation of plasticity is a fast and inexpensive characterization method but requires significant training and experiencing to be of beneficial use. To assist in learning, practicing, and field estimation a comprehensive dimension reference tool was developed for use with the USCS and USDA NCSS frameworks. This tool is a simple and effective means of accurate referencing dimensions when estimating soil plasticity.

Figure 6. Plasticity key demonstration
Photo @SoiloftheMonth

Acknowledgements

/u/terrygreasewel and the "MASA Engineering" Team from Thompson Rivers University
/u/TheRealSpaceTrout
/u/shinythingy
/u/GrievousBodilyHenry

References

Burmister, D. M. (1949). "*Principles and Techniques of Soil Identification*," *Proceedings,* Annual Highway Research Board Meeting, National Research Council, Washington, D.C., Vol. 29, 402–434

Schoeneberger, P.J., D.A. Wysocki, E.C. Benham, and Soil Survey Staff. 2012. *Field book for describing and sampling soils*, Version 3.0. Natural Resources Conservation Service, National Soil Survey Center, Lincoln, NE

Sowers, George F, and George B. Sowers. *Introductory Soil Mechanics and Foundations: Geotechnical Engineering*. New York: Macmillan, 1979. Print.

Standard, ASTM. "D2487 (2011) *Standard practice for classification of soils for engineering purposes (Unified Soil Classification System)."* ASTM International, West Conshohocken, PA www. ASTM. org.

Standard, ASTM. "D2488 (2009) *Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).*" ASTM International, West Conshohocken, PA www. ASTM. org.

Standard, ASTM. "D4318 (2003) *Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils."* ASTM International, West Conshohocken, PA www. ASTM. org.

USDA SCS National Employee Development Staff. *Soil Mechanics Level 1 Module 1 · Unified Soil Classification System Study Guide*. Rep. 1987. Print.