Teaching Soil Mechanics to the Would-Be Construction Professional

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Abstract

Conveying the essential fundamentals of soil mechanics in the context of an engineering technology or construction management degree poses some challenges. Soil mechanics curriculum is traditionally much more theoretical than applied. A successful construction engineer or manager needs to develop an understanding of how soils, groundwater and foundations interact, and all of this typically needs to be conveyed in one 15-week course. This leaves precious little space for the development of soil mechanics theory. For the construction career track, a very important aspect of career preparation is to develop a frame of reference to interpret soil-related construction documents such as boring logs, geotechnical reports, and foundation drawings. Relevant courses vary significantly in name within construction degrees, often variations of "Soil Mechanics" and "Foundation Construction Methods". Dividing such courses into thirds using some included activity modules has been found to be effective in preparing the students for construction careers.

Keywords

Soil, Mechanics, Construction, Pedagogy.

Introduction

The emphasis of this paper is to describe an effective approach to teaching a soil mechanics course in a construction program. The approach presented here has evolved over the decade the author has been teaching the class and is derived from theory and practice. The effectiveness relative to student learning is supported by testimonials from industry employers and student success in the course. It is acknowledged that neither of these is a comprehensive metric and more work remains to prove it's effectiveness.

Construction engineering and construction management training is in great demand. Typical positions occupied by construction professional program graduates are titled superintendent, project engineer, construction manager, estimator, scheduler, soil technician, etc. Most soil mechanics textbooks are configured to be taught in multiple sequential courses and are quite theoretical. Most construction degrees only accommodate one course, and the typical student is an experiential learner. A simplified approach is needed.

In addition to math and physics, prerequisites to this course typically include courses in statics, strength of materials, elements of structural design, and a materials lab focusing on soils. The following learning objectives for this author's course integrate the concepts from these prerequisites while introducing geotechnical engineering principles

In addition to developing an understanding of construction documents, students need to develop intuition and rudimentary understanding of both closed-form analytics as well as existing empirical methods. Simplified analysis methods have been developed here that accomplish this while being accessible to the construction student.

Dividing a 15-week semester into the following three sections is recommended.

1. Soils in Construction
2. Understanding Soil Behavior
3. The Engineering of Foundations

These sections provide a framework to navigate the construction student through the practical and theoretical aspects of soil mechanics and geotechnical engineering.

Soils in Construction

Often a geotechnical report is generated prior to construction design and is included in the front-end bidding documents of a construction project. The geotechnical report contains detailed information about the site soils including an outline of a subsurface investigation, a generalized soil profile, logs of in-situ tests like Standard Penetration Test (SPT) soil borings or cone penetrometer test (CPT) profiles, and results of geotechnical lab testing. Spending a portion of the class reviewing and explaining the components and terminology of a geotechnical report is an important and relevant component of a construction-track soils course. The geotechnical report also serves as a tool to introduce new concepts and it often keeps the student interested by remaining in the context of a construction project.

Toward the end of the 'Soils in Construction' portion of the class, the author has found that spending a fair amount of time discussing in detail the field testing performed to develop soil boring logs, or the Standard Penetration Test (SPT), a useful transition/connector/segue to diving deeper into soil mechanics analysis. Figure 1 is a useful visual aid for this initial discussion.

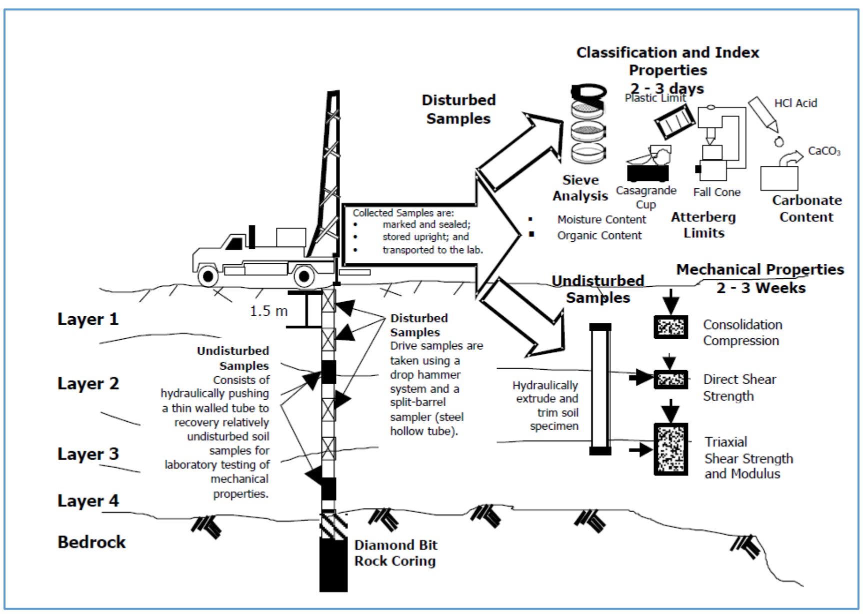


Figure 1 Traditional Drilling, Sampling, and Laboratory Testing (Ref. 4)

Understanding Soil Behavior

Soil classification systems such as the USCS (unified soil classification system) and AASHTO (American Association of State Highway Officials) primarily divide soil types by the size of the soil grain. This division works well for coarse grained sands and gravels but not for silts and clays. Although there is some correlation between size and behavior of 'fine' soils that pass through the #200 sieve, the behavior of fine grained silts and clays is not effectively delineated by size. If a soil is considered 'plastic', its behavior and consistency change significantly with changes in moisture content. Although rare, some silts exhibit plastic behavior but most silts behave like cohesionless soils. Therefore, for this course, clays are defined as fine-grained soils that exhibit plastic behavior while silts are considered fine-grained soils that are cohesionless, or exhibit very little plastic behavior. Therefore, dividing soil types into "cohesive" and "cohesionless" is preferred to size classifications such as "coarse grained" and "fine grained". This distinction stresses soil behavior over particle size. For simplification, silts, sands, and gravels, are considered cohesionless, clays are considered cohesive.

Mechanical Properties of Soil

Understanding soil mechanics requires understanding how soil behaves relative to mechanical properties. Mechanical soil properties, along with soil parameters and associated foundation design criteria, are summarized in Table 1. This table provides an overview of the interrelationship between mechanical soil properties and foundation design and is a framework around which the soil behavior portion of the class is built.

The Engineering of Foundations

Foundations are designed according to design criteria, and it is recommended that the discussion of foundation design be simplified to discuss only two analyses: bearing capacity analysis and settlement analysis. Equations for bearing capacity analysis are summarized in Figure 2. 'Bearing capacity' is a term students are likely to see often in reports, drawings and specifications. The term 'bearing capacity' is sometimes used inaccurately referring to a combination of analyses – both bearing capacity and settlement analyses. It is useful to clarify that an 'allowable bearing pressure' is sometimes the better term because it is associated with a full analysis incorporating both shear strength and compressibility properties while a soil's 'bearing capacity' is limited to a shear strength analysis like the one described in 2.

Figure 3 is a good tool for introducing settlement analysis, the design criteria associated with the compressibility mechanical property. The simplified approach depicted in the following figures limits compressibility analysis to two methods – consolidation settlement analysis and elastic settlement analysis. Simplified overviews of these are shown in Figures 4 & 5.

Table 1 Mechanical Properties of Soil

Mechanical Property of Soil	Soil Parameter		Foundation Design Criteria	Comments
	Cohesionless Soil	**Cohesive Soil**		
Shear Strength	friction angle	**s_u** – undrained shear strength	Bearing Capacity	s_u is a short-term strength used because a clay is weakest the moment it is loaded. See Figure 2.
Compressibility	**E** – soil stress strain modulus (elastic analysis)	If saturated, **c_c** and **c_r** – consolidation	Settlement	See Figure 3 and Figure 4
Permeability	**k** - permeability or hydraulic conductivity of soil		*Discussions are limited to dewatering applications	
Note - There are also chemical soil properties discussed in the context of corrosivity. Electrical soil properties such as conductivity and resistivity are considered when designing soil grounding grids.				

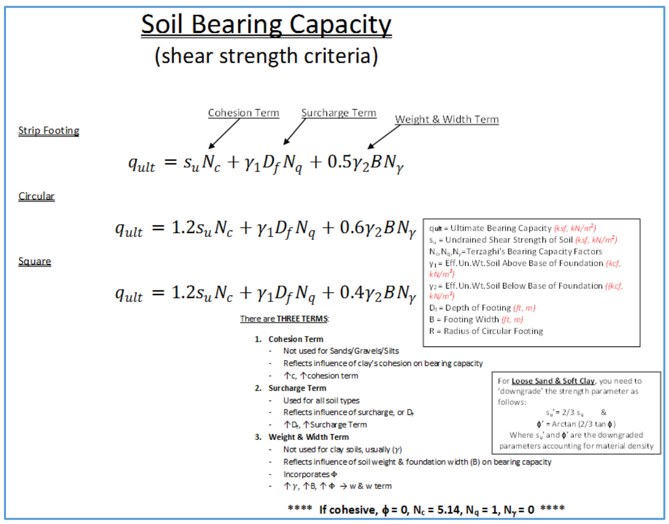


Figure 2 Simplified Bearing Capacity Analysis

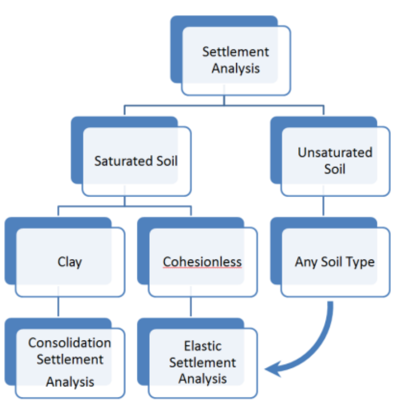


Figure 3 Simplified Settlement Analysis Flowchart

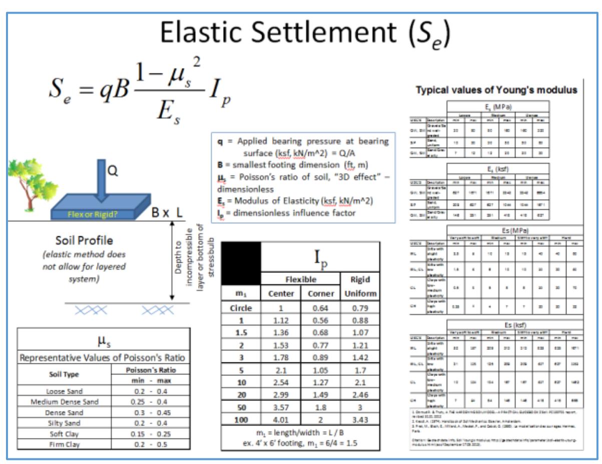
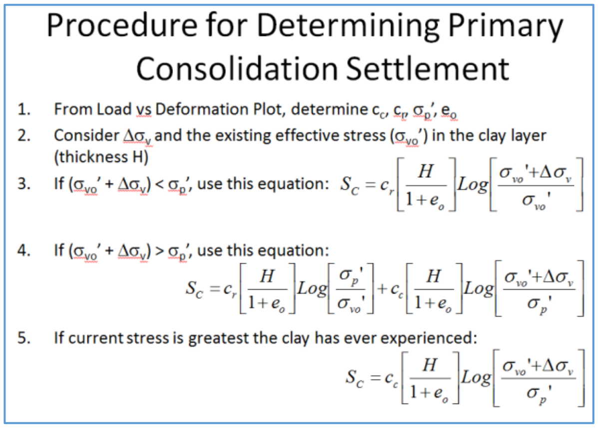


Figure 4 Simplified Elastic Settlement Analysis



Firgure 5 Simplified Consolidation Analysis

Course Activities

Table 1 lists sixteen suggested activities throughout the course that support the learning objectives. They are grouped into sections and are listed in the order presented in the class. Suggested (free) online references for some of the activities are included.

Table 1 Course Activity Modules

Section	Topic	Activity Title	Suggested Reference
Soils in Construction	Understanding information available	Online Resources	
	Site Visit	Visit a site and fill out checklist; Reading assignment: Problem Soils	(Ref. 7),
	Geotechnical Reports	Review existing reports and fill out checklist	(Ref. 3)
	Drilling & Sampling	Video with questions	(Ref. 1)
		Develop Soil Boring Logs	Obtain box of soil samples to be logged
Soil Behavior	Soil classification systems	Classify Soils	
	Effective Stress	Calculate Effective Stress at various locations in Soil Profiles	
	Mechanical properties of soil	Determine strength parameters for soils in a given soil profile	
		Reading Assignment: Dewatering & Groundwater Control	(Ref. 2)
The Engineering of Foundations	Shallow Foundations	Bearing Capacity Analysis	Figure 2
		Elastic Settlement Analysis	Figure 4
		Consolidation Settlement Analysis	Figure 5
	Deep Foundations	Reading Assignment: Pile Foundations	(Ref. 5)
		Group Project: Pile Cap Layout	Consider skin friction, end bearing, and group efficiency of piles. Generate CAD drawing with notes and installation specification
	Compaction & Ground Improvement	Standard, Modified & 1-point Proctor Analysis	
		Ground Improvement Techniques Reading Assignment	

Conclusion

Dividing the course into three sections as described above brought structure and clarity to the construction program soils course. Work remains to quantify the effectiveness of this approach. Although this course is not cited specifically in the survey, industry questionnaires submitted by employers of graduates indicate students are strong in theoretical understanding of engineering principles. Supplementary discussions with both former students and employers indicate graduates have consistently exhibited competence and comfort on earthwork construction projects. This is taken to be an endorsement, at least in part, of this approach to teaching soil mechanics in a construction management/engineering program.

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