**Soil Mechanics – 85824 – CEE 6402 - A**

**Time:** MW 2:00 - 3:15 pm

**Location:** Kendeda 230

**Instructor:** Sheng Dai, Ph.D., P.E., Associate Professor in Geosystems Engineering

Email: sheng.dai@ce.gatech.edu | Phone: 404.385.4757 | Office: Mason 2251

**Office Hours:** MW 10:00 - 11:00 am

Note: you are also welcome to set up a meeting time with me via email to talk about any aspect of the course during regular working hours other than the OH.

**Course Description and Objectives**

This course covers the fundamentals of soil properties and processes. The macroscale soil behavior and associated phenomena are explored at the microscale. By the end of this course, you are expected to be able to:

1. Interpret inherent soil properties as particulate materials and the importance of pore constituents and their pore habits.
2. Define and illustrate core concepts of geomechanics, e.g., stress/strain, stiffness/strength, effective stress, consolidation, conduction/diffusion, and pressure-temperature effects.
3. Identify the underlying physical and chemical mechanisms in soil phenomena and processes and explain hydro-thermo-chemo-mechanically coupled processes.
4. Perform basic pore network flow simulations and be able to solve the conduction/diffusion equations using the finite difference method.
5. Critically assess scientific literature that investigates soil behavior and recognize the role of geotechnical engineering in addressing energy and sustainability related issues.

**Course Textbook**

No textbooks are required for this course. Lecture notes and additional required/recommended references for each section of the course will be distributed during the term. The following references cover most of the material presented in this course and can be used for further reading:

- Santamarina, J. C (2001). Soils and Waves. John Wiley & Sons.
- Mitchell, J. K., & Soga, K. (2005). Fundamentals of soil behavior. New York: Wiley.
- Lambe, T. W., & Whitman, R. V. (2008). Soil mechanics SI version. John Wiley & Sons.

**Grading**

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|---|---|---|
| Exam I | 20% | Wednesday, Sept 21 |
| Exam II | 20% | Wednesday, Oct 26 |
| Homework | 30% | Due date will be specified for each homework. |
| Project | 30% | Nov 30 and Dec 5 (presentation) |
| **Final Exam** | | **Wednesday, Dec 14, 2:40 - 5:30 PM** |
| Final Grade: | $A \geq 90\% > B \geq 80\% > C \geq 70\% > D \geq 60\% > F$ | |

**Project Guidelines**

- A state-of-the-art review with deep insight into ***one*** soil property/behavior/process.
- The topic needs to be approved by the instructor before Exam I.
- The develiverables include a written report and a PPT presentation.
- The report should be written in a journal form with length, figures and references in a format suitable for submission to journals like *Geophysical Research Letters*. The report is due at **5 PM on December 5, 2022**.
- The project presentation will be delivered in front of the class during the last two lectures on 11/30 and 12/5. Each presentation will be 8 minutes, followed by 2 minutes of Q&A.
- The written report will count for 20 points and the presentation for 10 points toward the project.
- Suggested topics (not limited to):

  Physical – Specific surface; Fabric; Pore/grain size distribution; Density (terminal density)

  Mechanical – Small strain (stiffness); Large strain (friction); Strain rate; Dilation; Cementation; Shear band

  Hydraulic – Conductivity; Permeability (relative permeability); Interfacial tension + Contact angle; Soil water characteristic curve (or water retention curve)

  Electromagnetic – Electric conductivity; Permittivity; Magnetic permeability

  Thermal – Conductivity; Heat capacity; Latent heat (phase transformation); Frozen ground

  Chemical – Diffusion; Conduction (reactive flow); Diagenesis; Soil remediation

  Biological – Bio-cementation; Bio-geo-mimicry; Bio-remediation

**Academic Honor Code:**

This course will be conducted under the guidelines of the Georgia Tech Academic Honor Code. In particular, cheating of any kind is unethical and unacceptable; quote and attribute any words/ideas that are not your own; wireless communication systems of all kinds must be turned off while in the classroom. Please refer to http://www.honor.gatech.edu for further questions involving the Academic Honor Code.

*Attendance*. In accordance with the Institute requirement, verification of participation of the class will be reported to the Registrar's Office and the Office of Scholarships and Financial Aid.

*Exams*. There will be two exams throughout the semester. Refer to the Grading session for the exact time. Both exams will be held in the same lecture classroom (CoC 52). Missing an exam without prior approval will earn a grade of 0 for that exam. Make-up exams will be given only for documented reasons of illness, family emergency, or participation in approved Institute activities (such as field trips and athletic events, see http://catalog.gatech.edu/rules/12 for more information).

*Homework*. All the assignments will be posted on Canvas. The due date will be specified when

the assigning of each homework. Homework can be turned in during class. Grades for homework turned in after that time will be reduced by 10% per day late, including weekends. Homework must be submitted in electronic copy through Canvas.

You are allowed to discuss with other students on homework, but you must write up and turn in your own solutions. For assignments using computer-generated output, it is not acceptable for different students to turn in copies of the same printout. Please list any classmate with whom you studied on your assignment.

The following formats are **REQUIRED** for all homework assignments.

1. Homework must be neat, legible, and organized. Be certain to place your name, the assignment number, and the date on all the homework that is handed in.

2. All graphs must be computer generated. Hand drawn graphs will not be graded.

3. Experimental data should be plotted as discrete points, while theoretical relationships should be shown as continuous lines.

4. Show all units. Be certain to track units throughout the assignment and include them in the final answer.

5. Clearly state any assumptions (such as an assumed unit weight or density) you have made in solving the problems.

**Office of Disability Services**

The Georgia Institute of Technology has policies regarding disability accommodation, which are administered through The Office of Disability Services: http://disabilityservices.gatech.edu. For students with disabilities, please contact this Office to request classroom accommodations.

**Course Outline - Topics**

Introduction: inherent soil characteristics

History of geotech engineering

Governing laws: mechanics, electromagnetism, thermodynamics; conservation principles

Scales: spatial and temporal

Soil formation: minerals, rocks, and soils; diagenesis

A single particle: mineralogy, size, shape, Ss, double layer thickness, mechanical/thermal/electrical/chemical properties

Particulate media: grain mass, surface, pores; macro/micro properties; phase relations

Soil fabric: fine-grained (pH and c, fraction) vs. coarse-grained (Cu, size, shape)

Soil classification: underlying concepts, index properties, Schofield chart, limitations

Interparticle forces: electrical/capillary forces; contact, Hertz, Mindlin;

State of stress: in situ stress: effective stress, pore pressure, $K_o$; induced stress

Strain regimes: small vs. large strain; threshold strains

Small strain stiffness: moduli, G reduction, controlling parameters

Stress-strain response: compressibility; contractive and dilative tendencies

Strength: friction and internal shear strength (fine and coarse soils), MC and the failure line; critical state; drained vs. undrained

Saturated soils: Terzaghi, Skempton, Biot, poroelasticity; Mandel-Cryer

Pore constituents: gases (air, CO2, CH4,) fluids (water, electrolyte), crystallites; critical state; phase transformation; molecular dynamics

Seepage: Bernoulli, Pascal, Laplace, Darcy; flow net

Hydraulic conduction: different forms of conductions; conductivity, permeability, tortuosity, Kozeny-Carman

Flow in porous medium: tube flow (Hagen-Poiseuille); pore network simulation

Consolidation: different forms of diffusion; consolidation ; FDM to solve pore pressure dissipation

Unsaturated soils I: pore fluids; surface tension, capillarity, contact angle; SWCC, van Genuchten, relative permeability

Thermal properties: specific and latent heat; heat conductivity and capacity

Heat conduction: Fourier equation; FDM solution

Spatial variability: effective media models, bounds analyses

Energy geotechnology: energy consumption; carbon emission/sequestration; fossil fuels vs. renewable energy; reservoir geomechanics; coupled HTCM problems.