CIVE 353: GEOTECHNICAL ENGINEERING - I

Course Information – Winter 2021

Instructor:

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Lab coordinator:

Anne Allen	DWE 1452	Ext. 33656	anne.allen@uwaterloo.ca

Teaching Assistants:

Cristobal Lara	(Tutorials)	calara@uwaterloo.ca
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Recommended Text and Require Class Notes:

- Knappett J. & Craig, R.F. (2014). Craig's Soil Mechanics. Eighth Edition. Spon Press, UK.
- Class Notes – University of Waterloo. (D2L)
- CIVE-353 Laboratory Manual – University of Waterloo. (D2L)

Laboratory [Attendance is compulsory]

- Laboratories will start from the week of January 18.
- Experiments: permeability, compaction, consolidation, and, direct shear.
- The lab-manual includes all experimental procedures.
- Students will participate in a group of maximum **four** throughout the course.
- The Lab coordinator (*Anne Allen)* will confirm that all groups have self-enrolled in D2L (three students per group) by January 14.
- Students without a group should email the Lab coordinator (*Anne Allen)* asap.
- If a group is submitted with less than three student's names, additional students will be added from the list of students without group.
- Groups larger than four can only be accepted if requested and approved the Lab coordinator.
- Final groups and schedules will be posted on learn.uwaterloo.ca (D2L) by January 15.
- Laboratory Manual and Class Notes will be available at D2L.
- Each group will submit one brief report for each lab.

- Reports will be marked out of 25 marks (indicated in parenthesis). Reports must include:

  Title page and one-page Letter of submittal [signed by all the group members] (1)
  Brief introduction (3), Completed data sheets (4), Appropriate figures/graphs (5),
  Answers to questions (6), Conclusions and References (if applicable) (6).

  All members of the group must actively participate in the preparation of the report. Reports will not be accepted if the letter of submittal is not included. Lab report due dates are one week after they did the actual lab, with the exception of Consolidation lab. The reports need to be handed in by 5pm in the D2L drop box by the due date. All groups will get their reports back by the Friday before quizzes and final exam.

Assignments and Solutions

- Almost every week. Include problems from book and typical exam problems.
- Distributed on Mondays and due a week later the following Tuesday. Assignments will be checked for completeness and a one randomly selected problem marked in detail. Students are responsible for checking results with posted solution sets in D2L.
- Solutions sets will be posted in D2L on day after the due date.

Exams (time windowed in D2L) and Grades [1]

Final Exam	40%	(90% Problems, 10% Theory + Labs)
3 Quizzes	30%	(90% Problems, 10% Theory + Labs)
4 Lab-reports	15%	(one per group)
8 Assignments	15%	(only 5% if Final < 40%)

[1] The instructor reserves the right to adjust the class average on the ex12ams.

Schedule of Lectures, Tutorials, Labs, and Office hours

All notes for Lectures, Tutorials, and Labs, will be posted in D2L at least a week earlier. Then discussion sessions will take in Teams as indicated in D2L

Mondays	1:00 – 2:30 pm..............	Tutorials / Lectures / Office Hours
Tuesdays	....	Office Hours
Wednesdays	1:00 – 2:30 pm..............	Lectures
Thursdays	....	Quizzes
Fridays	....	Labs (only for the beginning of the term)

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Week	Dates	Topic	Assignments Due	Quizzes/ Labs
1	Jan 11th – 15th	I-Introduction, II-Origin of Soil, III-Particulate material. Phase relationships.	A1: Jan. 19th	
2	Jan 18th – 22nd	Simple packings, Grain size distribution.	A2: Jan. 26h	
3	Jan 25th – 29th	IV-Fine Soils. Diffuse double layer. Plastic properties. Soil compaction.	A3: Feb. 2nd	Jan.28 Compaction
4	Feb. 1st – 5th	Soil classification. USCS. V-Seepage. Capillary rise in soils. Darcy's Law. K, k.	A4: Feb. 9nd	Feb. 4. Perm. Feb. 5. Quiz #1
5	Feb. 8th - 12th	Bernoulli's Eq. One dimensional flow. Perm. tests. Laplace's Eq. Flow Nets.	A5: Feb. 23th	
/	Feb15th – 19th	Reading Week		
6	Feb 22nd –26th	Uplift pressure. Anisotropic flow. Total and effective stresses. Quick condition. Exit gradient. Base heave.	A6: Mar. 2nd	Feb.25th Quiz #2
7	Mar. 1st – 5th	VI-Consolidation. Spring analogy. Oedometer test. Cc, Cs, mv	A7: Mar. 9th	Mar.2st Consol.
8	Mar. 8th – 12th	Settlement calculation. 1D consolidation theory. Cv.	A8: Mar. 17th	Mar. 9th DSS Mar.18 Quiz #3
9	Mar.15th – 19th	Mar.15, 16. Pauses. Numerical solution to 1D consolidation. VII-Mechanics of particulate media. Mohr circle. Failure plane.	A9: Mar. 23th	
10	Mar.22nd – 26th	Principal and normal stresses. M-C Failure. Triaxial test. Stress path. UU, CU, CD. Direct simple shear tests. Skempton A.	A10: Mar. 30th	
11	Mar. 29th –Apr. 2nd	VII-In-situ and induced stresses. Ko condition. Point load. Line load. Strip footing. Square foundation.		
12	Apr. 5th – Apr. 9th	Strain influence diagram. Course overview.		
/	Apr.17th 26th	Exam Period		Final Exam

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Course Outline [*Sections of textbook*]

1. **Introduction**

   Historical developments
   Geotechnical Engineering - A general perspective
   General approach to solving problems in Geotechnical Engineering

2. **Soil Formation**

   Rock-Soil Cycle
   Weathering Processes
   Transportation, Sorting, Deposition
   Residual, Eolic, Fluvial, Marine, Lacustrian and Glacial Soils

3. **Particulate Media [** 1.2, 1.4, 1.5, 1.6 **]**

   Characterization of particulate media [void ratio, porosity, water content, etc.]
   Phase relations, specific gravity, soil compaction
   Multi-phase systems: solid, water and air phases
   Packing of uniform spheres. Inherent anisotropy
   Deformation: Hertz and Mindlin
   Strength: Amontons' laws of friction
   Particle size distribution curves

4. **Fine Soils - Colloids [** 1.1, 1.4 **]**

   Structure of clays, water molecule, ions, clay and water
   Diffuse Double Layer
   Related phenomena
   Soil Classification

5. **Seepage [** 2.1, 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 3.1, 3.2, 3.3, 3.4 **]**

   Capillary rise in soils, Shrinkage, Swell, Frost
   Hydraulic gradient, permeability and Darcy's Equation
   Determination of coefficient of permeability
   Heads and energy balance: Bernoulli
   Laplace's equation, models and analogues
   Graphical and numerical solutions. Anisotropy
   Seepage forces
   Gradients: electrical, chemical, thermal, hydraulic
   Total and effective stresses, the quick condition

6. **Consolidation [** 7.1, 7.2, 7.4, 7.6, 7.7, 7.8, 7.10 **]**

    Consolidation analogy, the oedometer test
    Preconsolidation pressure
    In-situ void ratio vs. effective stress curve
    Magnitude of Settlement
    Degree of consolidation,1-D theory of consolidation
    Average degree of consolidation
    Coefficient of consolidation, numerical solutions

7. **Mechanics of Particulate Media [** 4.1, 4.2, 4.3, 4.4, 4.6, 4.7 **]**

    Equilibrium, compatibility and constitutive equations
    Mohr circle of stress, Mohr-Coulomb failure criterion
    Stress path. Shear strength (direct shear, triaxial, unconfined tests)
    Contractive and dilative tendencies
    Drained and undrained shear strength
    Residual strength and sensitivity of clays
    Pore pressure parameters [Skempton and Henkel]

8. **In-Situ and Induced Stresses [** 6.2 (pressure at-rest), 5.1, 5.2, 5.3, Example 8.6**]**

    In-situ stress: vertical and horizontal
    Induced stresses: Boussinesq point load
    Displacements for elasticity theory

BIBLIOGRAPHY AND REFERENCES

Bowles, J. E. 1996. Foundation Analysis and Design. 5th Ed. MacGraw-Hill, NY.

Cernica J.N. 1995. Geotechnical Engineering: foundation design. John Wiley & Sons, NY.

CivE-353 Laboratory Manual. 2022. Civil Engineering Department. University of Waterloo.

Knappett J. & Craig, R.F. (2014). Craig's Soil Mechanics. Eighth Edition. Spon Press, UK. **[Textbook of the course]**

Das, B.M. 2002. Principles of Geotechnical Engineering. PWS Publishing Company, NY.

Dobry, R., Ladd, R.S., Yokel, F.Y., Chung, R.M. and Powell, D. 1982. Prediction of Pore Water Pressure Buildup and Liquefaction of Sands During Earthquakes by the Cyclic Strain Method. US Department of Commerce, National Bureau of Standards. Building Science Series 138.

Jumikis, A.F. 1984. Soil Mechanics. Van Nostrand Company Inc., NY.

Lambe, T. W. and Whitman, R.V. 1969. Soil Mechanics. Wiley, NY.

Skempton, 1979. Landmarks in early soil mechanics. Proc. 7th European Conference on Soil Mechanics and Foundation Engineering. Brighton, England, V5, pp. 1-26.

CIVE 353 OVERVIEW

Objectives: This course covers the fundamentals of soil mechanics, including characteristics of soil, flow of water through soil, effective stresses in soil, soil consolidation, and soil strength. Upon completion of the class, you should be ready to apply the knowledge of soil mechanics in geotechnical designs of foundations, slopes, and retaining structures.

Includes four lab sessions: permeability, compaction, consolidation, and, direct shear.

Course Learning Outcomes: Upon successful completion of the course, students will be able to:

Course Learning Outcomes	SO	Assessment Tools
1. Identify and classify soils;	1, 2, 3, 4	HW, Lab, and Exam
2. Understand soil compaction and factors affecting performance of compacted soils;	1, 2, 3, 4	HW, Lab, and Exam
3. Solve problems involving steady 1-D flow through saturated soils;	1, 2, 4	HW, Lab, and Exam
4. Solve 2-D problems involving steady seepage through simplified earth structures and dams;	1, 2	HW and Exam
5. Determine in situ stresses and stresses in the soil due to vertical surface loads;	1, 2, 4	HW and Exam
6. Calculate 1-D consolidation deformation of soils and time dependent deformations;	1, 2, 3, 4	HW and Exam
7. Determine soil strength using Mohr-Coulomb theory.	1, 2	HW, Lab, and Exam

Contribution of CIVE 353 towards fulfillment of Student Outcomes:

1) *Ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science and mathematics*: Knowledge of calculus, statics, mechanics of solids, and fluid mechanics principles are used in the analysis of soil behavior under the effect of water seepage and under other engineering loads. The in-class problems and homework assignments introduce the students to real-world problems where the theory is applied to solve problems albeit in a simplified scale, so they may apply their engineering knowledge to arrive at meaningful solution to the problems. It develops confidence and comfort on their abilities as engineers. The students are made aware of the shortcomings in the current understanding and/or applications of soil mechanics to solve complex problems, and the need to continue updating their knowledge.

2) *An ability to recognize ethical and professional responsibilities in engineering situations and make informed which must consider the impact of engineering solutions in global, economic, environmental and societal contexts:* Students are introduced to past geotechnical failures in appropriate topics, and are made aware of the professional and ethical responsibility of engineers in developing suitable solutions to real world problems with utmost care and dedication.

3) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions*: The students master the various experimental methods and the associated theory for measuring soil properties (permeability, compressibility, shear strength, soil classification) in the laboratory. They interpret and analyze mock laboratory data.

4) *An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgement to draw conclusions*: The students master the various experimental methods and the associated theory for measuring soil properties (permeability, compressibility, shear strength, soil classification) in the laboratory. They interpret and analyze mock laboratory data.

Major topics

- Index Properties and Physical Description of Soil. Engineering Description of Soil.
- Geology and Soil Formation. Soil Compaction.
- Flow of Water through Soil. Soil Compression and Consolidation.
- Stress State and Shear Strength of Soil. Induced Stresses in Soil Mass. In-situ Stresses.

HELP WITH CONTINGENCY MANAGEMENT

Fair Contingencies for Emergency Remote Teaching (include in syllabus and in course week-by-week schedules). We are facing unusual and challenging times. To provide contingency for unforeseen circumstances, the instructor reserves the right to modify course topics and/or assessments and/or weight and/or deadlines with due notice to students. In the event of further challenges, the instructor will work with the Department/Faculty to find reasonable and fair solutions that respect rights and workloads of students, staff, and faculty.

Online Academic Integrity.

All students are expected to work individually and submit their own original work. Under Policy 71, the instructor may have follow-up conversations with individual students to ensure that the work submitted was completed on their own. Any follow up will be conducted remotely (e.g., MS Teams, Skype, phone), as the University of Waterloo has suspended all in-person meetings until further notice.

Wellness Support and Contact Information.

University can be a challenging environment and it is normal to need support from time-to-time. Campus Wellness services are available to students through counselling and health services. If you are struggling or need someone to talk to you, please reach out. To book an appointment or learn more about the services, call 519-888-4567 x 32655 or explore www.uwaterloo.ca/campus-wellness. If you're experiencing a crisis and feel unable to cope and Campus Wellness is closed, contact any of these after-hours supports: Empower Me (1-833-628-5589), Good2Talk (1-866-925-5454) or Here 24/7 (1-844-437-3247). They are available at any time of the day or night to help.

CIVE 353 OVERVIEW

Particulate Materials I, II

Coarse Soils III
Sand and Gravel
Eng. characteristics:
e, w, GSD
Material characteristics:
Why? Hertz, Mindlin, Friction

Fine Soils IV
Clays
Eng. characteristics:
So, w_l, w_p, w_s, I_p
Material characteristics
Why? Coulomb, Ions, DDL

Soil Classification IV
Expected behaviour

Soils + Water: Seepage V
How much flow?
Up-lift force?
Quick condition?

Soils – Water: Consolidation VI
How much settlement?
How long?

Strength and Loading VII, VIII
Mohr-Coulomb failure criterion
Drained and undrained shear strength
Induced and in-situ stresses

Design CE354
Earth pressure
Slope stability
Bearing capacity