CEE 586 – Rock Mechanics & Behavior

Fall 2024

TTh 12:30 – 1:50PM, 1311 NCEL

Course Syllabus

Instructor: Professor Roman Y. Makhnenko, PhD (217) 300-4587 (phone)
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Office hours: Th 2:00-3:00PM, NCEL 2221

Teaching Assistant: Hyunbin Kim, NCEL B220, hyunbin3@illinois.edu
Office hours: M 4:00-5:00PM NCEL 2218

Class Meetings: Time: TTh 12:30 – 1:50PM, **Rm.:** 1311 Newmark Civil Engineering Lab
Lab Meetings: Time: T 3:30 – 4:50PM (see schedule), **Rm.:** B236 Newmark Civil Engineering Lab

Class Websites: https://canvas.illinois.edu/courses/51098
https://mediaspace.illinois.edu/channel/channelid/351261222

Textbooks and Reading:

Suggested: Jaeger, J.C., Cook, N.G.W, Zimmerman, R.W. (2007). *Fundamentals of Rock Mechanics, 4th Edition*. Blackwell, U.K., 475 p.

Supplemental text: Goodman, R.E. (1989). *Introduction to Rock Mechanics, 2nd Edition*. John Wiley and Sons, New York, NY, 562 p.

Other: Additional reading from handouts

Course description

Rock mechanics is the theoretical and applied science of the mechanical behavior of rock; it is that branch of mechanics concerned with the response of rock to the force fields of its physical environment. For practical purposes, rock mechanics is mostly concerned with rock masses on the scale that appears in engineering and mining work, and so it might be regarded as the study of the properties and behavior of accessible rock masses due to changes in stresses or other conditions. On one hand, shallow, weathered or fragmented rocks can be treated with the approaches similar to soil mechanics. On the other hand, there is an increasing demand to study the behavior of rocks under conditions that occur deep in the Earth's crust, i.e. at elevated pressures and temperatures. Additionally, accessible rock masses are broken up by joints and faults, and pressurized fluid is frequently present both in open joints and in the pores of the rock itself (after Jaeger et al., 2007).

This course introduces students to the theoretical and practical aspects of rock mechanics. Constitutive behavior of continuum media is reviewed and applied to the behavior of geomaterials. Elastic, inelastic, and failure response of dry rock is discussed. Fluid flow in porous media is described in terms of coupling

with rock deformation. Finally, it is shown how rock mechanics principles can be applied to geo-energy and engineering geology applications.

Class Sessions: Sessions begin at 12:30 pm and end at 1:50 pm. Class notes or slides will be posted to the Canvas website within prior to the lecture. All lectures are recorded and available live or as videos on Illinois Media Space platform, where you could login using your UIUC credentials. It is highly recommended to save on printing (and be sustainable) and try to take written notes (including using electronic devices). You are responsible for what is presented verbally, what is presented on the chalkboard, and what is presented on the slides and the assigned reading materials.

Participation and Attendance: Participation is an important part of learning and will be strongly encouraged. There will be no penalty for excused absences but you would have to watch the online recordings of the lectures.

Homeworks: There will be four homeworks that will include theoretical questions and technical problems based on the course material covered. You are encouraged to provide detailed solutions and discussions if needed. Thoroughly solving homework problems is a great way to prepare for the exams. You can discuss homework problems with your peers but should submit your own (individual) solutions.

Lab Sessions: There will be 5 laboratory sessions and lab reports are worth 25% of your grade. The lab report should cover background information, testing methods, experimental results, and discussion of the performed or demonstrated tests. The lab demonstrations will be filmed and available via Canvas website. The test data will be shared right after the completion of the lab and properly reporting it is part of the assignment.

Exams: There will be one 80-minute long mid-term exam during the semester and 3 hour long final exam at its end. Although tentative dates are shown in the schedule below, specific dates for the exams will be announced in class at least two weeks in advance. In the exams, you will be asked both qualitative and quantitative questions; the exams are not a mere repetition of the problems solved in class. You will be asked to apply material you have learned in lectures, readings, labs, and homeworks, as well as during in-class discussions and questions. Assisting others or receiving unfair assistance during exams will automatically result in 0 score.

Grade Distribution:

Attendance	5%
Homeworks	20%
Lab Projects	25%
Mid-term Exam	20%
Final	30%
Extra Credit	5%

Grades & Performance:
Superior 90 – 100 A (including +/-)
Proficient 80 – 89.9 B (including +/-)
Satisfactory 70 – 79.9 C (including +/-)
Mediocre 60 – 69.9 D (including +/-)
Unacceptable below 60 F

COVID-19

Following University policy, all students are required to engage in appropriate behavior to protect the health and safety of the community, including wearing a facial covering properly, maintaining social distance (at least 6 feet from others at all times), disinfecting the immediate seating area, and using hand sanitizer. Students are also required to follow the campus COVID-19 testing protocol. Students who feel ill must not come to class. In addition, students who test positive for COVID-19 or have had an exposure that requires testing and/or quarantine must not attend class. The University will provide information to the instructor, in a manner that complies with privacy laws, about students in these latter categories. These students are judged to have excused absences for the class period and should contact the instructor via email about making up the work. Students who fail to abide by these rules will first be asked to comply; if they refuse, they will be required to leave the classroom immediately. If a student is asked to leave the classroom, the non-compliant student will be judged to have an unexcused absence and reported to the Office for Student Conflict Resolution for disciplinary action. Accumulation of non-compliance complaints against a student may result in dismissal from the University.

Accessibility

To insure that disability-related concerns are properly addressed from the beginning, students with disabilities who require reasonable accommodations to participate in this class and related activities are contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, call 333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu..

Academic Integrity

The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/. Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy: https://studentcode.illinois.edu/article1/part4/1-401/. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Inclusivity

The effectiveness of this course is dependent upon each of us to create a safe and encouraging learning environment that allows for the open exchange of ideas while also ensuring equitable opportunities and respect for all of us. Everyone is expected to help establish and maintain an environment where students, staff, and faculty can contribute without fear of personal ridicule, or intolerant or offensive language. If you witness or experience racism, discrimination, micro-aggressions, or other offensive behavior, you are encouraged to bring this to the attention of the course director if you feel comfortable. You can also report these behaviors to the Bias Assessment and Response Team (BART) (https://bart.illinois.edu/). Based on your report, BART members will follow up and reach out to students to make sure they have the support they need to be healthy and safe. If the reported behavior also violates university policy, staff in the Office for Student Conflict Resolution may respond as well and will take appropriate action.

Emergency Response Recommendations

Emergency response recommendations can be found at the following website: http://police.illinois.edu/emergency-preparedness/. I encourage you to review this website and the campus building floor plans website within the first 10 days of class. http://police.illinois.edu/emergency-preparedness/building-emergency-action-plans/.

Sexual Misconduct Reporting Obligation

The University of Illinois is committed to combating sexual misconduct. Faculty and staff members are required to report any instances of sexual misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options. A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential. Other information about resources and reporting is available here: wecare.illinois.edu.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices in regard to admissions, class attendance, and the scheduling of examinations and work requirements. You should examine this syllabus at the beginning of the semester for potential conflicts between course deadlines and any of your religious observances. If a conflict exists, you should notify your instructor of the conflict and follow the procedure at https://odos.illinois.edu/community-of-care/resources/students/religious-observances/ to request appropriate accommodations. This should be done in the first two weeks of classes.

Family Educational Rights and Privacy Act (FERPA)

Any student who has suppressed their directory information pursuant to Family Educational Rights and Privacy Act (FERPA) should self-identify to the instructor to ensure protection of the privacy of their attendance in this course. See https://registrar.illinois.edu/academic-records/ferpa/ for more information on FERPA.

Impact on Society and Environment

As civil engineers, through the projects we design and build, we have the potential to significantly impact our communities and the environment we live in. Always be mindful of the impact of your projects, and always try to ensure that they are positive.

Sustainability

Here at Illinois, we are concerned about being sustainable. Please, be aware that everything you do has an environmental impact. Be conservative printing course materials and recycle used papers. Recycle cardboard, plastic, glass, aluminum, and compost – there are facilities for that available on campus and in Urbana-Champaign area. Save energy and water: turn of the lights if you do not need them and avoid having water running down the sink for no reason. Walk and bike instead of driving – it is healthier and environmentally friendly.

Course Schedule – Tentative and subject to change

1. Aug 27: Introduction, outline of main topics
2. Aug 29: Rock vs Soil, Rock classification
3. Sept 3: Traction and stress tensor
4. Sept 3: **Lab#1:** Index properties and error analysis
5. Sept 5: Mohr's circle, stress invariants
6. Sept 10: Displacement and small strain, strain and rotation tensors
7. Sept 12: Deformation of dry rock, laboratory testing, **Lab Report#1 is due**
8. Sept 17: Uniaxial and triaxial compression experiments
9. Sept 17: **Lab#2:** Conventional triaxial compression
10. Sept 19: Stress-strain diagrams, Generalized Hooke's law, **HW#1 is due**
11. Sept 24: Inelastic behavior of rock
12. Sept 26: Different regimes of rock failure
13. Oct 1: Advanced failure criteria, **Lab Report#2 is due**
14. Oct 1: **Lab#3:** Dynamic and static rock characterization
15. Oct 3: Jointed rock mass behavior
16. Oct 8: Review of dry rock behavior, **HW#2 is due**
17. Oct 10: Problems related to dry rock behavior
18. Oct 15: **Midterm #1**
19. Oct 17: Fluid flow in porous media
20. Oct 22: Theory of poroelasticity
21. Oct 24: Measurements of poroelastic properties, **Lab Report#3 is due**
22. Oct 29: Effective media theories
23. Oct 29: **Lab#4:** Poromechanical behavior
24. Oct 31: Time-dependent behavior of dry and fluid-saturated rock
25. Nov 5: Inelastic deformation of fluid-saturated rock, **HW#3 is due**
26. Nov 7: Coupling between fluid flow and rock deformation
27. Nov 12: Shales as intermediate geomaterials, **Lab Report#4 is due**
28. Nov 12: **Lab#5:** Steady-state and transient flow tests
29. Nov 14: Failure of fluid-saturated jointed rock
30. Nov 19: Thermo-hydro-mechanical-chemical processes in rock
31. Nov 21: Rock mechanical aspects of geologic storage, **HW#4 is due**

    Nov 23-Dec 1: Thanksgiving break
32. Dec 3: Induced seismicity
33. Dec 5: Field applications, **Lab Report#5 is due**
34. Dec 10: Course review
35. Dec ?: **Final exam**