UNIVERSITY OF ILLINOIS
AT URBANA-CHAMPAIGN

Department of Civil and Environmental Engineering
Newmark Civil Engineering Laboratory, MC-250
205 North Mathews Avenue
Urbana, IL 61801-2352

CEE 581 – Dams, Embankments, and Slopes (Fall, 2023)
Instructor: Timothy D. Stark, Ph.D., P.E., D.GE
2217 Newmark Civil Engineering Laboratory
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Prerequisite:
CEE 483 – Applied Soil Mechanics or Consent of Instructor.

Required Textbook:
Selected Technical Papers Available on the Course COMPASS-2G Website
Idriss, I.M. and Boulanger, R.W. (2009). *Soil Liquefaction,* Earthquake Engineering Research Institute

Recommended Textbook:
Sherard, Woodward, Gizienski, and Clevenger, (1963). *Earth and Earth-Rock Dams,* J. Wiley and Sons
Freeze, R.A. and Cherry, J.A. (1979). *Groundwater,* Prentice Hall
Kramer, S.L. (2004). *Geotechnical Earthquake Engineering,* Prentice Hall

CEE 581 Course Outline and Schedule:

Lecture Topic	Reading Assignment
PART I – Course Introduction	
Course Topics and Applications	
PART II – Static Shear Strength and Slope Stability	
Purpose	Peck (1988); Lane (1961);
Shear strength modeling	Stark & Eid (1994, 1997) Stark and Idries (2021); St. John et al. (1969); Deere and Peck (1958); Kezdi (1969); Pearce et al. (2010); CH2M-Hill (2013);
Methods of evaluating slope stability	Duncan and Wright (1979);
Stability analysis using microcomputer programs and charts	Duncan et al. (1987); Duncan (2000);
Construction induced pore pressures	Sherman and Clough (1968);
Stability analysis during reservoir operations	Duncan and Wright (2005)
PART III – Geotechnical Earthquake Engineering	
Introduction	Seed (1979)
Ground and site response (DMOD)	Idriss and Boulanger (2009)

Dynamic soil properties	Idriss and Boulanger (2009)
Seismic slope stability of earth dams	Makdisi & Seed (1978)
Earthquake-induced permanent deformations	Harder (1991); Swaisgood (2003)
Earthquake-induced liquefaction – triggering & post-triggering	Idriss and Boulanger (2009)
Remediation of seismic hazard	Marcuson et al. (1996)

PART IV – Saturated and Partially-Saturated Seepage

Seepage through dams and levees	Casagrande (1937)
Two-dimensional steady flow in soils	
2D Numerical techniques	Wong and Duncan (1984)
Methods for estimating location of line of seepage	Stark (1987)
Partially Saturated Flow	Freeze and Cherry (1979), pp. 38-49
Partially Saturated Seepage Software	SLIDE & SEEP/W User's Guide (2012)
Flow nets for earth dams	Casagrande (1961)
Seepage forces on soils, erosion, and piping	Terzaghi (1960)
Filter requirements	Sherard et al. (1984 & 1989); USACE (2000)
Seepage control measures	Lane (1934); Hendrix & Stark (2009)
Cutoff walls and grouting for dams	Rice & Duncan (2009a;b); Rice et al. (2006); Houlsby (1977); Stark et al. (2009)
Geotextiles in Dams: Forging Federal Regulations	Crum (2008)

PART V – Earth Dam Design, Construction, and Case Histories

Current Embankment Trends	Milligan (2003);
Elements of earth dams	Sherard et al. (1963)
Causes of earth dam failures	Sherard (1987)
Types and comparison of dams	
Factors influencing design section of earth dams and concrete dams	Wilson and Marsal (1979)
Rockfill dams	Sherard and Cooke I & II (1987)
Asphalt Core Dams	
Case Histories – Mission Dam	Terzaghi & Lacroix (1964), ENR(1961)
Case Histories – Lower Notch Dam	Taylor (1969), Terzaghi, Peck, & Mesri (1996)
Case Histories – Mactaquac Dam	Tawil & Harriman (2001) Whitehead (2001)
Case Histories – Peribonka Dam	DFI (2010)
Case Histories – Mica Dam	
Dam construction	

COMPREHENSIVE FINAL EXAM
Monday, December 11, 2023 – 1:30 – 4:30 p.m.

Required Reading:

Course Topics and Overview – (1) Slope Stability, (2) Earthquake Engineering, (3) Seepage, (4) Dam Design

Static Shear Strength and Slope Stability

1) Stark, T.D. and Eid, H.T. (1994) "Drained Residual Strength of Cohesive Soils," *Journal of Geotechnical Engineering*, ASCE, Vol. 120, No. 5, May, 1994, pp. 856-871.
2) Stark, T.D. and Eid, H.T. (1997) "Slope Stability Analyses in Stiff Fissured Clays," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 123, No. 4, April, 1997, pp. 335-343.
3) Stark, T.D. and Idries, A. (2021) "Static and Seismic Slope Stability: Volume I – Drained Soil Shear Strengths", TO BE SUBMITTED TO ASCE Press or Geo-Institute, Geotechnical Special Publication ???, August, 2021, 188 p.
4) Peck, R.B. (1988) "The Place of Stability Analysis in Evaluating the Safety of Existing Embankment Dams," *Civil Engineering Practice*, Fall, pp. 67-80.
5) Lane, K.S. (1961) "Field Slope Charts for Stability Studies," *Proceedings of 6th Intl. Conference on Soil Mechanics and Foundations Engineering*, Vol. 2, pp. 651-655
6) St. John, B.J., Sowers, G.F., and Weaver, C.E. (1969) "Slickensides in Residual Soils and Their Engineering Significance," *Proceedings of 7th Intl. Conference on Soil Mechanics and Foundations Engineering*, Vol. 2, pp. 591-597
7) Deere, D.U. and Peck, R.B. (1958) "Stability of Cuts in Fine Sands and Varved Clays," *Proceedings AREA*, Vol. 59, pp. 807-815
8) Kezdi, A. C.E. (1969) "Landslide in Loess Along the Bank of the Danube," *Proceedings of 7th Intl. Conference on Soil Mechanics and Foundations Engineering*, Vol. 2, pp. 617-626
9) Duncan, J. M. and Wright, S. G. (1979) "The Accuracy of Equilibrium Methods of Slope Stability Analysis," *Engineering Geology*, Vol. 16, pp. 5-17, Elsevier Scientific Publishing Company, Amsterdam. (Also: International Symposium on Landslides, New Delhi, June, 1980.)
10) Duncan, J. M., Buchignani, A., and DeWet, M. (1987) "An engineering Manual for Slope stability Studies," Engineering Report, Virginia Tech, Blacksburg, VA, 80 p.
11) Duncan, J.M. (2000) "Factors of Safety and Reliability in Geotechnical Engineering," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 126, No. 4, April, pp. 307-316.
12) Sherman, W.C. and Clough, G.W. (1968) "Embankment Pore Pressures During Construction," *Journal of Soil Mechanics and Foundations Division*, ASCE, Vol. 94, No. SM2, pp. 527-551.
13) Duncan, J.M. and Wright, S.G. (2005) *Soil Strength and Slope Stability,* Chapter 9: Analyses for Rapid Drawdown, John Wiley and Sons, pp. 151-160.
14) Pearce, R.A., Sapkota, B.K., Sharma, L.M., and Hashash, Y. (2010). "Numerical Analysis of Proposed Wharf Structure for Port of Anchorage Redevelopment," 2010 Ports and Terminal Technology Conference, Long Beach, CA, 12 p.
15) CH2M-Hill (2013). "Suitability Study for Port of Anchorage Redevelopment," report prepared for Municipality of Anchorage, 2013, 515 p.

Geotechnical Earthquake Engineering

16) Seed, H.B. (1979). "Considerations in the Earthquake-Resistant Design of Earth and Rockfill Dams," *Geotechnique*, Vol. 29, No. 3, pp. 215-263.
17) Makdisi, F.I. and Seed, H.B. (1978). "Simplified Procedure for Estimating Dam and Embankment Earthquake-Induced Deformations," *J. of Geotechnical Engrg.*, ASCE, Vol. 104, No. 7, pp. 849-867.
18) Idriss, I.M. and Boulanger, R.W. (2009). *Soil Liquefaction,* Earthquake Engineering Research Institute
19) Harder, L.F. (1991). "Performance of Earth Dams During the Loma Prieta Earthquake," *Proceedings of the Second Intl. Conf. on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics*, St. Louis, MO, pp. 1618- 1629

20) Swaisgood, J.R. (2003). "Embankment dam deformations caused by earthquakes," *2003 Pacific Conference on Earthquake Engineering*, Paper No. 014.
21) Marcuson, W.F., Hadala, P.F., and Ledbetter, R.H. (1996) "Seismic Rehabilitation of Earth Dams," *Journal of Geotechnical Engineering*, ASCE, Vol. 122, No. 1, pp. 7-20.
22) Robertson, P.K. (2015) "Comparing CPT and V_s Liquefaction Triggering Methods," *Journal of Geotechnical Engineering*, ASCE, 141(9), pp. 04015037-1 - 04015037-10.
23) Kramer, S.L. and Wang, C.-H. (2015) "Empirical Model for Estimation of the Residual Strength of Liquefied Soil," *Journal of Geotechnical Engineering*, ASCE, 141(9), pp. 04015038-1 - 04015038-15.

Seepage

24) Casagrande, A. (1937) "Seepage Through Dams," *J. of New England Water Works Assoc.*, pp. 131-172
25) Wong, K.S. and Duncan, J.M. (1984) "SEEP: A Computer Program for Seepage Analysis of Saturated Free Surface or Confined Steady Flow," U.C. Berkeley Rpt., UC/GT/84-05
26) Stark, T.D. (1987) "Determining the Line of Seepage in Earth Dams," prepared notes
27) Freeze, R.A. and Cherry, J.A. (1979). *Groundwater,* Prentice Hall, pp. 38-49.
28) Casagrande, A. (1961) "Control of Seepage Through Foundations," *Geotechnique*, Vol. 11, No. 3, pp. 161-181
29) Terzaghi, K. (1960) "Effect of Minor Geological Details on the Safety of Dams," *From Theory to Practice in Soil Mechanics*, John Wiley and Sons, 1960, pp. 119-132
30) Sherard, J.L., Dunnigan, L.P., Talbot, J. (1984) "Basic Properties of Sand and Gravel Filters," *Journal of Geotechnical Engineering*, ASCE, Vol. 110, No. 6, pp. 684-699
31) Sherard, J.L. and Dunnigan, L.P. (1989) "Critical Filters for Impervious Soils," *Journal of Geotechnical Engineering*, ASCE, Vol. 115, No. 7, pp. 927-947
32) U.S. Army Corps of Engineers (USACE) (2006) "Appendix D: Filter Design," Engineering Manual EM 1110-2-1913, Engineering Resarch and Development Center (ERDC), Vicksburg, MS, D-1 – DD-8.
33) Lane, E.W. (1934) "Security form Under-Seepage Masonry Dams on Earth Foundations," *Transaction*, ASCE, Paper 1919, 1235-1272
34) Hendrix, J. and Stark, T.D. (2010) "Predicting Underseepage of Masonry Dams," *Proceedings of 2010 Association of Dam Safety Officials (ASDSO) Conference*, San Diego, CA, May, 2010, 6 pp.
35) Rice, J.D. and Duncan, J.M., (2009a) "Findings of Case Histories on the Long-Term Performance of Seepage Barriers in Dams," *Journal of Geotechnical Engineering*, ASCE, Vol. 136, No. 1, pp. 2-16
36) Rice, J.D. and Duncan, J.M., (2009b) "Deformation and Cracking of Seepage Barriers in Dams due to Changes in the Pore Pressure Regime," *J. of Geotechnical Engrg.*, ASCE, Vol. 136, No. 1, pp. 16-25
37) Rice, J.D., Duncan, J.M., Sleep, M. and Davidson, R.R. (2006) "A Study of the Long-Term Performance of Seepage Barriers in Dams," *Proceedings, 26th U.S. Safety of Dams Conference*, San Antonio, TX, May
38) Houlsby, A.C. (1977) "Engineering of Grout Curtains to Standards," *Journal of Geotechnical Engineering*, ASCE, Vol. 103, No. 9, pp. 953-970
39) Crum, D.A. (2008) "Geotextiles in Dams: Forging Federal Regulations," *Geosynthetics*, 20-29

Design and Construction of Earth Dams and Levees

40) Milligan, V. (2003) "Some Uncertainties in Embankment Dam Engineering," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 129, No. 9, pp. 783-797
41) Sherard, Woodward, Gizienski, and Clevenger (1963). *Earth and Earth-Rock Dams,* Chapter 2: Failures and Damages*,* John Wiley and Sons
42) Sherard, J.L. (1987) "Lessons from Teton Dam Failure," *Engineering Geology*, Vol. 24, pp. 239-256.
43) Wilson, S.D. and Marsal, R.J. (1979) "Current Trends in Design and Construction of Embankment Dams," prepared for International Commission on Large Dams (ICOLD) and ASCE Geotechnical Division and published by ASCE

44) Sherard, J.L. and Cooke, J.B. (1987) "Concrete-Face Rockfill Dam: I. Assessment," *Journal of Geotechnical Engineering*, ASCE, Vol. 113, No. 10, pp. 1096-1113
45) Sherard, J.L. and Cooke, J.B. (1987) "Concrete-Face Rockfill Dam: II. Design," *Journal of Geotechnical Engineering*, ASCE, Vol. 113, No. 10, pp. 1113-1133
46) Terzaghi, K. and Lacroix, Y. (1964) "Mission Dam," *Geotechnique*, Vol. 14, pp. 13-50
47) ENR (1961) "Three Phases of Mission Dam," June 29, pp. 33-35
48) Taylor, H. (1969) "Performance of Terzaghi Dam, 1960 to 1969," *Proceedings of 7th Intl. Conference on Soil Mechanics and Foundations Engineering*, Vol. 2, pp. 377-385
49) Terzaghi, K., Peck, R.B., and Mesri, G. (1996) *Soil Mechanics in Engineering Practice,* John Wiley and Sons, pp. 485-489.
50) Tawil, A.H. and Harriman, F.B. (2001). "Aquifer Performance under the Mactaquac Dam," Canadian Dam Association, 2001 Annual Conference, pp. 1-11
51) Whitehead, J. (2001) "Geology of the Fredericton-Mactaquac Dam Area," *people.stu.ca/~jamesw/supportfiles/NEIGCfieldtripreport2001b.pdf*, pp. A1-1 – A1-11
52) DFI (2010) "Challenging Cut-Off Wall at Peribonka Dam," DFI Magazine, 6 p.

Suggested Reference Books:

Earth and Earth-Rock Dams, Sherard, Woodward, Gizienski, and Clevenger, J. Wiley and Sons, 1963
Advanced Dam Engineering: For Design, Construction, and Rehabilitation, edited by Robert B. Jansen, Van Nostrand Reinhold, 1988
Soil Mechanics in Engineering Practice, Terzaghi, Peck, and Mesri, John Wiley and Sons, 1999

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eMail Contact:

Please feel free to correspond with me using email, HOWEVER, please make sure that the email subject starts with "CEE581:" followed by the topic of your message. This will ensure that your message is directed to my CEE581 email box and I respond promptly to your message. If you do not receive a response in a short period of time, please ensure your subject line starts with "CEE581" and resend your message.

Compass Website:

The class will have a website in the "Illinois Compass" system. Class lecture notes/PowerPoint slides, homework assignments, exams, and solution keys will be posted on the course website. Students are responsible for announcements and course materials that will be posted periodically on the website. I hope that students will use the discussion board on the site, as well as other features, and I will monitor the discussions when I am online. If you are new to Compass, a number of Compass Help documents for students can be obtained from http://go.illinois.edu/student_help.

Homework Assignments:

Civil Engineering, in particular, geotechnical engineering, can have serious consequences to society and can result in significant construction and legal costs. Consequently, all civil engineering documents and calculations are important and should be given significant attention. A**nalysis and design computations of a geotechnical engineer are also legal documents and are used in legal proceedings.** To emphasize this point, homework assignments are subject to the following guidelines and *are an essential part of this course so they should be given the attention due a professional or job assignment:*

· Homework is due at the beginning of the designated class period.

· Late homework will *not* be accepted.

· Because this class is design oriented, all homework assignments must reflect a professional approach. Free-hand drawings and curves, smudged and/or sloppy lettering, and undocumented calculations do not reflect a professional approach. *Homework with these characteristics will be returned ungraded.*

· All graphs, tables, figures, etc. must be clearly labeled with descriptions, units, scales, sign conventions, etc.

· Use either engineering paper or white ruled paper of size 8.5" x 11". Spiral bound paper with frayed edges is unacceptable. Use only the front side of the paper, put your name on each page, number the pages, e.g., 1/5 or 1 of 5, and use only pencil. Ball-point pens and felt tip pens are inappropriate for engineering computations. All assignments must be stapled together. Loose pages will not be accepted.

Examinations and Grading:

Reading assignments will be assigned every week and must be studied in depth. Unannounced quizzes on the reading will be given periodically and included in the Class Participation grade. Discussing and asking questions about the course material is vital to **really learning** the subject matter. As a result, class participation is required and will be a major part of your total grade (30%; see below). Please read the course material and bring questions and comments to class. At the start of each class I will select "volunteers" to comment on the current readings, homework assignment, and term project analyses.

Class Participation, Homework, and Quizzes	30%
Mid-Term Exam (NEW)	20%
Term Project	20%
Final Exam	30%

The final exam is tentatively scheduled for Monday, December 11, 2023 – 1:30 – 4:30 p.m.

Office Hours in Room 2217 NCEL:

Tuesday	5:00 p.m. - 6:00 p.m.
Thursday	5:00 p.m. - 6:00 p.m.

Purpose and Scope of Course:

This course will focus on the geotechnical aspects of analysis, design, and construction of earth structures, such as dams, levees, heap leach pads, waste containment facilities, and compacted fills. In particular, this course will cover saturated and partially saturated seepage, static and seismic slope stability, and earthquake effects of earth structures. The importance of precedence will be emphasized in relation to the design section of concrete and earth dams and levees, the causes of failures, possible failure mechanisms, and viable remedial measures. Finally, emerging issues concerning the design, inspection, maintenance, and inspection of dams and levees will be addressed.

Graduate Student Term Project:

Graduate students should take this course for one unit and complete the following term project in addition to the other course requirements. Term project reports will be due Thursday, November 18, 2021. A comprehensive and in-depth report that is typed with a 12 point font and does not exceed a total of five (5) pages (including cover page, figures, tables, and references) must be submitted by each student on Thursday, November 18, 2021. Afterwards, selected students will give a 10 to 15 minute oral presentation to the class near the end of the semester, e.g., December 3 or 8, 2021. Each student or group will give a periodic 5 minute update presentation during class to demonstrate progress and present preliminary results. These update presentations are tentatively scheduled for September 9, October 7, and October 28, 2020 and should use the PowerPoint template on the COMPASS website.

The main objective of the term project is to research a slope stability failure, e.g., embankment, levee, landfill, tailings dam (mining or coal ash) failure, and apply the various analysis techniques, e.g., shear strength, stability, seismic, seepage, etc., to the case history. To accomplish this objective, each student will research a slope stability failure, e.g., one of the tailings dams failures that are listed at: http://www.wise-uranium.org/mdaf.html or a levee failure. Each student or group should submit their term project topic to Professor Stark by September 9, 2021 to ensure each student or group is studying a different case history.

Teachings of Ralph B. Peck:

Professor Peck had a profound impact on geotechnical engineering. He was world renowned and received the Medal of Science from President Gerald Ford. In addition to his teaching research, and consulting expertise, he left the geotechnical engineering profession with many "words of wisdom". Some are repeated below and will probably be useful throughout this course and your career.

- "If you can't reduce a difficult engineering problem to an 8 ½ x 11-inch sheet of paper, you will probably never understand it."
- "Geology enables us to establish what constraints may exist for a particular project."

Advice to a Young Engineer – R.B. Peck – Pub. No. 167, Military Eng., Vol. 69, p. 450, July, 1977.
Acquire two additional skills besides your course work: engineering judgment and professional and public responsibility

1) **Engineering Judgment** – a good sense of proportion
   - Make every assignment count because there is "always something to be learned"
   - "teach your brain to register what your eyes see" – keep a notebook
   - "learn how to think quantitatively" – visualize numerical quantities, dimensions, rates, and loads to develop a sense of proportion
   - "continue to read and study", and
   - "study precedents to cultivate engineering judgment".-

2) **Professional and Public Responsibility**
   - "Our personal, individual attitudes toward engineering and toward society have a potential impact on our country's future. However small that impact, each of us should try to make it for good."

Teachings of Karl Terzaghi: Rules for the Game of Engineering

- "Engineering is a noble sport which calls for good sportsmanship. Occasional blundering is part of the game. Let it be your ambition to be the first one to discover and announce your blunders. If somebody else gets ahead of you, take it with a smile and thank him for his interest."
- "The worst habit you can possibly acquire is to become uncritical towards your own concepts and at the same time skeptical towards those of others."
- "When you commit one of your ideas to print, emphasize every controversial aspect of your thesis which you can perceive."
- "Very few people are either so dumb or so dishonest that you could not learn anything from them."

Words of Wisdom from John Wooden: Legendary Basketball Player and Coach

- It's what you learn after you know it all that really counts.
- If you don't have time to do it right, when will you have time to do it over? (If you have time to do it, you have time to do it.)
- It isn't what you do, but how you do it.
- It's not so important who starts the game but who finishes it.
- Little things make big things happen.
- Failure to prepare, is preparing to fail.
- Never mistake activity for achievement.

Darryl Royal: University of Texas Football Coach

- Potential is a fancy way of saying you have not done it yet.

Timothy D. Stark: University of Illinois at Urbana-Champaign

- Substance over hype.
- Study in-depth.