CEE 406 – PAVEMENT DESIGN, I

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Office Hours: MWF 1:00 - 2:00 pm
(Feel free to e-mail or stop by any other time to consult and interact!)

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Office Hours: Tu Th 11:00 am to 12:00 noon

Prerequisite CEE 310 – Transportation Engineering

Texts
1. Pavement Analysis and Design, Y.H. Huang, 2nd Edition, Pearson Prentice Hall, Pearson Education Inc., Upper Saddle River, NJ, 2004.
2. Class Notes, National Highway Institute (NHI) training materials – Design Checks (*Available on the course website*).
3. Class Reference, National Highway Institute (NHI) Course No. 131064 – "Introduction to Mechanistic-Empirical Design of New & Rehabilitated Pavements" (*Available on the course website*).

Course Content This is a 3-hour undergraduate course or a 3/4-hour graduate level course on pavement analysis and design at the University of Illinois. This is the first pavement design course offered for students planning on only obtaining a bachelor's degree and a prerequisite course for the graduate courses on advanced pavement design (CEE 506: Pavement Design, II) and pavement evaluation and rehabilitation (CEE 508: Pavement Evaluation and Rehab).

This course covers the structural and functional design of pavement structures for highway and airport situations with emphasis on highways. Structural design examines the direct influence of the vehicles on material and thickness requirements to provide a pavement with suitable design life and good performance. Design considerations include climatic conditions, traffic loadings, life cycle design economics, and rehabilitation. The functional design examines the user aspects, which are primarily smoothness and safety considerations.

Course Website https://canvas.illinois.edu/courses/40791

GradeScope https://www.gradescope.com/login, Entry Code: K36J32

Introduction

A pavement is a support structure that has a surface that provides a safe means of conveyance of people and goods from one place to another. The analysis and design of pavements requires knowledge of materials, climate, and structural considerations to develop a system that will accommodate a given level of vehicular loading for a specified time, termed the design period. The general material aspects are covered in CEE 310, CEE 380, CEE 401, and CEE 405, which should be reviewed for material properties and classifications, materials tests, and mix designs. CEE 406 will therefore utilize the structural properties of these materials to evaluate the impact on structural and functional design and rehabilitation of highway and airport pavements.

There are many agencies that will "own" pavements. The Federal Government is one of the biggest with the Federal Highway Administration (FHWA), Federal Aviation Administration (FAA),

Coast Guard, Forest Service, Park Service, Bureau of Indian Affairs, The Department of Defense (DOD) with the Army, Air Force, Navy, Marines, National Guard, etc. being the most noticeable. State Departments of Transportation (DOTs), cities, counties, townships, shopping malls, trucking companies, railroads, airlines, etc. representing the more diverse agencies that utilize and own pavements in one form or another depending on their individual needs.

The Civil engineer has the responsibility for this component of our infrastructure, and they work in nearly every agency mentioned above. Additionally, they will work for the companies that design and construct the pavements. Private consultants will hire Civil engineers to provide expertise to these agencies to supplement the in-house staff, typically to provide management services and rehabilitation planning. Industry associations, such as the Asphalt Institute, the American Concrete Pavement Association (ACPA), the National Asphalt Pavement Association (NAPA), and the Asphalt Pavement Alliance (APA) utilize the expertise of Civil engineers throughout the United States to provide current information to their members who deal with detailed pavement problems. Professional organizations such as the American Association of State Highway and Transportation Officials (AASHTO), a nonprofit, nonpartisan association representing highway and transportation departments in the 50 states, the District of Columbia and Puerto Rico, foster the development, operation, and maintenance of an integrated national transportation system.

Pavement engineering has become a specialized discipline for well over half a century. Knowledge of both the theoretical mechanisms and the practical field observations is required to successfully design and maintain pavements. The status of the transportation infrastructure has over two million miles of paved roads in use plus a large amount of airport and private parking pavements. All these pavements require continual attention to ensure they serve existing needs, and to ensure that upgrades are consistent to serve future needs. At present, it is these future needs that drive the emphasis on maintenance and rehabilitation rather than new construction, but reconstruction is an ever-increasing cost-effective alternative, which requires pavement design expertise and a more thorough understanding of material behavior and pavement deterioration cycles.

Increasing traffic has continually frustrated the pavement design engineer as predictions have continually lagged actual increases. Increased traffic, both in quantity and loading magnitudes, results in more rapid deterioration of existing pavements and an increased need for expertise in rehabilitation and construction. At some point, decisions must be made to provide new facilities, thus accurate forecasting of traffic is an important aspect of pavement management and planning.

CEE 406 provides comprehensive instruction in pavement design, especially for highways. Basic principles can be applied to other types of pavements as well. Both theoretical concepts and principles and the practical design aspects are covered. This course will familiarize the student with the many analytical tools that are useful in pavement design. Several personal computer software programs will be utilized. A frustration that we will overcome is the recognition that due to the complexities involved, there is still a great deal of knowledge in this area that has yet to be applied. We will be attempting to close that gap slightly before the semester is over.

You will be able to distinguish the difference between analysis and design. Analysis applies technology to analyze an existing structure to describe its behavior and determine if/why/where/ problems may develop. It is not always possible to apply design principles to analysis. Design procedures do not always utilize state-of-the-art technology. Design procedures are structured to produce a system of materials and layers that will fulfill the design function of the pavement. It is often the case that significant assumptions are made in design when precise materials/properties/traffic etc. are not known and must be developed from the engineer's background. This ***engineering judgment*** is something we will attempt to develop during the semester. A pavement engineer should be able to analyze a pavement that has been designed and describe how well the design could be expected to function.

A mechanistic based pavement design guide for AASHTO, ***the Mechanistic-Empirical Pavement Design Guide (MEPDG) for Design of New and Rehabilitated Pavement Structures,*** was developed and delivered to state highway agencies for their evaluation in 2004. The ***MEPDG Guide*** was prepared with extensive documentation that contains all the individual chapters and appendices of the Design Manual). The MEPDG Guide was evaluated by a team of experts in the NCHRP Project 1-40A project, entitled, "Independent Review of the Recommended Mechanistic-Empirical Design Guide and Software," for adoption recommendations to AASHTO.

The ***AASHTOWare Pavement ME Design*** *(https://me-design.com/MEDesign/)* was designed and adopted based on the ***MEPDG Guide*** *t*o provide many improvements over current empirical pavement design procedures. The mechanistic-empirical design approach is anticipated to allow pavement designers to: (1) improve design reliability; (2) include concepts for sustainability such as reducing life cycle costs; (3) predict specific failure modes; (4) better evaluate the impact of new load levels and conditions; (5) make better use of materials, e.g., recycled/by-product/local materials; (6) minimize premature failures; (7) better characterize seasonal and drainage effects; (8) improve rehabilitation design; and in overall create more efficient and cost-effective designs.

Course Objectives

This course has been developed to provide students with the needed knowledge to analyze and design flexible and rigid pavements. Upon successful completion of this course, the student will have gained knowledge in the following areas:

- Pavement Performance: Explain the difference between structural performance of a pavement and functional performance. Identify distress types common to flexible and rigid pavements and their mechanisms. List several means for evaluating the functional performance of pavements.

- Material Characterization: Characterize fine and coarse grain soils in terms of their physical and mechanical properties. Apply measured soil properties to pavement design examples. Explain the behavior of granular materials under loading and list factors affecting their performance. Identify base types used for pavements and their properties. Determine the material property inputs required for asphalt concrete and Portland cement concrete pavement types.

- Traffic Analysis: List the types and axle configurations of typical highway trucks and their corresponding standard loads. List the various types of aircraft gears, wheel load magnitudes, and wheel and axle spacing. Convert mixed traffic into an equivalent single axle load (ESAL) for flexible and rigid pavement systems. Understand axle load spectra for ME designs.

- Pavement Analysis: Calculate stresses, strains, and deflections in flexible pavements using Boussinesq solutions and layered elastic analysis. Calculate wheel load and temperature stresses in concrete pavements using Westergaard's equations.

- Pavement Design: Design new flexible pavements using the 1993 AASHTO method, Illinois DOT's (IDOT's) design procedure, and 2011 AASHTO Pavement ME (Mechanistic-Empirical) Design Guide. Design new rigid pavements using the AASHTO methods, PCA method, and IDOT's design procedure. Design the various pavement foundation layers and their structural and functional purposes. List the process to construct a flexible and rigid pavement system. Describe and detail the features of a continuously reinforced concrete pavement and the key factors affecting their design and performance.

- Transfer Function Application: Apply asphalt concrete fatigue and unbound material rutting equations to predict the performance life of flexible pavements. Utilize concrete fatigue transfer functions to relate load repetitions to fatigue cracking.

Policies and Procedures

• The course outline will serve as a general guide for the order of the class work. However, it is subject to change at the discretion of the instructor at any time during the semester.

• Class attendance is expected, and participation is encouraged. Good attendance leads to better understanding of the course material, better grades, and it will strengthen your chances for obtaining scholarships, fellowships, research and teaching assistantships, and potential employment opportunities in the future. Students with an excused absence from lecture will be allowed to watch the captured lecture online.

• The important course information will be discussed in class; however, the student should be cognizant of the complementary material in the reading assignments. Students are encouraged to ask questions in class.

• Please check CANVAS course website before class to download any class notes relevant to the lecture.

Homework and Class Project

• Homework will be assigned regularly every week. Often, more than one homework will be out at a time during the week. Homework assignments and solutions will be uploaded to GradeScope course website. If not indicated otherwise, each assignment will be worth 100 points. Please box or underline your final answers. Sloppy homework or homework difficult to read or understand will be penalized a minimum of 5 points. Homework will be due at the beginning of the class on the due date. Unexcused late homework will receive a maximum mark of 80 points, wrong answers receive a minimum 40 points.

• A one-page typed letter report must accompany all homework assignments to summarize: (1) the answers, (2) assumptions made in the solution, and (3) the final design related recommendations, if applicable (you are welcome to be entrepreneurial and start your pavement engineering company and make your stationary, or you can always write your cover letter to Professor Tutumluer). The solution including formulas, graphs, tables, spreadsheets, computer printouts, etc., must be attached to this letter report. Individual students may be called on to present their homework solutions to the class, rather than just the Professor giving you the right answers.

• Graduate students (those registered for 4 hours) will be required to submit the semester project assignment as a formal report requiring title pages, table of contents, section headings, etc., which will be discussed towards the middle of the semester.

• Be prepared to discuss homework/ reading assignments and take short 5-minute pop quizzes.

• All submitted work shall be considered graded work, unless otherwise noted. The University of Illinois Code on Campus Affairs and Regulations Applying to All Students will be strictly enforced in this class (http://studentcode.illinois.edu/). All aspects of your course work are covered by the UIUC Student Code. Honesty in your academic work will develop into professional integrity and ethics.

- GradeScope (https://www.gradescope.com/login), Entry Code: K36J32

Exams and Grading

• There will be two mid-term exams and a final exam. The semester exams are *tentatively* scheduled for September 26 and November 14 (see the class schedule on pages 8 and 9). The final examination is scheduled for 1:30-4:30 pm, Friday, December 8, 2023. If a take-home final is given, it will be due 4:30 pm on December 8, 2023. Grades are distributed as follows:

Exam #1:	20%
Exam #2:	20%
Final Exam:	20%
Homework / Quizzes / Project Report (if applicable):	40%

• If you miss a semester or final exam without instructor approval or certified medical excuse, a zero will be averaged into your exam grade for that test.

• Grading weights will be based on the formula given above. Final grades may be based upon a curve; however, final grade cutoffs will not exceed the following:

A+=95%; A = 91.0%; A- = 89.0%; B+ = 86.7%; B = 83.3%; B- = 80%; C+ = 76.7%; C = 73.3%; C- = 70%; etc…

• Students who have borderline scores may be rounded to the next highest-grade category depending on the following factors at the discretion of the instructor: (1) student attendance and participation in the class; and (2) whether student overall performance has been improving (tests and homework grades increasing) or declining (tests and homework grades decreasing).

This is your opportunity to learn and inquire about the current practice of pavement analysis and design. Since this is a technical elective course for the undergraduate students and an essential course to take for graduate students, feel comfortable to get to know your fellow classmates, learn from each other as well as from the instructor by engaging in classroom discussions, give often feedback to the instructor, and as a result, make this an educational and profitable semester.

Classroom Etiquette

To foster and promote integrity among students, the CEE Honor Code was developed with input from several CEE undergraduate organizations, the CEE Graduate Student Advisory Committee, and the CEE Graduate Affairs Committee. You (the student) commit to honor the code each time you sign an exam, and implicitly whenever you sign homework or other class assignments.

The **CEE Honor Code** pledge is the following:

"I pledge to uphold the highest levels of professional and personal integrity in all of my actions, including (1) never assisting or receiving unfair assistance during exams, (2) never assisting or receiving assistance on class assignments beyond that specified by an instructor, and (3) always fully contributing to group activities that are part of a course activity."

For University policies and regulations please refer to the Student Code (http://studentcode.illinois.edu/). You are responsible for maintaining compliance with the University policy on academic integrity as defined in Section 1-402 (http://studentcode.illinois.edu/article1/part4/1-401/) of the Student Code, and the Department Honor Code as defined above.

Finally, please note that posting any content from this course, including homework assignments, exams, quizzes, etc. to the Web without explicit permission from the course instructors violates copyright law, the Student Code, and the CEE Honor Code and is therefore not permitted.

Absence Policy

You are expected to attend all classes and exams. Unexpected absences and ramifications on assignments and exams will be dealt in accordance with the Student Code as follows:

Part 5, 1-501 of the Student Code provides background on class attendance and provides useful information for students (and instructors). Consider a direct link to this resource in your course policies. Please note that the code stipulates the conditions under which an absence letter from the Office of the Dean of Students may be requested. Note, a brief illness (less than 3 days) would not qualify for an absence letter.

Course policies that provide leniency to accommodate unexpected health situations are encouraged and, if adopted, should be clearly communicated at the beginning of the semester. Policies such as allowing students to miss a predefined number of sessions (if attendance is graded), dropping one or two homework grades, or allowing a conflict exam due to illness can accomplish this while minimizing the amount of absence requests instructors must field.

Please note, though, that in general such a policy does not circumvent the need to accommodate absences related to religious observances and practices. That is, one cannot require a student who cannot hand in an assignment on its due date due to a religious practice to use a "free drop" for that assignment.

Emergency Response

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/.

Other Important Policies

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.

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.

Religious Observances

Illinois law requires the University to reasonably accommodate its students' religious beliefs, observances, and practices regarding 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.

Disability-Related Accommodations

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must 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 217-333-4603, e-mail disability@illinois.edu or go to https://www.disability.illinois.edu. If you are concerned you have a disability-related condition that is impacting your academic progress, there are academic screening appointments available that can help diagnosis a previously undiagnosed disability. You may access these by visiting the DRES website and selecting "Request an Academic Screening" at the bottom of the page.

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.

Anti-Racism, Inclusion and Diversity

The Grainger College of Engineering is committed to the creation of an anti-racist, inclusive community that welcomes diversity along several dimensions, including, but not limited to, race, ethnicity and national origins, gender and gender identity, sexuality, disability status, class, age, or religious beliefs. The College recognizes that we are learning together amid the Black Lives Matter movement, that Black, Hispanic, and Indigenous voices and contributions have largely either been excluded from, or not recognized in, science and engineering, and that both overt racism and micro-aggressions threaten the well-being of our students and our university community.

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 Campus Belonging Resources (https://diversity.illinois.edu/diversity-campus-culture/belonging-resources/). Based on your report, Members of the Office of the Vice Chancellor for Diversity, Equity & Inclusion staff 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.

CEE 406 Course Timetable
Fall 2023 – 1311 Newmark CEE Laboratory – 9:30-10:50 am Tu Th

Text: Pavement Analysis and Design, Y.H. Huang, ***2nd Edition, 2004,*** Pearson Prentice Hall, Upper Saddle River, NJ.
Class Notes: National Highway Institute training materials – Design Checks (*Available on the course web site)*.
Class Reference: National Highway Institute (NHI) Course No. 131064 – "Introduction to Mechanistic-Empirical Design of New & Rehabilitated Pavements" (*Available on the course web site*).

Date	Topic	Text	Class Notes	Class Reference
Aug 22	Block 1: Introduction, Course Content, and Terminology	Ch 1, App. E	1-0.1 to 1-1.5	1-1.1 to 1-2.14
Aug 24	Block 1: Pavement Types, Functions, and Structural Layers	Ch 1, App. E	1-0.1 to 1-1.5	1-1.1 to 1-2.14
Aug 29	Block 2: Pavement Performance	Ch 9.1 to 9.3	1-2.1 to 1-2.11	1-2.15 to 1-2.30; 2-5, & 3-5
Aug 31	Block 2: Pavement Performance, Pavement Distresses	Ch 9.1 to 9.3	1-2.1 to 1-2.11	1-2.15 to 1-2.30, App. A
Sep 5	Block 2: Pavement Distresses/Responses	Ch 9.1 to 9.3	2-2.1 to 2-2.7 3-1.1 to 3-1.9	1-2.15 to 1-2.30, App. A
		Reference: 2003 FHWA LTPP Distress Identification Manual		
Sep 7	Block 3: Roadbed Soils – Properties, Characterization	Ch 7	2-1.4, 22, 40	1-3.47 to 1-3.54
Sep 12	Blocks 3-4: Soils and Aggregates, Properties, Characterization	Ch 7	3-2.8, 31, 44, 45	1-3.47 to 1-3.54
Sep 14	Block 4: Materials for Transportation Facilities, Testing	Ch 7, App. D	3-2.8, 31, 44, 45	1-3.33 to 1-3.47 3-2.5 to 3-2.11
Sep 19	Block 5: Traffic and Pavement Loading	Ch 6	2-1.4, 21, 40	1-3.1 to 1-3.33
Sep 21	Block 5: Traffic and Pavement Loading	Ch 6	3-2.10, 30, 46	1-3.1 to 1-3.33
Sep 26	***Examination 1*** *(tentative and likely to change)*			
Sep 28	Block 6: Analyses of Flexible Pavements	Ch 2, App. B	2-2.7 to 2-2.44	3-1.1 to 3-1.37
Oct 3	Block 6: Analyses of Flexible Pavements	Ch 2, App. B	2-2.7 to 2-2.44	3-1.1 to 3-1.37
Oct 5	Block 7: Flexible Pavement Design – AASHTO Procedure	Ch 11	2-1.19 to 2-1.38	
Oct 10	Block 7: Flexible Pavement Design – AASHTO Procedure	Ch 11	2-1.19 to 2-1.38	
Oct 12	Block 7: Flexible Pavement Design – Mechanistic Procedures	Ch 11	2-1.2 to 2-1.19	3-6.1 to 3-6.25; 4-1
Oct 17	Block 7: Flexible Pavement Design – MEPDG / Pavement ME Design	Ch 11, App. F – *Additional Handouts*		

Date	Topic	Text	Class Notes	Class Reference
Oct 19	Block 8: Analyses of Rigid Pavements	Ch 4	3-1.9 to 3-1.45	2-1.1 to 2-1.53
Oct 24	Block 8: Analyses of Rigid Pavements	Ch 4	3-1.9 to 3-1.45	2-1.1 to 2-1.53
Oct 26	Block 9: Rigid Pavement Design – AASHTO Procedure	Ch 12	3-2.27 to 3-2.42	
Oct 31	Block 9: Rigid Pavement Design – AASHTO Procedure	Ch 12	3-2.27 to 3-2.42	
Nov 2	Block 9: Rigid Pavement Design – Mechanistic Procedures	Ch 12	3-2.2 to 3-2.26	2-6.1 to 2-6.29; 4-1
Nov 7	Block 9: Rigid Pavement Design – Mechanistic Procedures	Ch 12	3-2.43 to 3-2.61	2-6.1 to 2-6.29; 4-1
Nov 9	Block 9: Rigid Pavement Design – MEPDG / Pavement ME Design	Ch 12, App. F – *Additional Handouts*		
Nov 14	***Examination 2*** *(tentative and likely to change)*			
Nov 16	Block 9: Rigid Pavement Design – Joint Layout and CRCP Designs	Ch 4 & 12	3-1.34 to 3-1.45	2-4.1 to 2-4.23
Thanksgiving break				
Nov 28	Block 9: Rigid Pavement Design – Concrete Pavement Construction	*Additional Handout by Portland Cement Assoc.* Ch 12, *Supplemental Presentation by ACPA*		
Nov 30	Block 10: Drainage Design for Transportation Facilities	Ch 8		
Dec 5	Block 10: Drainage Design for Transportation Facilities	Ch 8		
Dec 7	Reading Day – No Class			
Dec 8 (1:30-4:30 p.m., Friday, December 8)	***Final Exam***			

Ch: Chapter; App.: Appendix

Recorded Lectures:

Pavement Design I (CEE 406 4) (CEE 406 ONC) (CEE 406 ONL) Fall 2023
https://mediaspace.illinois.edu/channels/channelid/310153182