CE4G04: Highway Materials and Pavement Design

COURSE DESCRIPTION
Pavements consist of all structural elements or layers of roads above the subgrade. Functions of the pavement are: to reduce and distribute the traffic loading so that no pavement layers fail or have excess deformation; and to provide a safe, smooth and comfortable ride (serviceability) without undue delays and excessive wear and tear.

The design of pavement structures requires a good understanding of the properties of materials that the engineer must work with along with an appreciation for pavement-subgrade interaction. The first part of the course deals with materials, in particular the properties of soils, including both the subgrade and the unbound granular layers acting as structural components of pavements. The aggregates used to make asphalt concrete or Portland cement concrete must meet certain requirements to ensure that the pavements can perform their intended function over their design life. Discussion on hot-mix asphalt focuses on the Superpave technology.

The second part of the course addresses advanced analysis/design of both flexible and rigid pavement structures, including the Mechanistic-Empirical method that allows the determination of stresses and strains in the various layers of the pavement structure and subgrade by considering climate and environmental impacts. Case studies will be provided to demonstrate how both theory and different approaches are incorporated into the design and construction of both flexible and rigid pavements.

The final part of the course concerns itself with life cycle cost analysis, pavement management, an introduction to pavement sustainability, airport pavements and the impact of climate change of highway pavements.

LECTURES/LABS
Lectures: Mon. & Thur. 9:30-10:20; Tue. 10:30-11:20 KTH/B124
Tutorials: Tue. 11:30-13:20 ABB163
Labs: Tue. 11:30-14:20 (Lab 1) and 14:30-17:20 (Lab 2) JHE144/ADL

INSTRUCTOR
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TEACHING ASSISTANTS
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TERM WORK (Assignments, design project and examinations)
Assignments/Design projects: 25%
Laboratory: 20%
Term Test: 15%
Final Examination: 40%

LABORATORY PROJECT
The laboratory component of CE 4G04 will be worth 20% of the final course grade this year. Groups, comprising typically four (no more than 5) members, will work on different tests on soil, aggregates and asphalt mix in the laboratory.
Group lab reports, with specific contribution from each individual, are due two weeks after completion of a lab. The reports should contain summary of the lab activities, test results and major findings. The reports will be graded by taking into account the technical content, discussion of the findings and presentation (organization, grammar, etc.). More details can be found in the notes for lab reports.

The following four labs will be carried out:
1) Resilient modulus testing of coarse granular materials
2) CBR tests
3) Gyratory compaction of select Superpave hot mix
4) Foamed-asphalt stabilization of soil (Demonstration)

LEARNING OUTCOMES
1. Ability to understand and characterize the properties of various pavement construction materials and how to select materials to meet requirements.
   • CEAB attribute 1.4 "Competence in specialized engineering knowledge"

2. Ability to properly deal with uncertainties in material properties, traffic information, various assumptions in analysis and designs.
   • CEAB attribute 2.1 "Ability to identify reasonable assumptions (including identification of uncertainties and imprecise information) that could or should be made before a solution path is proposed"

3. Ability to use advanced tools for pavement structural analysis (using KenPave and PerRoad)
   • CEAB attribute 5.2 "The ability to use of modern/state of the art tools"

4. Ability to learn the current development and engineering practice in pavement engineering using provided additional reference materials
   • CEAB attribute 12.2 "Is aware of the wide range of engineering societies, literature, conferences, and other information sources"

COURSE REFERENCES (Note: Refs. 5-13 are available at the course home page and they can only be used exclusively for your study in CE 4G04)

Recommended texts (Primary references):

Additional references for your personal library of pavement engineering:
10. Asphalt Institute (1999). Asphalt overlays for highway and street rehabilitation, MS-17, Asphalt Institute, Lexington, KY.

USEFUL WEBSITES
- AASHTOWare Pavement ME Design: me-design.com/MEDesign/Documents.html
- Western Research Institute (WRI): http://www.westernresearch.org/
- U.S. Department of Transportation Federal Highway Administration: http://www.fhwa.dot.gov/
- Turner-Fairbank Highway Research Center (TFHRC): http://www.fhwa.dot.gov/research/

LABORATORY SAFETY
The Faculty of Engineering is committed to McMaster University’s Workplace and Environmental Health and Safety Policy which states: "Students are required by University policy to comply with all University health, safety and environmental programs". It is your responsibility to understand McMaster University Workplace and Environmental Health and Safety programs and policies. For information on these programs and policies please refer to McMaster University Environmental and Health Support Services Occupational Safety Risk Management Manual at: http://www.workingatmcmaster.ca/med/document/Lab-Safety-Handbook-1-36.pdf. It is also your responsibility to follow any specific Standard Operating Procedures (SOPs) provided for some of the experiments and the laboratory equipment.

The safety requirements for the labs are listed below. Students not abiding by these safety requirements will be asked to vacate the laboratory, and receiving a grade of zero for that particular lab.

- General requirements: Closed-toe shoes must be worn at all times.
  - No loose clothing allowed and long sleeve shirts must be worn.
  - No short (i.e., above the knee) pants or skirts are permitted in the lab
  - Lab coats must be worn over top of your clothing in these instances.
  - Long hair must be tied back.
- Specific requirements for Geotechnical laboratory:
  - Closed-toe shoes must be worn at all times.
- Safety glasses for CBR test – Supplied
- Ear plugs for resilient modulus test – Supplied

• Specific requirements for Asphalt laboratory at ADL:
  - Safety glasses – Supplied
  - Heat resistant gloves – Supplied
  - Hard hats – Supplied
  - Green patch safety boots/shoes – student is responsible to provide
  - In general, students are required to wear safety boots, hard hats, and safety eye-glasses at all times

**ETHICS**

Academic dishonesty consists of misrepresentation by deception or by other fraudulent means and can result in serious consequences, e.g., the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: “Grade of F assigned for academic dishonesty”), and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various kinds of academic dishonesty please refer to the Academic Integrity Policy, Appendix 3, [http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf](http://www.mcmaster.ca/policy/Students-AcademicStudies/AcademicIntegrity.pdf)

The following illustrates only some forms of academic dishonesty:

1. Plagiarism, e.g., copying another’s material verbatim as well as paraphrasing another’s ideas without providing one’s source(s) for the materials.
2. Helping or attempting to help another to commit an act of academic dishonesty, such as cheating or plagiarism.
3. Copying or using unauthorized aids in tests and examinations.

**UNIVERSITY STATEMENT ON CHANGES OF THE COURSE**

The instructor and McMaster University reserves the right to change or revise information contained in course outlines in extreme circumstances. If a modification becomes necessary, reasonable notice and communication with the students will be given with an explanation and the opportunity to comment on changes. It is the responsibility of students to check regularly their primary email account via their @mcmaster.ca alias and course website.

**ACADEMIC ACCOMMODATION OF STUDENTS WITH DISABILITIES**

Students who require academic accommodation must contact Student Accessibility Services (SAS) to make arrangements with a Program Coordinator. Academic accommodations must be arranged for each term of study. Student Accessibility Services can be contacted by phone 905-525-9140 ext. 28652 or e-mail sas@mcmaster.ca. For further information, consult McMaster University's Policy for Academic Accommodation of Students with Disabilities.
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<th>Lect #</th>
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<td>Sept. 5/7</td>
<td><strong>Introduction:</strong> Scope of the course; Role of pavements in Transportation systems</td>
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<td><strong>Pavement structures:</strong> Types of pavements and functions; Factors influencing pavement performance; Framework of pavement design (Ref: NHI 05-037 Ch. 1)</td>
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<td>3-5</td>
<td>Sept. 11/12/14</td>
<td><strong>Review of soils:</strong> Soil classification and characterization; Mechanical properties and their measurements. (NHI 05-037, Section 5.4)</td>
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<td>Sept. 18/19/21/25</td>
<td><strong>Highway subgrade structure, bases and subbases;</strong> (Ref: NHI 05-037, 3.1-3.3); <strong>Soil compaction and stabilization</strong> (Ref: NHI 05-037, 7.4-7.6, 8.3)</td>
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<td>10-11</td>
<td>Sept. 26/29</td>
<td><strong>Water in Pavement System and Drainage Consideration</strong> (Ref: NHI 05-037, 7.2)</td>
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<td>12-15</td>
<td>Oct. 2/3/5/16</td>
<td><strong>Asphalt technology and Superpave Mix Design:</strong> Asphalt materials and aggregates for HMA</td>
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<td>Asphalt materials; Aggregates for HMA; Hot mix asphalt (HMA) design; HMA specification; HMA construction and quality control; Case studies. (Ref: SP-1, SP-2, MS22 Chapter 2)</td>
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<td>Oct. 17/19/23/24</td>
<td><strong>Pavement mechanics-Flexible pavements:</strong> Stress analysis and traffic characterization</td>
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<td>Stresses in flexible pavements; Traffic characteristics (Ref: Mallick, Ch. 2, 2.8; Huang, Ch.2, 2.1-2.2; MS-17 Chapter 4;)</td>
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<td><strong>Flexible pavements: Analysis and design</strong></td>
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<td>Mechanistic characterization of materials; Asphalt Institute Method; AASHTO 93; AASHTO M-E Method; History and future of ME design methods; Case studies. (Ref: AASHTO 1988 Part II &amp; IV; Mallick, 14.3)</td>
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<td>Nov. 7/9/13</td>
<td><strong>Pavement mechanics-Rigid pavements:</strong> Stress analysis</td>
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<td>Stresses in slab: Effects of temperature and moisture. (Mallick, Ch. 3; Huang, Ch 4, 4.1-4.2)</td>
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<td>28-30</td>
<td>Nov. 14/16/20</td>
<td><strong>Rigid pavements:</strong> Analysis and design</td>
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<td>Stresses in slab: Effects of temperature and moisture; Rigid pavement structural design; Rigid pavement maintenance (Mallick, Ch. 15, 15.2)</td>
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<td>Nov. 21/23/27/28</td>
<td><strong>Pavement maintenance, pavement management and life cycle cost analysis</strong></td>
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<td><strong>Airport pavements: a brief introduction</strong></td>
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