# CIVE 5801 – Permafrost Engineering

Fall 2026 | Department of Civil and Environmental Engineering | Graduate Course

## Teaching Team

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| **Instructor** | Mehdi Pouragha |
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| **Office** | EDC 4530 |
| **Office hours** | By appointment |
| **Teaching assistants** | None |

## Course Description and Requirements

### 1) Course schedule

**Wednesdays, 2:35 pm–5:25 pm.** Class location and the most recent scheduling information are available through the Public Class Schedule.

### 2) Course description

**Permafrost Engineering**

This course explores the engineering challenges and solutions associated with permafrost regions with emphasis on climate-resilient design and northern infrastructure performance.

Topics include the formation and characteristics of permafrost, thermal and mechanical properties, and the design considerations for infrastructure in cold environments.

### 3) Precluded courses

None.

### 4) Prerequisites and recommended knowledge

There are no formal prerequisites for this course. Familiarity with the following topics is required, but advanced knowledge is not expected:

- fundamental soil mechanics, including phase relationships, effective stress, shear strength, slope stability, seepage/Darcy flow, and consolidation;
- basic differential equations and the principles of heat conduction/diffusion; and
- basic experience with numerical/computer programming (e.g., MATLAB, Python, or a similar language).

Relevant concepts and numerical methods will be reviewed or developed as needed during the course.

### 5) Learning Outcomes

By the end of the course, students should be able to:

- Explain the key characteristics and engineering significance of permafrost and frozen ground.
- Analyze heat transfer, freezing, thawing, and ground-temperature evolution in permafrost.
- Assess the mechanical behaviour of frozen and thawing soils.
- Evaluate permafrost-related engineering problems, including slope stability, frost heave, thaw settlement, and foundations.
- Compare and assess mitigation and adaptation strategies for infrastructure in permafrost regions.

## 8) Text book(s)/Learning Materials and their costs

Students are not required to purchase textbooks or other learning materials for this course.

| Material | Status | Estimated cost | Notes |
|---|---|---|---|
| Andersland, O.B. and Ladanyi, B., Frozen Ground Engineering, 2nd ed., Wiley. | Recommended; not required | Approx. CAD $280 new | Price estimate checked August 2026 and may change. Used/second-hand copies are acceptable. |
| MATLAB | Required for numerical assignments | CAD $0 | Available to Carleton students through the University licence. |
| GeoStudio / SLOPE/W | Used for the slope-stability assignment | CAD $0 expected | Free academic/student access is available; course-specific access instructions will be provided. |
| Lecture notes, selected papers, and other readings | Required/recommended as posted | CAD $0 | Provided through Brightspace or University-accessible resources. |

## 9) Topics and tentative plan

The schedule below is tentative and may be adjusted as the course develops. Any changes will be communicated in class and/or through Brightspace.

| Date | Tentative topic | Assessment / activity |
|---|---|---|
| Sep. 9 | Introduction to permafrost engineering: permafrost and active layer; distribution; ground ice and cryostructure; engineering significance; climate-change context | Course and final-project introduction |
| Sep. 16 | Heat conduction and the ground thermal regime: heat flux, thermal properties, seasonal temperature profiles, and boundary conditions | |
| Sep. 23 | Freezing, thawing, and phase change: unfrozen water, latent heat, apparent heat capacity, zero curtain, and analytical concepts | |
| Sep. 30 | Guest lecture – topic to be confirmed (intended as a self-contained applied permafrost / northern engineering topic) | Guest lecturer |
| Oct. 7 | Numerical thermal modelling: 1-D heat equation, discretization, initial/boundary conditions, and MATLAB soil-column modelling | Assignment 1 released |
| Oct. 14 | Thermal forcing and permafrost response: surface forcing, snow/surface effects, warming scenarios, thaw depth, and interpretation of numerical results | |
| Oct. 16 (Fri.) | | Final project topic/proposal due for approval (ungraded) |
| Oct. 21 | Mechanical behaviour of frozen soils: soil skeleton, pore ice and excess ice; strength and stiffness; temperature and rate effects; creep; thaw-induced degradation | Assignment 1 due Oct. 23 |
| Oct. 28 | Fall break – no class | |
| Nov. 4 | Slope stability in degrading permafrost: temperature-dependent strength, thaw/degradation zones, limit-equilibrium analysis, and thermal-to-stability workflow | Assignment 2 released |
| Nov. 11 | Frost heave and thaw settlement: ice-lens formation, frost susceptibility, water migration, thaw consolidation, and differential settlement | |
| Nov. 18 | Foundations on permafrost: site considerations; preserve/manage/thaw strategies; shallow and deep foundations; serviceability and stability considerations | |
| Nov. 25 | Permafrost engineering design and infrastructure response: foundations, embankments, thermal protection, and selected case studies | Assignment 2 due Nov. 27 |

| Date | Tentative topic | Assessment / activity |
|---|---|---|
| Dec. 2 | Integrated design, synthesis, project consultation, and/or catch-up lecture | |
| Dec. 9 | Student presentations: permafrost engineering mitigation and adaptation strategies | Final project presentations |
| Dec. 11 (Fri.) | | Final project report due |

### 10) Evaluation and marking scheme

There is no midterm or final examination in this course. Assessment is based on individual technical assignments and an individual final project.

| Component | Weight | Indicative scope |
|---|---|---|
| Assignment 1 – 1-D thermal modelling using MATLAB | 25% | Students will be provided with a basic MATLAB framework and will be asked to understand, modify, and extend it for a prescribed permafrost thermal problem. |
| Assignment 2 – Thermal degradation and slope stability | 30% | Students will use thermal states derived from the thermal-modelling framework to inform a slope-stability analysis and interpret the effect of permafrost degradation on stability. |
| Final project report | 30% | An individual technical investigation of a distinct permafrost mitigation/adaptation method. A quantitative or technical analysis appropriate to the selected topic is expected; a purely descriptive literature review is not sufficient. |
| Final project presentation | 15% | Presentation of the final project to the class, including engineering rationale, technical findings, limitations, and response to questions. |

**Additional requirement.** To pass the course, students must earn at least 35% of the marks available in each of the four assessed components.

**Final project topic.** Each student will investigate a different mitigation or adaptation method relevant to engineering in permafrost regions. Topics must be approved by the instructor before fall break to avoid duplication across the class.

**Late work and extensions.** Requests for extensions will be considered on a case-by-case basis.

**Deferred term work and academic consideration.** Students who claim extenuating circumstances defined in the Academic Consideration Policy as a reason for missed term work are responsible for informing the instructor and making alternate arrangements as soon as possible. Where applicable, the University's Academic Consideration Policy and procedures will be followed.

### 11) Academic dates

Students should be aware of important academic dates (for example, the last day for academic withdrawal) published in the Carleton University Academic Calendar.

## Course and University Policies

### Academic Integrity and Plagiarism

Please consult the Faculty of Engineering and Design information page about the Academic Integrity Policy and procedures: FED Academic Integrity. Violations of the Academic Integrity Policy may result in penalties including reduced grades, an F in a course, suspension, or expulsion.

Submitted work must be your own unless collaboration is explicitly authorized. Plagiarism includes presenting the ideas, expression of ideas, data, research findings, computer programs, or other work of others as one's own without appropriate acknowledgement or citation.

## Unauthorized Dissemination

As per Carleton's Academic Integrity Policy, Unauthorized Dissemination is a violation of the standards of academic integrity to publish, disseminate, or otherwise make available to a third party instructional material where the instructor has explicitly prohibited its dissemination.

The materials (including the course outline, slides, posted notes, videos, projects, assignments, exams, and solutions) created for this course are intended for personal use only. They may not be reproduced, redistributed, or disseminated in any form or by any means - electronic, mechanical, photocopying, recording, or otherwise - without written permission from the author(s), both during and after the semester.

## Generative Artificial Intelligence (GenAI)

Generative AI tools may be used in this course for conceptual clarification, brainstorming, language/editing support, and coding/debugging assistance. Their use should support, rather than replace, the student's own technical reasoning and learning.

Students remain fully responsible for the technical correctness of all submitted work and must understand and be able to explain any code, calculations, models, results, or interpretations they submit. Material use of GenAI in an assignment, report, or presentation must be briefly disclosed, identifying the tool used and the nature of the assistance.

Students may not submit AI-generated analysis, calculations, interpretation, code, or written material as their own without verification, adaptation, and appropriate disclosure. The purpose of this policy is to allow productive use of emerging tools while ensuring that assessment continues to reflect each student's own understanding and engineering judgement.

As our understanding of the uses of GenAI and its relationship to student work and academic integrity continue to evolve, students are required to discuss their use of GenAI in any circumstance not described here with the course instructor to ensure it supports the learning goals for the course.

## Safer Learning and Working Environment

Carleton University and all members of the University community share responsibility for ensuring that the University's educational, work and living environments are free from discrimination and harassment. Should you have concerns about harassment or discrimination relating to your age, ancestry, citizenship, colour, creed (religion), disability, ethnic origin, family status, gender expression, gender identity, marital status, place of origin, race, sex (including pregnancy), or sexual orientation, please contact the Department of Equity and Inclusive Communities, Ombuds Services, or use Carleton's anonymous human-rights concern reporting process.

## Academic Accommodations

Carleton is committed to providing academic accessibility for all individuals. You may need special arrangements to meet your academic obligations during the term. The accommodation request processes, including information about the Academic Consideration Policy for Students in Medical and Other Extenuating Circumstances, are outlined on the Academic Accommodations website.