Module 3D8 - Building Physics and Environmental Geotechnics

ENGINEERING TRIPOS PART IIA 2011/12

Timing: Lent Term
Prerequistes: None
Structure: 16 lectures & Lab
Module Instructors: Dr. R. Choudhary & Dr G. Madabhushi

1 AIMS

This module introduces the physics behind heat, liquid, and mass (air and moisture) transfer in materials, buildings, and energy systems and their interactions with outside environment, both air and ground. It aims to provide the foundational knowledge for understanding environmental characterstics of the built environment, with a focus on aspects important for structural durability and energy efficiency. The following topics will be covered:

1. **Flow of Water through Porous Media**, which is an important aspect in the design of many civil engineering structures such as retaining walls, caissons, excavation for foundations, etc. As it will be shown in the second part of the module, the same physical principles and mathematical concepts can be used to understand flow of heat in porous media, for example, in the design of energy piles or ground source heat pumps.
2. **Heat, air and moisture transfer** across building elements: composite roofs and walls, surface-to-air, air gaps, ventilated spaces, transparent envelopes, and heat exchange between surfaces in a room; Heat exchange with ground will be covered for slab-on-grade, sub-surface structures, and ground-source heat exchangers.

The topics cover theoretical aspects of important energy flows through most common building elements, from foundations to the building envelope. This knowledge is also pre-requiste for learning simulation and modelling techniques for energy balance and environmental control systems of buildings.

2 LECTURE SYLLABUS

2.1 Groundwater and Seepage (8L)

- Introduction
- Concept of porous media and bulk properties
- Definitions of potential head, pressure head, and pore pressure
- Groundwater flow and seepage
- Theory of flownets

- Darcy's law and Hydraulic conductivity
- Laboratory and in-situ measurements

2.2 Heat, Air, and Moisture Transfer through Building Elements (8L)

- Conservation of energy, Fourier's laws, concept of steady state, periodic, and transient
- Conduction: 1D heat flow through single and multi-layered structures, response to temperature variations, contact temperature between layers, network analysis
- Heat exchange with ground: examples of 2D, and 3D heat flow between ground and building elements – pipes, slabs, sub-surfaces
- Radiation: reflectance, absorption, and transmission; radiant surfaces and black bodies; heat gains from solar (short wave) radiation, long wave radiation exchange between 2 isothermal surfaces in enclosures
- Ventilation: Driving forces (wind, stack, mechanical), air exchange rates
- Infliteration: air through permeable materials, gaps, ventilated cavities, heat losses due to transmission and ventilation
- Moisture: Water vapour in air and relative humidity, characterstics of moist air, mold and surface condensation, moisture balance of building components and ventilated spaces
- Combined Heat and Mass Transfer: exercises from practical scenarios

3 OBJECTIVES

Upon completion of the course students will have the ability to:

1. Understand the geotechnical environment
2. Determine flow patterns in steady state groundwater seepage
3. Evaluate potentials, pore water pressures, and flow quantities in the ground by constructing flow nets
4. Analyze environmental behaviour of building components, such as heat flow rates, temperature variations (seasonal and diurnal)
5. Calculate steady state energy balance for a building to determine heating, cooling, and ventilation demand from auxillary systems
6. Understand how choice of design and components influences the indoor environment and energy consumption of building