Engineering Tripos Part IIB, 4D2: Advanced Structural Design, 2021-22

Module Leader

Prof A McRobie [1]

Lecturers

Prof A McRobie and Prof W Baker [2]

Timing and Structure

Lent term. 16 timetabled sessions (lectures + design sessions). Assessment: 100% coursework.

Prerequisites

3D3 and 3D4 assumed

Aims

The aims of the course are to:

- Instil an intuitive approach to structural design.
- Introduce advanced concepts related to the design of structures.

Objectives

As specific objectives, by the end of the course students should be able to:

- Design a wide variety of structures which meet both aesthetic and efficiency criteria.
- Describe the relationship between form and force.
- Manipulate structural geometry or forces to improve the structural behaviour.
- Describe Airy stress functions and be able to design structures using them.
- Describe the relationship between states of self-stress and mechanisms.
- Design prestressable structures which contain mechanisms.
- Describe the load path and how to optimise it.
- Use Lagrange multipliers in constrained optimisation problems in structural design.
- Understand the requirements for minimal total structural volume.
- Describe stiffness and stability from a geometrical perspective.
- Design gridshells and nets. Understand the unique behaviour of each.
- Intuitively understand structural behaviour so that visual design can occur.
- Describe the implications a structure's design has on the stakeholders.

Content

Content and delivery will be largely provided by Prof Bill Baker. Prof Baker is the consulting partner at Skidmore Owings and Merrill in Chicago and Honorary Professor of this department. He is the world's leading structural engineer for the design of buildings and has been responsible for the design of many of the world's more iconic buildings. Prof Baker will teach the skills needed to become a proficient structural designer. The course aims to inform students about powerful new design tools which are growing in popularity throughout industry, many of which have been developed by Prof Baker in collaboration with this department.

Introduction to the course

A short history of structures and architecture. The importance of geometry and design. Discussion of its wide-reaching impacts and implications.

Graphic statics

Relationship between the form and force. How to design structures so that the forces flow where the designer wants them to.

Maxwell load path theorem

What it is and how it relates to the total volume of structural material used.

Force density

How we can use it to solve linear problems to find the geometry.

Virtual work and energy sizing

How it may be used to optimise the structural geometry, using Lagrange multipliers.

Michell trusses

Optimal structures and their behaviour.

Form finding for trusses

Discussion of the tools available to optimise topology, shape and size for structure.

Mechanisms and states of self-stress

The geometric relationship between mechanisms and states of self-stress, and the Maxwell-Calladine and Euler counts to obtain structurally sound trusses.

Geometric stiffness

The stiffness of structures and mechanisms is considered using force density. A short introduction to rigidity theory.

Airy stress functions and their application to truss design

To identify states of self-stress and mechanisms. The use of funiculars to include external loading.

Design of Gridshells and Cable Nets

How to design shells and gridshells using the Airy stress function and force density. The importance of obtaining planar faces and torsion free nodes. We also consider the design of tension structures, using prestress to stabilise mechanisms.

Coursework

Coursework	Format	Due da & marks
Coursework 1: Fundamental theory Answers to be submitted to a set of open-ended questions on theoretical topics.	Individually submitted Anonymously marked	Due da [10/60]
Coursework 2: Bridge Design Students will design a discrete bridge structure using the tools developed in the course, choosing from a list of possible scenarios.	Individual report Anonymously marked	Due da [20/60]
Coursework 3: Roof Design Students will design a more innovative roof structure using the tools developed in the course; they will decide on the structural system of the roof and choose from a list of possible venues.	Individual report + video presentation Anonymously marked	Due da [30/60]

Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

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