# Engineering Tripos Part IIA, 3D3: Structural Materials & Design, 2021-22

### Module Leader

Dr R Foster [1]

### Lecturers

Dr R Foster, Prof A Lawrence, Dr J Becque

### Lab Leader

Dr R Foster [1]

### Timing and Structure

Michaelmas Term. 16 Lectures.

## Aims

The aims of the course are to:

- Provide a general understanding of the relationship between the properties of common structural materials, and the principles and approaches underpinning their use in structural design
- Provide a bridge between the fundamental general engineering understanding of structures and materials developed in Part I and the applied specialist modules of Part II
- Provide knowledge and knowhow enabling structural designers to improve our use of energy and material in the design of the built environment while providing safe, useful structures for people to use

## Objectives

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

- [1] Use the lower-bound theory of plasticity to perform load-path design of structural arrangements and to appreciate the benefits and limitations of the approach
- [2] Consider the influence of risk, and variability of loading and material properties, in structural design and calculation
- [3] Explain the environmental impacts of structural material and design choices
- [4] Understand and carry out early-stage structural design with various structural materials
- [4.1] Identify the theoretical and practical considerations governing structural design in various materials and explain how these may be accommodated in design
- [4.2] Make reasonable conceptual design decisions regarding appropriate structural form, initial layout and initial member sizing for simple structures in various materials;
- [4.3] Perform preliminary technical design calculations for simple structures in various materials
- [4.4] Determine what design approaches may be appropriate, and what calculations necessary, for more complex structures in various materials

## Content

The course this year will be 'blended', meaning that a mix of **in-person**, **online live** (Teams) and **online recorded**

(Moodle) components will be used. We plan to deliver some of our lectures in-person in the department (although these will also be recorded and subsequently uploaded to Moodle). We plan to deliver others remotely through a combination of recorded lectures and 'live' Q&As. Recorded lectures have been updated for this year and benefit from the many lessons we learned during 2020. Full details are available on the course Moodle page.

The implications of the general principles of structural mechanics – equilibrium, compatibility, constitutive laws, and stability – are investigated for different materials. This leads to discussion of typical structural forms in the various materials, the reasons for adopting them, and appropriate methods of construction. The significant types of structural behaviour, and therefore the most useful methods of analysis and calculation, are investigated for the different material types. Our basic aim is to establish means of making reasonable preliminary decisions about structural form, layout and initial sizing of structural members made from a range of common construction materials.

Design methodologies will be developed, and design of typical elements will be discussed, for:

- materials of low tensile but high compressive strength, such as masonry and glass;
- composite materials of low tensile strength combined with a ductile tensile material, such as reinforced concrete;
- high-strength, ductile materials such as steel and aluminium alloys;
- moderate- to high-strength, anisotropic, brittle materials such as engineered timber.

The critical modes of failure of structures made from these materials tend to differ, as do other considerations such as environmental impacts, so design approaches will be correspondingly different.

**Lecture timetable**

| | Lecture | Date | Timeslot | Lecturer |
|---|---|---|---|---|
| **Week 1** | 1. Introduction and overview | Thu 7th Oct | 1100-1200 | Dr Foster |
| | 2. Load paths and lower bounds | Mon 11th Oct | 0900-1000 | Dr Foster |
| **Week 2** | 3. Limit states and variability | Thu 14th Oct | 1100-1200 | Dr Foster |
| | 4. Resource efficiency \| sustainability | Mon 18th Oct | 0900-1000 | Dr Foster |
| **Week 3** | 5. Timber design 1 | Thu 21st Oct | 1100-1200 | Prof Lawrence |
| | 6. Timber design 2 | Mon 25th Oct | 0900-1000 | Prof Lawrence |
| **Week 4** | 7. Timber design 3 | Thu 28th Oct | 1100-1200 | Prof Lawrence |
| | 8. Masonry design | Mon 1st Nov | 0900-1000 | Dr Foster |
| **Week 5** | 9. Glass design 1 | Thu 4th Nov | 1100-1200 | Dr Foster |
| | 10. Glass design 2 | Mon 8th Nov | 0900-1000 | Dr Foster |
| **Week 6** | 11. Concrete design 1 | Thu 11th Nov | 1100-1200 | Dr Foster |
| | 12. Concrete design 2 | Mon 15th Nov | 0900-1000 | Dr Foster |
| **Week 7** | 13. Steel design 1 | Thu 18th Nov | 1100-1200 | Dr Becque |

| | Lecture | Date | Timeslot | Lecturer |
|---|---|---|---|---|
| | 14. Steel design 2 | Mon 22nd Nov | 0900-1000 | Dr Becque |
| **Week 8** | 15. Steel design 3 | Thu 25th Nov | 1100-1200 | Dr Becque |
| | 16. Conclusions | Mon 29th Nov | 0900-1000 | Dr Foster |

## Coursework

**Concrete Lab**

This lab will run in 'blended' form for 2021, with the morning session remote and the afternoon session in-person. Feedback from our first experience of running the lab in this way in 2020 was overwhelmingly positive, so we have changed very little this year. We retain the capability to run the afternoon session fully remotely, but we are hopeful that this will not be needed this year.

Learning objectives:

To be able to:
1.Describe the common ingredients of concrete and their properties;
2.Design a concrete mix to satisfy certain technical requirements and cast a trial cube;
3.Supervise the casting of reinforced concrete beams and various plain concrete specimens for subsequent testing;
4.Observe and record results of destructive testing and identify different failure modes in concrete;
5.Compare empirical results with theoretical predictions based on as built-data, and evaluate the effectiveness and limitations of the theory.

Practical information:

Details will be available on the course Moodle page early in the term.

Full Technical Report:

Students will have the option to submit a Full Technical Report.

## Booklists

Please refer to the Booklist for Part IIA 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 [2].

## UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] standard:

Toggle display of UK-SPEC areas.

**GT1**

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

**IA1**

Apply appropriate quantitative science and engineering tools to the analysis of problems.

**KU1**

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

**KU2**

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

**D1**

Wide knowledge and comprehensive understanding of design processes and methodologies and the ability to apply and adapt them in unfamiliar situations.

**S1**

The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.

**S3**

Understanding of the requirement for engineering activities to promote sustainable development.

**S4**

Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues.

**E1**

Ability to use fundamental knowledge to investigate new and emerging technologies.

**E2**

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

**E3**

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

**P1**

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

**P4**

Understanding use of technical literature and other information sources.

**P6**

Understanding of appropriate codes of practice and industry standards.

**P7**

Awareness of quality issues.

**US1**

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

**US2**

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

**US3**

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

**US4**

An awareness of developing technologies related to own specialisation.

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