Engineering Tripos Part IIA, 3D4: Structural Analysis & Stability, 2017-18

Module Leader
Dr F Cirak

Lecturers
Dr F Cirak, Prof S D Guest

Lab Leader
Dr F Cirak

Timing and Structure
Lent term. 16 lectures.

Aims
The aims of the course are to:

- Provide students with an understanding of elastic methods of structural analysis.
- Ensure that students recognise that an understanding of stability and the failure of structures by buckling, is a key part of understanding structural behaviour.

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

- Determine stress distributions in asymmetric open sections, taking account of bending, shear, torsion and warping effects.
- Calculate the relevant section properties for complex sections.
- Apply Virtual Work.
- Analyse grillages under out-of-plane loading.
- Solve beam bending problems using Macaulay’s method, and to obtain influence lines thereby.
- Explain the reciprocal theorem and the importance of influence lines.
- Recognise the shortcomings of the structural analysis learnt thus far and appreciate the need to include stability as a fourth concept in any complete theory of structures.
- Draw stable and unstable paths on a load/displacement diagram for various bifurcation and snap through models.
- Understand how elastic stability may be determined from the total potential energy and may be described by the eigenvalues of the total stiffness matrix.
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- Determine elastic critical loads for simple structures by eigenvalue analysis, whilst appreciating the importance of imperfection sensitivity and the limitations of such analysis.
- Apply approximation methods based on energy to determine the stability of simple systems.
- Understand second-order beam theory, using s and c functions.
- Understand how the tangent modulus and double modulus theories of inelastic buckling led to the column
paradox, and how this was resolved by Shanley's analysis, thereby presenting further difficulties for a
general theory of structures.
  - Understand the importance of lateral-torsional buckling of beams.
  - Understand how of the above ideas combine in the context of column design.

Content

There are two themes in this module: elastic analysis & stability and buckling of structures. Each section leads on
from and extends a corresponding section of the first or second year courses in Structures.

In the first course the aims are to extend the elastic analysis of beam elements as given in Part I to cover
asymmetric sections in bending, to revise the determination of shearing stresses in beams, to consider the torsion
of open section beams, including effects due to restraint of warping) and to introduce the concept of shear centre.
The course will cover the analysis of beams via differential equations, and their efficient solution using Macaulay’s
method. This will be applied to beams on elastic foundations, as well as to normal beams. The reciprocal theorem
will be introduced which will lead to the study of influence lines. The course will also cover some new applications
of virtual work, grillages and other beams curved in plan, and the cable catenary.

In the second course the aims are to understand the fundamental principles of structural stability, to become
familiar with common types of bifurcation and buckling phenomena and to formulate methods capable of dealing
with geometrically non-linear structural behaviour. Once the general concept of stiffness degradation and the
various post-buckling possibilities are understood, the course addresses the specific problem of column and beam
design, taking account of initial imperfections, coexistent end-moments, residual stresses and material inelasticity.

Elastic Theory (8L) (Dr F Cirak)

- Asymmetric beams; principal axes;
- Shear centre; torsion and warping of open-sections;
- Virtual work;
- Grillages;
- Differential equation of beam (Macaulay);
- Reciprocal theorem and influence lines;
- Beams on elastic foundations;
- Catenary.

Stability and Buckling (8L) (Prof S D Guest)

- Fundamentals of buckling and stability: total potential energy approach and direct equilibrium approach;
- Classification of instabilities into snap-through type and bifurcation type;
- Eigenvalues and eigenvectors of stiffness matrix;
- Buckling of elastic structures; approximate estimates of buckling load; Rayleigh quotient;
- Lateral buckling of columns: Euler strut, imperfections, Southwell plot, beam-columns, stability coefficients,
buckling of frames;
- Elasto-plastic buckling: tangent-modulus, double-modulus, Shanley's analysis;
- Design of columns;
- Lateral-torsional buckling of beams.

Coursework

Buckling Elastic and Inelastic

Learning objectives:

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Practical information:

- Sessions will take place in [Location], during week(s) [xxx].
- This activity [involves/doesn't involve] preliminary work ([estimated duration]).

Full Technical Report:

Students [will/won't] have the option to submit a Full Technical Report.

Booklists

Please see the Booklist for Part IIA Courses [2] for references for this module.

Examination Guidelines

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

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [4] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the 'Accreditation of Higher Education Programmes' (AHEP) document [5] which sets out the standard for degree accreditation.

The Output Standards Matrices [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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Links

[1] mailto:fc286@cam.ac.uk