Engineering Tripos Part IIA, 3D4: Structural Analysis & Stability, 2020-21

Module Leader

Dr F Cirak [1]

Lecturers

Dr F Cirak, Prof A McRobie

Lab Leader

Prof A McRobie [2]

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 students recognise that stability and 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:

- Understand and calculate the biaxial bending stress distribution in asymmetric sections.
- Calculate the section properties of complex sections with different techniques.
- Understand and determine the torsional stresses in thin-walled open cross-sections.
- Analyse statically determinate and indeterminate space frames.
- Solve beam bending problems using the Macaulay's method.
- Understand the application of virtual work principles.
- Explain the reciprocal theorem and the importance of influence lines.
- Understand and apply the displacement method.
- Recognise the shortcomings of the structural analysis learnt in Part I and appreciate the need to include stability in a complete theory of structures.
- Draw stable and unstable paths on a load/displacement diagram for bifurcation and snap through.
- Understand how elastic stability may be determined from the total potential energy and described by the eigenvalues of the stiffness matrix.
- Determine elastic critical loads for simple structures by eigenvalue analysis, whilst appreciating the importance of imperfection sensitivity.
- 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.
- Understand the importance of lateral-torsional buckling of beams.

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, the course aims are to extend the elastic analysis of beams to cover asymmetric sections in bending, to revise the determination of shear stresses, to consider the torsion of thin-walled open sections and to introduce the concept of shear centre. After that, the course will introduce the analysis of beams via differential equations and the reciprocal theorem, which will lead to the study of influence lines. The course will also cover the displacement method of structural analysis and some new applications of virtual work and curved beams.

In the second, the course 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
- Torsion and warping of thin-walled open sections
- Analysis of space frames
- Solution of the beam differential equation (Macaulay)
- Virtual work
- Reciprocal theorem and influence lines
- Displacement method

Stability and Buckling (8L) (Dr A McRobie)

- Fundamentals of buckling and stability: total potential energy approach and direct equilibrium approach
- Classification of instabilities into snap-through tpe 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:

- Understand the difference between *stable* and *unstable* buckling.
- Appreciate the circumstances in which a "classical" buckling calculation gives a useful estimate of the buckling strength of a structure, and those in which it does not.
- Be able to cite examples of structures for which the buckling load is both significantly less than the prediction of "classical" theory, and the postbuckling behaviour is highly *unstable*.
- Be aware of the "classical" buckling formulae for bars (including the "tangent-modulus" formula), simple plates and cylindrical shells.

Practical information:

- Signup on http://to.eng.cam.ac.uk/teaching/apps/cuedle/index.php?context=3D4 [3].

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 [4].

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