Structural Analysis III

Course Introduction

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Contents

1. Introduction

1.1 Background

In order to design safe structures, the load effects (stresses, bending moments etc.) that may exist in a structure must be predicted with reasonable accuracy before the structure is built. Getting this wrong can lead to collapse and sometimes massive loss of life. It is therefore imperative that an appreciation of structural behaviour become ingrained in any structural engineer. That is what this course is about.

There are two stages of predicting load effects:

1. Qualitative Stage (or the 'sense' of behaviour):

At this level of investigation, we are not interested in numbers, or amounts, only the sense of a load effect. Some examples of what we mean by sense are:

- Is there tension on the top or bottom of a beam?
- Does the tip of a cantilever deflect up or down?
- Is the moment reaction clockwise or anti-clockwise?

Getting this level of analysis right is not only the first step, but the most important step. If we don't get this level right, then the answers to a more complicated analysis will be meaningless.

The ability to get the right answers to this level is called *Structural Intuition*. The better your structural intuition, the better you will be a designer.

2. Quantitative Stage (the 'amount' of a certain behaviour):

This is the 'number-crunching' stage of an analysis. It is this stage that tells us whether the cantilever tip deflects upwards by 10 mm or 12 mm. This stage is vital for giving us the numerical information for a design.

1.2 Course Aims

Given the background just discussed, the general aims of this course are to provide students with:

- An intuitive understanding of structural behaviour;
- Methods for the determination of various load effects;
- Appreciation of different types of structures and their behaviour.

We will focus on statically indeterminate structures. That is, structures that cannot be solved for using the equations of statics alone. Most structures are indeterminate to some degree.

To teach you to solve indeterminate structures, we will try to build your structural intuition to a minimum standard. Then we will cover various topics or methods of quantitatively analysing such structures. So a lot of our time will be spent doing calculations (or number-crunching) but remember – if you don't know if the column will deflect to the left or the right an answer of 10.2 mm is meaningless!

Lastly;

If you cannot analyse determinate structures you will not be able to analyse indeterminate structures.

So let's be honest here: given this last point, if you scrapped through 2nd Year Structural Analysis you will have immense difficulty with this course – please please revise your 2nd Year material so that you are properly equipped for this course.

1.3 Programme

Teaching

For each week of term, this course is taught as follows:

Semester 1:

- 2 hours of structural laboratory;
- 3 hours lectures.

Semester 2:

- 3 hours of lectures.

Assessment

We asses your performance on this course as follows:

Semester 1:

- Submission of laboratory work - 20% of the marks;
- A 2-hour examination - 80% of the marks.

Semester 2:

- A 2-hour examination – 100% of the marks.

In the unlikely event of changes to the above arrangements, the changes will be notified to you well in advance of their implementation by your lecturer.

1.4 Reading Material

Reading about projects and new techniques will be a major part of your engineering career (CPD). You should read as many different versions or explanations of the same topic or material as you can. This way it is more likely that you will find a means of explanation that works best for you.

Some good sources for this course are:

General Understanding of Structural Behaviour

- Brohn, D., *Understanding Structural Analysis*, 4th Edn., New Paradigm Solutions, 2005.
- Heyman, J., *Basic Structural Theory*, Cambridge University Press, 2008.
- Jennings, A., *Structures: from theory to practice*, Spon Press, 2004.
- Ji, T., and Bell, A., *Seeing and Touching Structural Concepts*, Taylor & Francis, 2008.
- Williams, M.S., and Todd, J.D., *Structures: theory & Analysis*, Macmillan, 1999.

General Structural Analysis

- Coates, R.C., Coutie, M.G., and Kong, F.K., *Structural Analysis*, 3rd Edn., Chapman & Hall, 1987.
- Ghali, A., Neville, A., Brown, T.G., *Structural Analysis: A Unified Classical and Matrix Approach*, 5th Edn., Taylor & Francis, 2003.
- McKenzie, W.M.C., *Examples in Structural Analysis*, Taylor and Francis, Abington, 2006.

Books for Specific Topics

- Baker, J.F., Horne, M.R. and Heyman, J., *The Steel Skeleton, Volume II, Plastic Behaviour and Design*, Cambridge University Press, 1956.
- Charlton, T.M., *Analysis of Statically Indeterminate Frameworks*, Longmans, 1961.
- Charlton, T.M., *Energy Principles in Theory of Structures*, Oxford University Press, 1973.
- Davies, G.A.O., *Virtual Work in Structural Analysis*, John Wiley & Sons, 1982.
- Dym, C.L., *Structural Modeling and Analysis*, Cambridge University Press, 2005.
- Guarracino, F. and Walker, A., *Energy Methods in Structural Mechanics*, Thomas Telford, 1999.
- Heyman, J., *Beams and Framed Structures*, 2nd Edn., Pergamon Press, 1974.
- Heyman, J., *Elements of the Theory of Structures*, Cambridge University Press, 1996.
- Hodge, P.G., *Plastic Analysis of Structures*, McGraw-Hill, New York, 1959.
- Kong, F.K., Prentis, J.M. and Charlton, T.M., 'Principle of virtual work for a general deformable body – a simple proof', *The Structural Engineer*, Vol. 61A, No. 6, 1983.
- Neal, B.G., *Structural Theorems and their Applications*, Pergamon Press, 1964.
- Rees, D.W.A., *Mechanics of Solids and Structures*, Imperial College Press, London, 2000.
- Thompson, F., and Haywood, G.G., *Structural Analysis Using Virtual Work*, Chapman and Hall, 1986.

1.5 Website

The course will be supported through the lecturer's website:

www.colincaprani.com – go to the *Structural Engineering* section of the site.

On the site there are two main resources:

- **Lecture notes**: most of the lecture notes will be available in PDF format for download from the website. Class handouts will still be the main source of material.
- **Discussion Forum**: to facilitate students studying on their own, or maybe when home for the weekend, there is a forum through which you can liaise with others. Feel free to ask questions and to answer them. Though the forum will be facilitated by your lecturer, there is no guarantee that a question will receive an answer from me. This is primarily a way to encourage student-to-student remote learning.

Some other resources that may prove useful will be links to sites with good material and the provision of some software (with absolutely no guarantees!).

This is the first year that the course will be supported by website, so please:

- Do not abuse either the facility or the facilitator!
- Try to use the site to best help you and your friends.
- Suggest ways to improve the usefulness of the website.

Any inappropriate comment/content or discussion will be removed and access to the site will be barred with more serious consequences also possible.

2. Syllabus

2.1 Semester 1

The topics are as follows:

Qualitative Analysis

This topic studies the first stage of the analysis process (previously described) in which the structural behaviour is predicted without numerical calculations.

Stability, Statical Determinacy and Indeterminacy, Kinematic Indeterminacy

This topic studies the identification of the type of structure being analysed and whether it is stable or not and the movement that structures may undergo.

Mohr's Theorems

These two theorems are used to calculate deflections and reactions of determinate and indeterminate structures.

Moment Distribution

This is very flexible hand method for the analysis of indeterminate structures.

2.2 Semester 2

The topics are as follows:

Further Qualitative Analysis

Just because it's so very important.

Virtual Work

This is a fundamental theory used in the analysis of all advanced structures. We will use it to analyse frames and trusses for moments and deflections.

Macaulay's Method for Indeterminate Structures

This is a direct integration approach that can be used to solve for unknown reactions as well as deflections and rotations in both beams and frames.

Plastic Analysis

This topic examines the calculation of the actual collapse load of structural frames, given the capacity of the members.

3. Assessment

3.1 Examination

Semester 1 and Semester 2 examinations follow the same format:

Layout

There will be 3 questions and you are to answer all 3.

Marking

The marking scheme is:

- Question 1 is worth 20 marks;
- Question 2 is worth 40 marks;
- Question 3 is worth 40 marks.

Timing

The exam is 2 hours in duration. The time allotted to each question should reflect the marks attached to the question: 24, 48 and 48 mins for Qs 1, 2 and 3 respectively.

Format

The questions will cover a topic or topics from each semester. Further information will be given.

Exam Handout

A handout will be attached to the paper in each exam with relevant information and formulae. A copy of this will be given to you during Semester 1.

3.2 Laboratory Work

The laboratory work is being revised this year to better support the aims of the course. The exact nature of the lab work and submissions is being worked out and will be conveyed to you in due course.