Structural Analysis III

Course Introduction

20010/11

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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 structural engineer.

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:

- Continuous assessment - 20% of the marks;
- A 2-hour examination - 80% of the marks.

Semester 2:

- Continuous assessment - 20% of the marks;
- A 2-hour examination - 80% 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. 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!).

The website support for the course is only meant to help, 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.
- Do not post inappropriate comment/content – your site access will be removed, with more serious consequences also possible.

You are required to register for the forum – **only registrations in your own name will be approved**. You can change your display name later on.

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.

Introduction to Virtual Work

This is a fundamental theory used in the analysis of all advanced structures. We will introduce it here for simple problems.

2.2 Semester 2

The topics are as follows:

Further Qualitative Analysis

Just because it's so very important.

Virtual Work

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 capacities of the structural members.

3. Assessment

3.1 Examination

Semester 1 and Semester 2 examinations follow the same format:

Layout

There will be 4 questions and you are to answer all 4.

Marking

The marking scheme is all questions are worth 25 marks.

Timing

The exam is 2 hours in duration.

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. Past exam questions are available online, but will also be given at the end of class lecture notes.

3.2 Continuous Assessment

General

For this year only, this course is being assisted by a DIT Teaching Fellowship. The means of teaching the conceptual understanding of structural behaviour is under study. To measure the effectiveness of various interventions, we will be carrying out tests before and after the interventions to help us indentify best practice.

Improvement Assessment

To assist the Teaching Fellowship, pre- and post-testing will be carried out before and after a specific intervention. This way, we will be able to assess the effectiveness of the intervention. For marking purposes only the post-tests will contribute to your Continuous Assessment marks. The exact amount will be conveyed to you.

Laboratory Work

The laboratory work is being revised this year in line with the aims of the Teaching Fellowship. The lab work is not the same as traditional labs you may have already done. You will be given tasks, with a schedule of dates for delivering various aspects of the problem to ensure an even distribution of workload. You will be given access to the lab to facilitate your work, not only at scheduled lab times. We hope that this will improve your prospects to self-direct your learning.