

UNIVERSITY OF EDINBURGH

Civil and Environmental Engineering (Subject Area: (M) Civil)

School of Engineering and Electronics

COURSE GUIDE

This version effective from: 25 September 2006

Course Title:	<i>Plastic Analysis of Frames and Slabs 4</i>
Course Code:	U00408
School Acronym:	EEL-4-CVPFS
Credit Level:	10
Credit Points:	10
Pre-requisites:	Prior attendance at U00317:Theory of Structures 3 or equivalent

Summary

The two segments of this module extend the student's knowledge and understanding of the theory of structures to realistic failure criteria and plastic behaviour. The first presents a deeper understanding of the plastic analysis of frames: the second covers yield line analysis of reinforced concrete slabs.

Plastic Analysis of Frames and Slabs 4 (U00408; EEL-4-CVPFS)

Course Organiser: Dr J.F. Chen
Responsible Academic: Prof JM Rotter
Other Lecturers:

Aims & Objectives

This module is intended to:

- deepen the students' understanding of the mechanics of failure of frame structures and slabs and their relationship to ultimate limit state design;
- deepen the student's understanding of plastic collapse phenomena;
- provide practical examples of plastic collapse in frames and slabs.

Learning Outcomes

By the end of the course, the student should be able to:

- calculate the plastic collapse loads of complex two dimensional frame structures
- identify the independent mechanisms in frames and combine them
- the upper and lower bound theorems to find the true collapse load
- produce engineering designs for frame structures based on plastic collapse analysis;
- calculate the yield line collapse load of reinforced concrete slabs of moderately complex geometry with isotropic and orthotropic reinforcement using the upper bound theorem
- apply yield line collapse analysis to achieve proportioning of reinforcement in a slab.

Course Structure

The module consists of a total of 18 x 1 hour lectures, and 4 x 1 hour tutorials.

There are two segments within this course:

1. Plastic collapse of frame structures (9 lectures)
Lecturer: Prof. J.M. Rotter
2. Yield line analysis of reinforced concrete slabs (9 lectures)
Lecturer: Prof. J.M. Rotter

Lectures: Titles & Contents

Segment 1 Plastic collapse of frame structures

L1 Introduction

Structure of the course. Aims of the course. References with comments. The theorems of plastic analysis: upper and lower bound theorems, their basis and assumptions. Ductility requirements for plastic collapse in steel members: plastic and compact sections.

L2 Full plastic moments of cross-sections

Stress-strain relationships for materials and their simplification into a 2 parameter model. Models for hand and for computer analysis. The analysis of cross-sections of any complexity to determine the full plastic moment about an axis.

L3 Axial loads and cross sections in different materials

The effect of axial load on the plastic moment. The interaction diagram for simple sections: all four quadrants of the interaction diagram and its significance in structures. Ultimate moment interaction diagrams in reinforced concrete or composite steel-concrete sections.

L4 Plastic collapse of continuous beams

Review of plastic collapse of beam structures. Changes of section at supports and within spans. Rules for locations of plastic hinges and number of mechanisms. Minimisation of collapse loads when hinge locations are not pre-ordained.

L5 Portal frames

Plastic collapse of a simple single bay portal frame. Locations of hinges, types of mechanisms illustrated in this simple example. Effect of pinned bases. The interaction diagram. Over-complete collapse and its significance. Non-proportional loading.

L6 General rules on collapse of frames

Application of plastic analysis to multi-storey and multi-bay frames. Elementary and combined mechanisms. Joint rotation as an elementary mechanism, simple beam mechanisms, simple sway mechanisms, combining mechanisms. Rules for the locations of plastic hinges. Rules for assessing numbers of redundancies. Rules to determine the number of sway modes. Rules to determine the numbers and types of elementary and combined mechanisms. Application of the rules.

L7 Single storey portal frames

Analysis of a multi-bay portal frame. Application of the upper bound theorem. Identifying hinge locations. Determining the number of independent elementary mechanisms. Identifying the elementary mechanisms. Combining mechanisms: compatibility requirements and methodology. Application of the lower bound theorem to verify the collapse load. Use of the lower bound theorem on the wrong mechanism.

L8 Multi-storey portal frames

Identifying hinge locations. Determining the number of independent elementary mechanisms. Identifying the number of sway modes and their forms. Identifying possible elementary mechanisms: alternative choices. Analysis of the elementary mechanisms. Combination of mechanisms. Compatibility requirements and methodology. Lower bound theorem in the presence of multiple sway modes. Sway equilibrium equations.

L9 Upper and lower bound theorems and their significance

Full statement of the two theorems. Uniqueness. Demonstration of outcome of applying each theorem to modes that are not the correct collapse mode. Use of the upper bound theorem and minimisation. Use of the lower bound theorem and safe design. Exploitation of lower bound theorem in elastic analysis. Requirements for the theorems to be valid. Ductility and stability effects.

L10 Other factors and aspects

Modifications of the evaluated collapse loads caused by different phenomena. Effect of axial loads on full plastic moment, and on ultimate moments in reinforced concrete. Effect of instability on collapse loads. Geometric nonlinearity and its outcomes for different loadings and geometries. Brittle materials and the effects of shrinkage, creep, lack of fit, settlement etc.

Segment 2 Yield line analysis of reinforced concrete slabs

L1 Introduction

Introduction to yield line analysis: behaviour of rigid plastic material, fundamentals of yield line theory and methods of analysis, equilibrium and virtual work methods.

L2 Simple example of one way bending

Simple calculation of a collapse load for one way bending and its relationship to plastic collapse of beams.

L3 The yield line: bending and twisting moments

Calculations of bending and twisting moments on the yield lines for isotropic and orthotropic reinforcement; calculation of normal rotation on a yield line. Compatibility requirements of yield line patterns.

L4 Collapse mechanisms

Fundamentals and assumptions for collapse mechanisms. Collapse mechanisms for slabs with different boundary conditions based on these assumptions.

L5 Example problems

Orthotropic slabs of different geometries and load cases. Determination of collapse loads using the upper bound theorem. Discussion of the reasons for examining alternative collapse mechanisms. Derivation of formulae for the analysis of slabs of various shapes under different loading conditions (point load, line load and distributed load) and different boundary conditions.

L6 Lower bound theorem and other phenomena

The yield line as an upper bound method: upper and lower bound theorems of plasticity for slabs. Use of finite element analysis with the lower bound theorem. Compressive membrane action and its causes. Relationship of yield line load to true collapse. Tensile membrane action. Geometrically nonlinearity and its effect on behaviour. The meaning of a collapse load. Punching shear.

L7 Revision

Review of the whole module. Significance of collapse load evaluation. Lower bound theorem and its importance in elastic analysis and design. Importance of ductility, and warnings about brittle materials. Relationship between hand calculations and computer calculations. Material and geometric nonlinearity.

Tutorials: Titles & Contents

Segment 1 Plastic analysis of frames

Tutorial 1 Plastic moments of cross-sections

This tutorial covers the determination of the full plastic moment of various cross-sections, followed by the development of interaction diagrams for cross-sections.

Tutorial 2 Plastic collapse of multi-bay and multi-storey frames

This tutorial covers problems involving interaction diagrams for simple frames, combined mechanisms for multi-storey and multi-bay frames.

Segment 2 Yield line analysis of slabs

Tutorial 3 Yield line analysis of slabs

A single tutorial sheet with many questions, beginning with simple problems and progressing to complex yield line mechanisms.

References

Segment 1 Plastic analysis of frames

Course reference

- Plastic Design of Frames
J.F. Baker and J. Heyman
Cambridge University Press 1969

Suggested further reading

- Plastic Theory of Structures
M.R. Horne
Pergamon Press 1981
- The Steel Skeleton Volume II
J.F. Baker, M.R. Horne and J. Heyman
Cambridge University Press 1956
- Plastic methods for steel and concrete structures
S.S.J. Moy
Macmillan 1996

Course reference

- Reinforced and pre-stressed concrete
F.H. Kong and R.H. Evans
van Nostrand Reinhold (UK) 1987

Suggested further reading

- Yield line analysis of slabs
L.L. Jones and R.H. Wood
Thames and Hudson, Chatto and Windus, 1967
- Structural Concrete
R.P. Johnson
McGraw Hill
- Yield line analysis of slabs
K.W. Johanson
Cement and Concrete Association, London 1972
- Plastic methods for steel and concrete structures
S.S.J. Moy
Macmillan 1996

Course Assessment

Degree Examination

The degree examination for this module will consist of two compulsory questions of equal value. The exam will be of 1.5 hours duration.

Assessment Weightings

Degree examination	100%
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All marks are provisional until they have been approved by the appropriate Board of Examiners. Exam Boards meeting in January are preliminary and results released at that time are provisional. The main Board of Examiners meets in May / June and considers the entire spectrum of honours marks. Where the Board of Examiners considers it appropriate, it may adjust the marks for an individual exam paper to make allowance for, for example, a difficult/easy paper, irrespective of whether that paper was in the December or April / May exam diet.