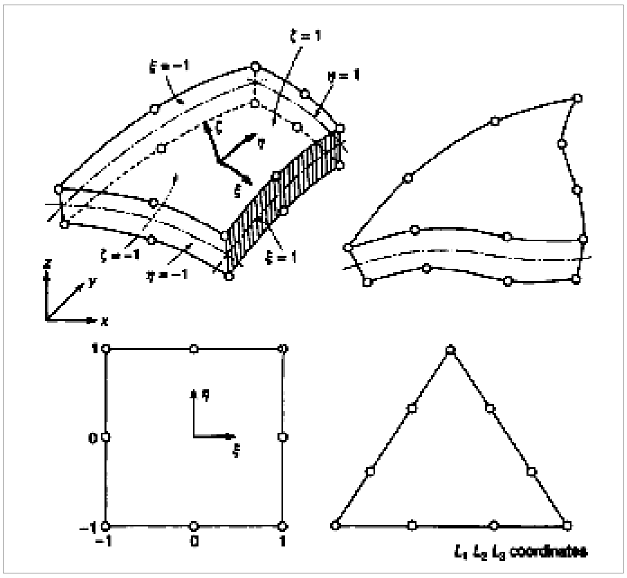
CE6502 FINITE ELEMENT METHOD IN STRUCTURES

Lecture:	*Wednesdays 14:00 – 17:00*
Credit Hrs.:	*3 (Lect 3 hrs)*
Academic Year:	*2019/20 (Second Semester)*
Instructor:	*Shifferaw Taye*

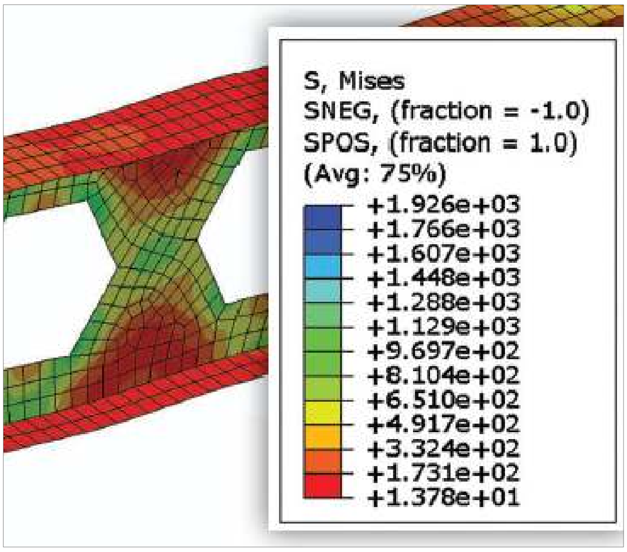
CENG 6502 – Finite Element Method in Structures [3]

Introduction to finite elements: One dimensional elements and convergence criteria. Plane stress and plane strain problems: two dimensional stresses and strains, triangular elements, rectangular elements, quadrilateral elements. Isoparametric formulations: General solids: hexahedral and tetrahedral elements, quadrilateral sections, plates in bending: rectangular, triangular and quadrilateral elements. Shells.



COURSE OBJECTIVES

The main objective of **CE 6502 – Finite Element Method in Structures** is to present the principles and concepts of structural analysis making use of " finite elements ". The Finite Element Method of static structural analysis is a numerical approach that involves the theoretical breaking up of a structural system – discrete or continuum – into a network of smaller units, called *elements*, that have got *finite* dimensions (not infinitesimals), thus *finite elements*, to study their responses to the actions of forces. Indeed, it is the best and widely accepted analysis approach available so far for the numerical solution of structural continua and practically all commercial computer programs are based on this method.



The coursework presents the fundamental concepts and assumptions upon which the method is based. It discusses all the three phases of a structural analysis endeavor – *modeling, computation*, and *interpretation* in relation to the finite elements based formulation. A number of element types that will be suitable to model various types of structural systems will be presented. The method, as presented in this coursework, is based on the *displacement method* of structural analysis. Accordingly, element stiffness matrices corresponding to the various types of finite elements will be established along with the formulation of corresponding load matrices.

Establishment of system (global) equilibrium equations follows the basic formulation of the stiffness method and course participants are strongly advised to review their knowledge of stiffness method of structural analysis. Finally, interpretation of analysis results pertaining to the elements and overall structural system will be presented.

LEARNING OUTCOMES

Upon successful completion of the coursework, course participants will obtain the necessary knowledge to:

- Identify the appropriate types of FE to be used for modeling various structural forms for analysis
- Establish a variety of FE-based structural mechanics analysis models

LEARNING OUTCOMES (cont'd)

- Establish the various variables and parameters required for solving structural mechanics problems using the FE method
- Establish the necessary expressions and equations for solving structural mechanics problems using the FE method
- Establish the various stress / generalized force diagrams resulting from FE analysis
- Interpret computational results from FE analysis models
- Write FE codes for solving a variety of linear structural mechanics problems
- Implement the FE method using available commercial software packages

COURSE COVERAGE

1. Introduction to finite elements method; one dimensional elements and convergence criteria
2. Plane stress and plane strain problems
3. Isoparametric formulation – general concepts
4. Two dimensional – triangular, rectangular, and quadrilateral elements, isoparametric formulation
5. General solids – hexahedral and tetrahedral elements, isoparametric formulation
6. Plates in bending – triangular, rectangular and quadrilateral elements
7. Shells
8. Computer Programs for the analysis of continuum structures (modeling, analysis, and interpretation)

The first chapter introduces the basic concepts behind the finite elements method. It addresses constitutive relationships and their role in the formulation of structural analysis procedures. The basis of forming finite element models, assumptions and limitations will be presented. Virtual work basis, shape functions, interpolation functions and generalized displacements will be discussed. Matrix formulation of the analysis of one-dimensional elements based on the finite elements method shall be discussed. The concept of generalized stresses and strains, axis transformation and the formulation of analysis equations along with convergence criteria will be established.

The second chapter presents the fundamental principles for establishing the solution of solid mechanics analysis problems using triangular and rectangular elements and this will be extended to formulations based on corresponding isoparametric counterparts; i.e., introducing and implementing the concept of isoparametric formulation, in Chapter Three. Both one- and two-dimensional isoparametric formulations in the finite elements method will be presented. These formulations stipulate that the same interpolation expressions and formulas define both the geometric and displacement shape functions and it is assumed that isoparametric elements satisfy both geometric and displacement compatibility conditions. The concept of natural coordinates as related to one- and two-dimensional triangular and rectangular elements will be discussed.

Chapter Four presents the principles for formulating the solution of solids using the finite element approach making use of hexahedral and tetrahedral elements including isoparametric counterparts.

The subsequent three chapters will take up the presentation of Plane Stress and Plane Strain problems, Plates in Bending and General Shell Structures in respect of constitutive relationships, natural coordinates and numerical integration.

The last chapter will discuss application of commercial software systems for the analysis of a variety of solid mechanics problems using the finite element method.

TEXTBOOK AND REFERENCES

The standard textbook for the coursework is:

- W. Weaver and P. Johnston, *Finite Elements for Structural Analysis*, Prentice-Hall, 1984

There are a number of books and other published materials on all topics to be covered in this coursework. Course participants are advised to refer to professional publications, technical papers and manuals of practices. Among these, the following are recommended as reference materials:

– O. C. Zienkiewicz, R. Taylor and J.Z. Zhu, The Finite Element Method: Its Basics and Fundamentals, Elsevier, 2013.
– D.L. Logan, A First Course in the Finite Element Method, Cengage Learning, USA, Thomson, 2012.
– K.-J. Bathe, Finite Element Procedures, Prentice Hall, 1996
– E. Onate, Structural Analysis with the Finite Element Method Linear Static, Vol. 1: Basis and Solids, Springer, 200
– E. Onate, Structural Analysis with the Finite Element Method Linear Static, Vol. 2: Beams, Plates and Shells, Springer, 2013

TEXTBOOK AND REFERENCES (cont'd)

Additional citations will also be provided on specific topics.

All assignment problems shall be solved using, preferably, the latest version of MATLAB, a well-established software system for the scientific and engineering community both in the academic and industry environments. The following material provides an excellent introduction to the computational aspect of the coursework for using MATLAB.

- Gilat, *MATLAB An Introduction with Applications*, 6th Ed., Wiley, 2017

COURSE DELIVERY

Many of the topics and specialized features of specific subject matters will be discussed during classroom sessions through lectures, class discussions, group projects, case study analysis and student peer teaching. Some of the topics will be covered through supervised reading.

Course participants are expected to develop and demonstrate their potential capabilities for self-motivated reading and to bring a variety of relevant issues for discussion during class sessions. They are also expected and very much encouraged to take part in all the discussions thereby becoming active contributors and effective stakeholders in the teaching-learning process. This approach will help develop the classroom into becoming a discussion forum where course participants will learn and freely share their opinions on the contents of the subject matters on one hand and on the method of course conduct on the other.

This approach is believed to enhance the whole concept of participatory teaching-learning process – to enable students develop confidence in their ability to deliver results. It is believed that such participatory mode of course conduct will create a positive teaching-learning environment through which students will be the primary stakeholders in the process of developing their future directions in the profession.

This is also intended to be a project-based coursework. Course participants will form groups of three to five for Group project and report. Each such group of course participants is advised and encouraged to come up with a semester project of its own interest and relevant to the ideas of the coursework. Emphasis on fundamentals finite-elements-based structural modeling for analysis as related to their structural behavior, meshing and other issues related to modeling for analysis and, subsequently, interpretation of results along with practical applications in relevant engineering assignments are expected to constitute core components of the project work. Course participants will be guided to develop projects of their interest early in the course delivery process and subsequently apply the concepts learned in the coursework to solve real-world engineering problems.

Students are expected to come to class prepared to participate in class discussions. Students should be prepared to verbally summarize out-of-class readings assignments.

ASSESSMENT / EVALUATION

It is intended to evaluate each course participant based on her / his performance. Performance evaluation is measured for all course participants through individual assignments, one written examination and a final group project.

The following point assignment will be adapted:

Individual assignments	20
Group Project	30
Written examination	50

All assignments and reports shall be submitted according to instructions and guidelines given by the Instructor.

Please note: The Instructor reserves the right to introduce additional Assessment / Evaluation criteria; such a process, if introduced, may modify the number of points in each category.

GRADES

The following table provides the Letter Grading equivalent of the sum of points earned in Assessment / Evaluation for the coursework:

Grade	Raw Point
A+	95 - 100
A	85 - 95
A-	80 - 85
B+	75 - 80
B	70 - 75
B-	65 - 70

Grade	Raw Point
C+	60 – 65
C	50 – 60
D	40 – 50
F	0 – 39

MAKE-UP WORK

The Instructor is to establish this on a case by case basis; assignment of make-up work is extremely rare and not guaranteed. It is the student's responsibility to obtain any missed information, handouts, etc from the Instructor and / or classmates.

ATTENDANCE / PARTICIPATION

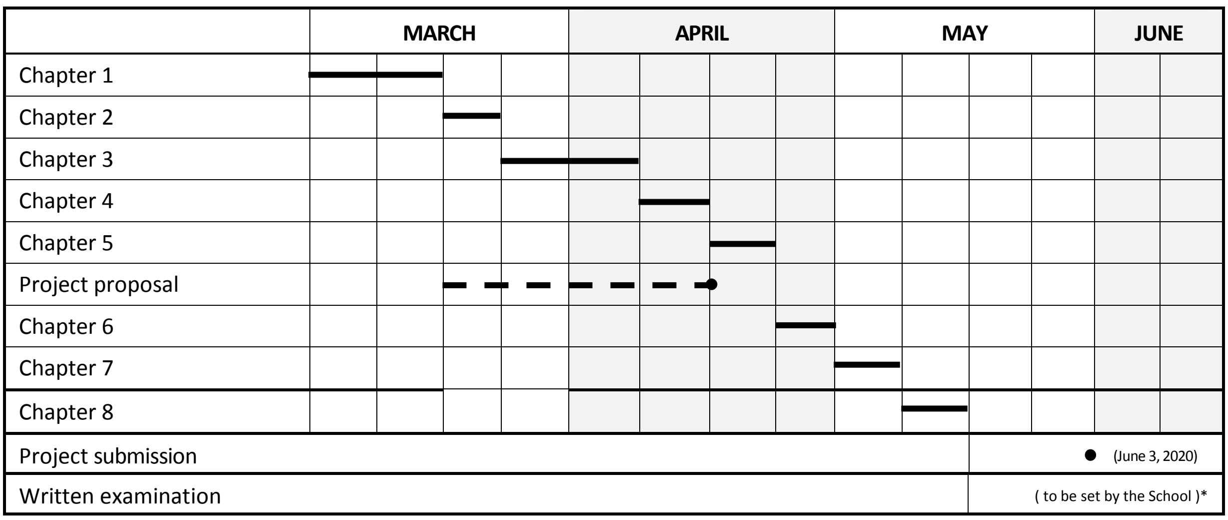
Attendance and in-class participation is required for all course participants unless special permission is obtained from the School. The Instructor records attendance in accordance with the Institute's policies. Any student not attending or participating as expected by the course instructor may be withdrawn from the course or may be required to meet with the Program Chair / Dean.

The following are the expectations for successful participation:

- Be in the classroom for all work time, arriving in time and not leaving early from class.
- Complete readings and assignments prior to the start of class.
- Prepare notes in advance to actively participate in classroom discussions.
- Be professional at all times in attitude, dress, and communication.
- Be receptive to feedback provided in critiques.
- Respect the time, talents, and differences of your peers.
- Cell phone use and disruptive calls are NOT acceptable in class and any such act (knowingly or incidentally) may involve removal from class of the concerned student. *All cell phones must be put to "silent" mode or switched off while the class is in session*.

The environment provided by the Instructor emulates the professional work environment. An inclusive, respectful team atmosphere is expected to be maintained by all.

SCHEDULE



* Written examination may be arranged to take place earlier than anticipated time schedule and in consultation with course participants.