Finite Elements in Civil Engineering

CES 5116, Class # 11526, Section 6577

Class periods: Tue., Thu., Periods 2–3 (8:30 am – 10:25 am)
Location: WEIL 234 (Weil Hall)
Academic term: Fall 2018

Instructor:

Dr. Gary R. Consolazio
E-mail: GRC@UFL.EDU
Phone: (352)294-7796
Office: 475-J Weil Hall
Office hours: posted next to office door.
Class website: Canvas (UF E-Learning) - CES5116

Teaching assistant:

None.

Course description:

Introduction to finite elements, use of finite element concepts for structural analysis. Application of 1D, 2D, and 3D elements of structural problems, (3 credits).

Course prerequisites/co-requisites:

A course in matrix-based direct-stiffness structural analysis.

Course objectives:

The objectives of this course are *1*) to provide the student with an understanding of the mathematical basis of the finite element method and *2*) to provide the student with an understanding of the steps involved in creating and validating finite element analysis models; appropriately using finite element software; and interpreting analysis results.

Material and supply fees:

Not applicable.

Textbooks and software:

Required course notes: Posted to course website in PDF format for printing by students.

Recommended textbook: Cook, R.D., Malkus, D.S., Plesha, M.E., Witt, R.J. *Concepts and Applications of Finite Element Analysis*, 3rd or 4th Ed., John Wiley & Sons, Inc.

Required software: MathCad (or similar) and ADINA (provided).

Software Use:

All faculty, staff and students of the University of Florida are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Course Outline:

General

- Review of strain-displacement relationships and constitutive relationships: 1D, 2D, 3D
- Numeric integration using Gauss-quadrature

1D, displacement DOF, truss element & general formulation methods

- Governing differential equation; interpolation using linear C^0 shape functions; finite element formulation via virtual work; axial truss (bar) element; element stiffness and load; assembly of global matrices; solution; force recovery; Lagrange polynomials as 1D shape functions; numeric integration of element matrices
- Alternate finite element matrix formulation techniques: method of weighted residuals; variational methods; strong form; weak form; essential and natural boundary conditions; Galerkin method; Rayleigh-Ritz method

2D, triangular, scalar DOF, torsional warping element

- Governing differential equation; application of variational method; 2-D scalar DOF interpolation using triangular elements; torsional constant J; solution convergence
- Automatic 2D triangular mesh generation based on geometric description; resolution control; mapped meshing; mesh compatibility

2D, triangular, displacement DOF, plane stress/strain

- Element formulation for constant-strain triangular (CST) elements; applications to planar analysis
- Limitations of CST elements
- Concept and application of symmetry boundary conditions

2D, quadrilateral, displacement DOF, plane stress/strain, axisymmetric elements

- Bilinear interpolation and shape functions for 2D rectangular domains
- Plane-stress & plane-strain analysis using rectangular elements; locking
- Remedies for locking: biquadratic interpolation and shape functions for 2D rectangular domains; reduced integration; spurious (hourglass) modes; addition of incompatible quadratic modes; finite element stress analysis tutorial; principal stresses & effective stress; interpretation of results; section forces
- Isoparametric 2D element formulation: shape functions in natural coordinates; coordinate transformations; Jacobian [J] matrix; local (element) coordinate system; stress recovery and interpretation
- Transitioning mesh density: transition elements; free form meshing using isoparametric elements; effects of element distortion
- Axisymmetric elements: element formulation; wedge vs. ring; loads; boundary conditions

3D, displacement DOF, solid (brick) elements

- 3D shape functions; isoparametric element formulation

2D/3D, displacement DOF, plate/shell elements

- Plate bending elements: Kirchoff and Mindlin theories; strain-displacement relationships; constitutive relationships; element formulation; locking; split integration; spurious (hourglass) modes;
- Interpretation of plate bending analysis results: sign conventions; transformation of plate bending forces; principal moments and shears; flat slab analysis tutorial; assessing slab strength adequacy
- Shell elements; flat shell formulation; superposition of membrane and plate bending; drilling DOF

1D, displacement DOF, beam element & composite action

- Governing differential equation; Euler-Bernoulli beam theory; cubic Hermitian C^1 shape functions; formulation of element stiffness and load matrices; numeric integration of element matrices; force recovery; sign convention
- Modeling girder-slab composition action: connecting beam and shell elements with rigid links

Attendance:

Students are expected to attend class regularly, however, attendance will not be formally recorded. Habitual tardiness will not be tolerated. Excused absences are consistent with university policies (https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx) and require appropriate documentation.

Make-up exam policy:

Make-up exams will not be given except in cases of valid medical emergencies (for which the student must provide written documentation) or certain other admissible emergencies. Students with questions regarding this policy are urged to consult the instructor.

Grading policy :

A 100-93; A- 93-90; B+ 90-87; B 87-82; B- 82-80; C+ 80-77; C 77-72; C- 72-70; D+ 70-67; D 67-62; D-62-60. Grades may be curved at the instructor's discretion.

Grading and assignments:

Assignments: 15 %, Exam 1: 30 %, Exam 2: 30 %, Final Project: 25 %

All assignments will be evaluated for overall degree of completion. A randomly selected subset of assignments will also be graded in detail. Solutions to assignments will be distributed by the instructor. Each student is responsible for comparing their solution to the solution posted by the instructor to determine if errors were made. Questions relating to the posted solutions should be brought to the instructor for clarification.

A due date and time will be indicated on each assignment. Assignments submitted late will be penalized as follows: 0-24 hrs late: 25% penalty; 24-48 hrs late: 50% penalty; 48+ hrs late : 100% penalty. Exceptions may be made in cases where the student has spoken to the instructor *prior* to the due date of the homework or cases where there is a valid excuse (e.g. medical emergency with written proof).

Assignments will consist of hand calculations, spreadsheet/program development, use of commercial software, or a combination of any of these components. Each problem solution submitted <u>shall begin with a statement of the problem being solved</u>. All hand calculations <u>must be submitted on engineering computation paper</u> with clear calculations, and neat sketches. Sloppy, disorganized homework will <u>not be graded</u>. Spreadsheets/programs must include <u>comments</u> documenting the procedures being implemented, variables used, degrees of freedom chosen, units, etc. Where appropriate, <u>sketches should be included</u> either as hand drawn supplements that are referred to in the spreadsheet printouts (e.g. "see Figure 1") or as computer sketches included directly in spreadsheet/program printouts. Finite element analysis problems must include a complete description of the model (overall geometry, boundary conditions, loading conditions, material properties, etc.). Print-outs of <u>complete input files</u> and <u>relevant data from output files</u> shall be included.

Undergraduate students, in order to graduate, must have an overall GPA and an upper-division GPA of 2.0 or better (C or better). Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. Graduate students, in order to graduate, must have an overall GPA of 3.0 or better (B or better). Note: a B- average is equivalent to a GPA of 2.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit: catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

Honesty statement:

Each student is expected to submit work that constitutes an independent effort on their part. While open discussion of <u>assignments</u> (but <u>not</u> exams) is acceptable and, in fact, encouraged, the written work submitted by each student must reflect that student's understanding of the topics covered. Failure to comply with this policy will result in serious consequences.

University honesty policy:

UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Honor Code (https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Course evaluation:

Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu/evals. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

Students requiring accommodations:

Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, https://www.dso.ufl.edu/drc) by providing appropriate documentation. Once registered, students will receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Campus resources:

Health and Wellness

U Matter, We Care:
If you or a friend is in distress, please contact umatter@ufl.edu or 352 392-1575 so that a team member can reach out to the student.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or http://www.police.ufl.edu/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, http://cms.uflib.ufl.edu/ask. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. https://teachingcenter.ufl.edu/.

Writing Studio, 302 Tigert Hall*,* 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:* https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf.

On-Line Students Complaints*:* http://www.distance.ufl.edu/student-complaint-process.