

# Finite Elements in Civil Engineering

**CES 5116, Class # 11410, Section 6577**

**Class periods:** Tue., Thu., Periods 2-3 (8:30 am – 10:25 am)

**Location:** Online

**Academic term:** Fall 2020

**Instructor:**

Dr. Gary R. Consolazio

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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.

**Required notes and software:**

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

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

**Recommended textbook:**

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

**Course schedule:****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 composite action: connecting beam and shell elements with rigid links

**Online Course Recording:**

Our class sessions may be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the chat feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

**Attendance:**

Students are expected to attend class regularly. Excused absences must be in compliance with university policies in the Graduate Catalog (<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance>) 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.

**Evaluation of grades:**

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

**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.

More information on UF grading policy may be found at:  
<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

**Assignments:**

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 student solution will be submitted through Canvas as a single, merged PDF file. Each submitted solution shall begin with a statement of the problem being solved. All hand calculations shall be submitted as clear, undistorted scans of calculations written on engineering computation paper with accompanying neat sketches. Sloppy, disorganized homework will not be graded. Spreadsheets/programs must include comments documenting the procedures being implemented, variables used, degrees of freedom chosen, units, etc. Where appropriate, sketches should be included 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 complete input files and relevant data from output files shall be included.

**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.

**Course evaluation:**

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.ua.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.ua.ufl.edu/public-results/>.

**Class honesty policy:**

Each student is expected to submit work that constitutes an independent effort on their part. While open discussion of assignments (but not 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://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-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.

**Commitment to a safe and inclusive learning environment**

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, [rbielling@eng.ufl.edu](mailto:rbielling@eng.ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto:nishida@eng.ufl.edu)

**Software use:**

All faculty, staff, and students of the University 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.

**Student privacy:**

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

**Campus resources:***Health and Wellness***U Matter, We Care:**

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact [umatter@ufl.edu](mailto:umatter@ufl.edu) so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**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 Discrimination, Harassment, Assault, or Violence**

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the Office of Title IX Compliance, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, [title-ix@ufl.edu](mailto:title-ix@ufl.edu)

**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 support**, 352-392-4357 (select option 2) or e-mail to [Learning-support@ufl.edu](mailto: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](https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf).

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