Aalto University
School of Engineering

MEC-EV12 Theory and Analysis of Laminated Composite and Functionally Graded Structures

by Prof. JN Reddy Texas A&M University, USA

Practical Info

Jani Romanoff, Mikko Suominen, Federica Mancini

Aalto University
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ABOUT DR. REDDY

Dr. Reddy is a Distinguished Professor, Regents' Professor, and inaugural holder of the *O'Donnell Foundation Chair IV* in Mechanical Engineering at Texas A&M University, College Station, Texas. Dr. Reddy, an ***ISI highly-cited researcher***, is known for his significant contributions to the field of applied mechanics through the authorship of 25 textbooks and nearly 800 journal papers. His pioneering works on the development of shear deformation theories (that bear his name in the literature as the *Reddy third-order plate theory* and the *Reddy layerwise theory*) have had a major impact and have led to new research developments and applications. Some of the ideas on shear deformation theories and penalty finite element models of fluid flows have been implemented into commercial finite element computer programs like ABAQUS, NISA, and HyperXtrude. In recent years, Reddy's research has focused on the development of locking-free shell finite elements and nonlocal and non-classical continuum mechanics problems involving couple stresses and damage and fracture in solids.

Dr. Reddy has received numerous honors and awards. Most recent ones include: 2022 *IACM Congress (Gauss-Newton) Medal*, 2019 *SP Timoshenko Medal* from American Society of Mechanical Engineers, 2018 *Theodore von Karman Medal* from the American Society of Civil Engineers, the 2017 *John von Neumann Medal* from the U.S. Association of Computational Mechanics, the 2016 *Prager Medal* from the Society of Engineering Science, and 2016 ASME Medal from American Society of Mechanical Engineers. He is a member US National Academy of Engineering and foreign fellow of the Brazilian National Academy of Engineering, Indian National Academy of Engineering, the Canadian Academy of Engineering, the Chinese Academy of Engineering, the Royal Engineering Academy of Spain, the European Academy of Sciences, and the European Academy of Sciences and Arts. A more complete resume with links to journal papers can be found at http://mechanics.tamu.edu.

Outline and Venue

A four-day course on

THEORY AND ANALYSIS OF LAMINATED COMPOSITE AND FUNCTIONALLY GRADED STRUCTURES

5-8th September 2023

by **J. N. Reddy**

Texas A&M University, College Station, Texas USA

The present course is primarily intended for structural engineers from aerospace, civil, and mechanical/marine engineering industries as well as graduate students and faculty from academia. The course has 3+2 credit points with first 3 cp from participation to lectures and computational tasks to be delivered after the course and remaining 2 cp for those writing a reflective learning diary about the theory, practice and applications to be delivered also after the course.

COURSE OBJECTIVES

The course is aimed at providing participants with the theory and analysis (and some design considerations) in dealing with composite structural components in the form of beams, plates, and shells laminated of fiber-reinforced materials and two-constituent functionally graded beams and plates. Theoretical formulations and applications will be presented to illustrate the concepts.
The participants of the course must have a background in mechanics of materials and structures and a course on differential equations (i.e., at least an undergraduate degree in engineering is required). The course will not discuss any specific industrial applications.

BACKGROUND

The increased use of composite and functionally graded materials in a variety of engineering structures (e.g., aerospace, automotive, off-shore, and marine and underwater structures, as well as in medical prosthetics and sports equipment) and the number of journals and conferences held in the last five decades attest to the fact that there has been a major effort to develop modern composite and functionally graded material systems for a variety of applications, and analyze and design structural components made from composite materials. The subject of composite materials is truly an interdisciplinary area where chemists, material scientists, chemical engineers, mechanical engineers, and structural engineers contribute to the overall product.

COURSE OUTLINE

Tuesday September 5th, 2023, 09:00-15:00:
Otakaari 1, U358

- Composite Materials: An Introduction
- Anisotropic Elasticity and Functionally Graded Materials
- Structural Theories of Composite Laminates: Classical laminate plate theory (CLPT)
- Structural Theories of Composite Laminates: First-order shear deformation theory (FSDT)
- Interaction session (Q&A)

Wednesday September 6th, 2023, 09:00-15:00:
9-12: Otakaari 1, U119 DELOITTE ; 12-15: Otakaari 1, U358

- Analytical Solution Methods: Navier solution procedure
- Numerical examples of bending, vibration, and buckling solutions of laminated plates
- Finite Element Models of Composite Laminates: Theoretical developments
- Numerical Results and Discussion
- Interaction session (Q&A)

Thursday September 7th, 2023, 09:00-15:00:
9-12: Otakaari 1, U147 U5 ; 12-15: Otakaari 1, U154 U1

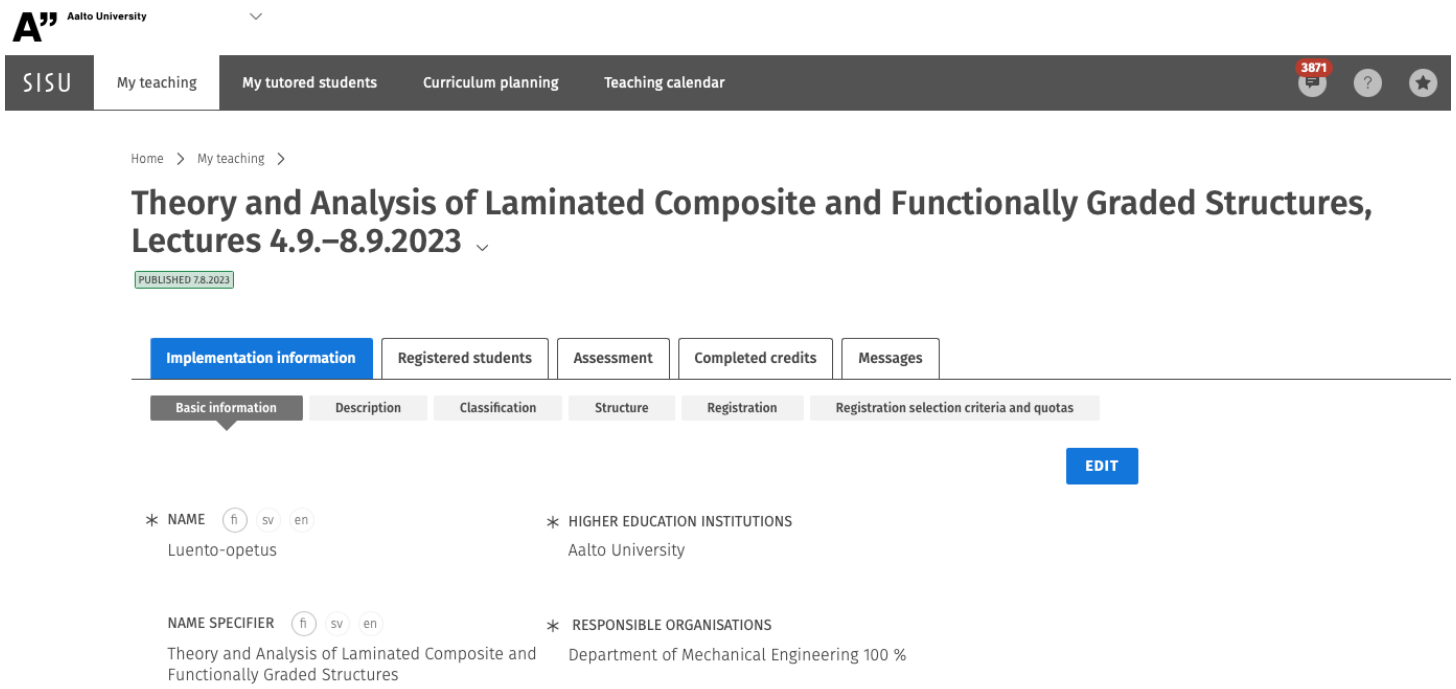
- Functionally Graded Materials: Beams
- Functionally Graded Materials: Plates
- Finite element models of FGM Beams and Plates
- Numerical Results and Discussion
- Interaction session (Q&A)

Friday September 8th, 2023, 09:00-15:00:
9-15: A Grid / Otakaari 5, A108b / A111a Mordor

- Finite Element Models of Laminated Shell Structures
- Numerical Examples and Discussion
- Failures in composites and Design Considerations
- Overview of the course
- Interaction session (Q&A)

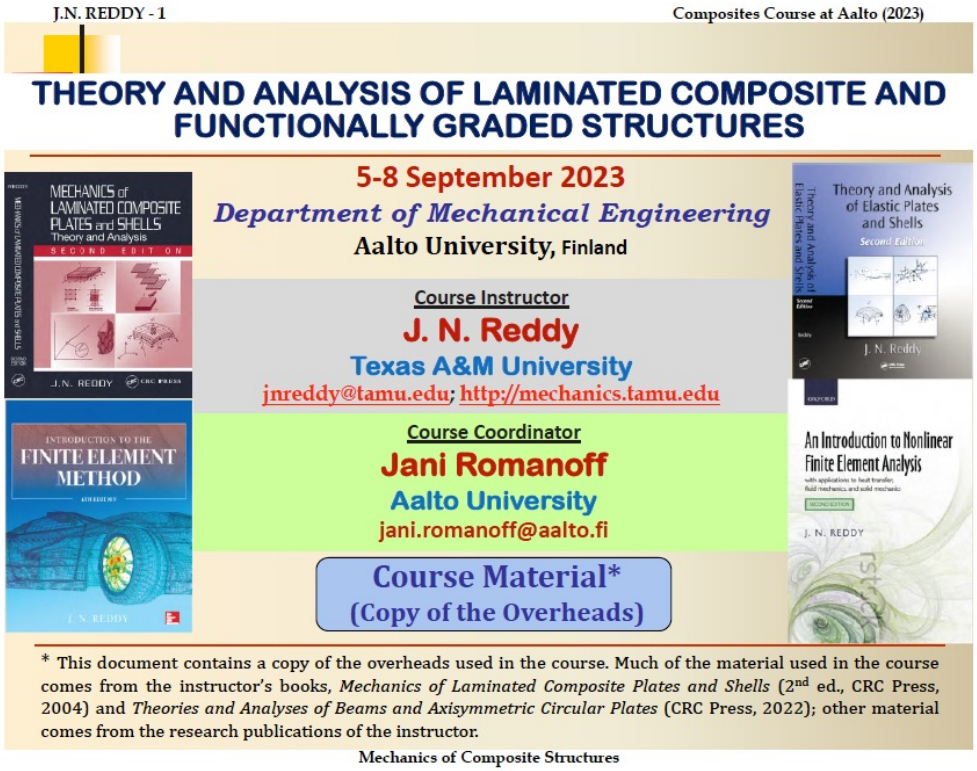
Registration

- Some of you have done preliminary registration by email
- For credits, you need to register in sisu.aalto.fi
- In case you have any problems to register, send email to jani.romanoff@aalto.fi



Materials

- Prof. Reddy has prepared 260 slides to cover the course contents
- The slides will be send to course participants by email during Tuesday September 5th 2023
- There are several books on these topics published by prof. Reddy from which details beyond this course can be found



Tasks

4 days course, 3 ECTS

- Participation to lectures (names collected twice a day)
- Small daily assignments to test your learning (1 / day, in total 4)
- To be completed by Friday September 15th 2023

Task 1: Create a Matlab/python script that computes the CLT and FSDT stiffness matrices for given stacking sequence.

Task 2: Do option a or b:

Option a) Compute the Navier solution for the laminated rectangular plate when being simply supported from all four edges and under uniform pressure load.

Option b) Show with commercial FE-solver the role of shape functions and CLT vs FSDT to the computed results on simply supported square plate with uniform pressure load acting normal to plate surface.

Task 3: Create a Matlab/Python script to compute ABD-matrix for functionally-graded plates with given decay of material properties through the thickness.

Task 4: Explain with equations the difference between degenerated continuum shell elements and equivalent single layer shell elements. Explain also the benefits and weaknesses of both modelling strategies.

Learning Diary, + 2ECTS

- Reflective description of your own learning during the course
- Minimum 2-3 pages containing description of what did you:
  - ***Knew in past*** about the subject and related fields of science (e.g. numerical methods, solid mechanics, materials science)
  - ***Learned during the course*** and what were the main new items learned and their links to the pre-existing knowledge
  - ***What did you*** identify as topics that you must learn more ruing your studies and work
- To be completed by October 8th 2023
- The learning diaries must contain text, equations and figures that show how you understand the subject learned (do not repeat word by word what teachers state)

All submission to be send to jani.romanoff@aalto.fi for grading