Dept. of Civil and Environmental Engineering, Washington State University

CE 537 Section 02 Structural Composites
- Composite Materials in Civil Infrastructure

An Introductory Composites Design Course for Graduate/Senior Undergraduate Students

SPRING 2007: TU and TH 9:10 - 10:25 AM, Sloan 175
INSTRUCTOR: Dr. Pizhong Qiao (Chiao), Sloan 120 (Phone: 509-335-5183)
Email: Qiao@wsu.edu
Class website: http://pas.ce.wsu.edu/CE537-2

BACKGROUND: Advanced Composite Materials (ACMs) are being used in civil engineering infrastructure as structural shapes and reinforcements for concrete, wood, and steel. The favorable properties of ACMs are light-weight, high strength-to-weight and stiffness-to-weight ratios, corrosion resistance, nonmagnetic, nonconductive, and the ability to tailor the material system (fibers and resins) and shape for specific applications. ACMs have been used for bridges, piers, retaining walls, airport facilities, storage structures exposed to salts and chemicals, chemical and water treatment plants, and many other structures. Two major applications of composites in civil engineering structures are fiber reinforced polymer (FRP) composite highway bridge decks and external reinforcement of concrete structures with FRP fabrics to sustain seismic loads.

OBJECTIVE AND SCOPE: This is an introductory composites design course for Graduate/Senior Undergraduate* students (*for the senior undergraduate students who are interested in pursuing a graduate degree). This class will emphasize fundamental aspects of composites design (i.e., micro/macromechanics of composites) and their practical aspects and applications, and will provide design guidelines and methodologies for structural shapes and reinforcements for concrete (re-bar and externally bonded fabrics) and wood (bonded plates and fabrics).

HIGHLIGHTS OF THE COURSE:
- Constituent materials and properties (resins and fibers); manufacturing processes.
- Micro/macro-mechanics of composites.
- Design of composite properties (of manufactured panels or fabrics).
- Simplified analysis and design of thin-walled ACM beams, columns, and applications to building structures and highway bridge decks.
- ACM reinforcing bars for concrete and reinforcing fabrics bonded externally to concrete.
- ACM reinforcements for laminated wood beams and other wood composites.
- Learning Composites Design through CADEC - a computer design software.

LABORATORY ACTIVITIES: Students in teams of about four or five will participate in:
- Manufacturing of panels from basic constituents.
- Testing of samples in tension, shear, and other.
- Testing of FRP structural shapes (in-class demonstration only).

FIELD TRIPS: We will visit one ACM manufacturing (i.e., extrusion process at WMEL) facility.
POLICY AND GUIDELINES:

Academic Honesty:

You are bound by the university honor code; it is your responsibility to know the code and the risks of violations (See Student Handbook, Washington State University).

Grading:

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<td>Homework</td>
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Homework:

It does not matter how you acquire your knowledge. You may seek help from anyone. However, the final work has to be yours. **Don't copy!** Homework due dates will be specified on each assignment; generally, late homework will not be accepted.

Students are expected to submit work which is reasonably neat, complete yet concise, orderly and well organized. Calculations and sketches should be presented in pencil on standard engineering paper **8.5 x 11**. No off-size sheets and/or ragged edged papers will be accepted. Please staple all sheets together, **assignment sheet on top**, and hand-in flat, **not folded**.

Suggestions for Meaningful Learning:

Participate in class and make an effort to think with me. If you can't follow, let me know. Review your class notes as soon as possible: Clarify them; identify weaknesses in your background (you may not always have time to eliminate them, but it is important to recognize them); **write down questions**: how does it work and why does it work?
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Email: Qiao@wsu.edu

TEXTBOOK (REQUIRED):

COMPUTER SOFTWARE FOR DESIGNING COMPOSITES:
Download: CADEC - Computer Aided Design Environment for Composites
at http://www.mae.wvu.edu/~barbero/icmd.html or
from the link at my homepage http://composites.wsu.edu/qiao/

Class Website: http://composites.wsu.edu/qiao/ or http://pas.ce.wsu.edu/CE537-2

Reference Books:
5. ACI 440R-96, State-of-the-Art Report on Fiber Reinforced Plastic (FRP) Reinforcement for Concrete Structures, American Concrete Institute, Detroit, MI, 1996.

OBJECTIVES:
1. To understand the fundamentals about composite materials – their mechanical behaviors, fabrication process, and design flexibility
2. To acquire the basic knowledge in mechanics of composites
3. To learn the applications of composite materials in Civil Infrastructure
4. To get hands-on experience with composite materials
5. To design composite materials and structures with aid of computer software

TOPICS:

1. INTRODUCTION (Ch. 1)
   Overview of Composites
   Applications of Composites in Civil Infrastructure
2. MATERIALS (Ch. 2)
   Fiber Materials
   Resin Materials

3. MANUFACTURING PROCESSES (Ch. 3)
   Concentration on processes suitable for structural applications:
   - Bag Molding, RTM, Pultrusion, Filament Winding, and SCRIMP.

4. MANUFACTURING OF COMPOSITE LAMINATED PANELS
   Vacuum Bagging: Fabrication of a Composite Plate

5. MICROMECHANICS (Ch. 4)
   Conceptual Understanding of the Theory
   Applications to Simple Cases

6. COMPUTER LAB SESSION
   Micromechanics Analysis with the Computer Program CADEC

7. PLY MECHANICS (Ch. 5)
   Conceptual Understanding of Stress and Strain
   Coordinate Transformations
   Transformed Reduced Stiffness Matrix
   Especial Cases

8. COMPUTER LAB SESSION
   Macromechanics Analysis with the Computer Program CADEC

9. LAMINATE MECHANICS (Ch. 6)
   Conceptual Understanding of Plate Stiffness and Compliance
   Coupling Effects
   Computation of Stresses
   Definition of Laminate Types
   Engineering Elastic Constants
   Design Using Carpet Plots
   Interlaminar Stresses

10. COMPUTER LAB SESSION
    Laminate Analysis with the Computer Program CADEC

****** MID-TERM EXAM ******

11. LABORATORY SESSION
    Tensile stiffness and strength of coupon samples
    Shear Stiffness and Strength of notched samples
12. FAILURE AND STRENGTH CRITERIA IN DESIGN (Ch. 7)
   Introduction of Relevant Failure Criteria
   Applications in Design Using Carpet Plots

13. THIN-WALLED BEAMS (Ch. 8 + Classnotes)
   Overview of Mechanics of Laminated Beams (MLB)
   Engineering Equations for Beam Stiffnesses
   Conceptual Understanding of Beam Global and Local Buckling
   Simplified Design Equations for FRP Thin-walled Beams

14. COMPUTER LAB SESSION
   FRP Beam Analysis with the Computer Program CADEC

15. LABORATORY SESSION
   Displacements and Strains for Simply-Supported Beams
   Lateral Torsional Buckling (Illustration)

****** Visiting Wood Materials and Engineering Laboratory (WMEL) (Extrusion process of wood plastic composite shapes) ******

16. COLUMN BEHAVIOR (Ch. 8)
   Euler's Column Buckling
   Local Buckling
   Compressive Strength
   Mode Interaction
   Design Equation for Buckling of FRP Column

17. ADVANCED COMPOSITE BRIDGES: DESIGN AND APPLICATIONS (Class Notes)
   Case Applications
   Design Aspects and Considerations
   Systematic Design of FRP Bridges

18. REINFORCEMENT OF CONCRETE WITH FABRICS (Class Notes)
   Applications in Practice
   Design Equations for Concrete Beams Wrapped with Composite Fabrics
   Fracture Toughness and Design of the Interface Bond

19. REINFORCEMENT OF WOOD WITH PLATES OR FABRICS (Class Notes)
   Applications in Practice
   Qualification Test Methods for Interface Bond Performance
   Fracture Toughness of the Interface
   Design of Reinforced Glulam Beams

****** REVIEW and EVALUATION ******
****** FINAL EXAM ******