

**53:086 Civil Engineering Materials**  
**Department of Civil & Environmental Engineering**  
**The University of Iowa**  
**Spring Semester, 2008**

Assignment #9

Due: Thursday, May 1<sup>st</sup>.

The questions that comprise this assignment come from two sources:

1. Chapter 11 of Materials for Civil and Construction Engineers, 2<sup>nd</sup> Ed. by M.S. Mamlouk and J.P. Zaniewski, Prentice-Hall (2006); and
2. Chapter 16 of The Science and Technology of Civil Engineering Materials by J.F. Young et al, Prentice-Hall (1998).

**Question 11.5:** a) Why are fibers much stronger than the bulk material? b) Give an example of a material that is relatively weak in bulk form and very strong in fiber form.

**Question 11.6:** Compare the desired properties of the matrix and fiber phases of the fiber-reinforced composite.

**Question 11.7:** Name three functions of the matrix phase in fiber-reinforced composites. State the reason for the need for a strong bond between the fibers and the matrix.

**Question 11.8:** What are the functions of aggregate used in portland cement concrete?

**Question 11.11:** Calculate the modulus of elasticity of carbon-epoxy composite under isostrain condition if the composite consists of 30% carbon fibers and 70% epoxy by volume. Also, calculate the percentage of load carried by the carbon fibers. The modulus of elasticity of the carbon fibers and the epoxy are  $50 \times 10^6$  psi and  $.5 \times 10^6$  psi, respectively.

**Question 11.12:** Repeat Question 11.11 for 40% carbon fibers by volume.

**Question 11.13:** Repeat Question 11.11 under the isostress condition.

**Question 11.17:** A fiberglass composite consists of epoxy matrix reinforced with randomly oriented and uniformly distributed E-glass fibers. The modulus of elasticity of the glass fibers and epoxy are 70 GPa and 6 GPa, respectively. Calculate the modulus of elasticity of the fiberglass if the volume percentage of the fibers is: a) 25%; b) 50%; and c) 75%. Plot a graph showing the relationship between modulus of elasticity of the glass and percent of the fibers. Comment on the effect of the percent of glass fibers on the modulus of elasticity of fiberglass. (Hint: Use Eq. 11.20 of the textbook).

**Question 11.19:** A short reinforced concrete column is subjected to a 1000 kN axial compressive load. The moduli of elasticity of plain concrete and steel are 25 GPa and 207 GPa, respectively, and the cross-sectional area of the steel is 2% that of the reinforced concrete. Considering the column as a structural member made of a composite material and subjected to load parallel to the steel rebars, calculate the following:

- a. the modulus of elasticity of the reinforced concrete.
- b. the load carried by each of the steel and the plain concrete.

- c. the minimum required cross-sectional area of the column given that the allowable compressive stress of the plain concrete is 20 MPa and that the allowable compressive stress of plain concrete will be reached before that of the steel.

**Question 16.1:** Calculate the tensile strength and initial modulus of elasticity of a thin composite material containing 30 percent by volume of uniformly dispersed fibers in two dimensions:

**Properties of the fibers**

Tensile strength = 1500 MPa  
E=70 GPa  
d=20 $\mu$ m

**Properties of the matrix**

Tensile strength = 20 MPa  
E=2 GPa

**Properties of interface**

bond strength = 0.7MPa

**Question 16.2:** Glass fibers are being used to reinforce a brittle and ductile matrix. Both the matrices have the same strength. Determine which of the composites will have higher strength. The fibers are continuous and are positioned parallel to the direction of loading of the composite. Their content is 20 percent by volume.

**Fiber**

Tensile strength = 1300 MPa  
E=70 GPa

**Ductile matrix**

Tensile strength = 100 MPa  
E<sub>m</sub>=5 GPa (assumed)

**Brittle matrix**

Tensile strength = 100 MPa  
Linear to failure;  $\epsilon_{mu}$ =0.5%  
E<sub>m</sub>=20 GPa (deduced)

**Question 16.3:** Calculate the stress-strain curves of the two composites in Question 16.2.

**Question 16.4:** Calculate the critical fiber volume fraction of a composite consisting of the following components:

**Properties of the fibers**

Tensile strength = 1000 MPa  
d=200 $\mu$ m  
length = 20mm

**Properties of the matrix**

Tensile strength = 50 MPa  
linear-brittle behavior  
 $\epsilon_{mu} < \epsilon_{fu}$

**Properties of interface**

bond strength = 0.7MPa