MEG 461/661
Introduction To Composite Materials

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Composite Materials…

…combination of multiple materials to produce a structure that is:

… better

… stronger

… faster

… lighter

…than the original materials by themselves.

Composites

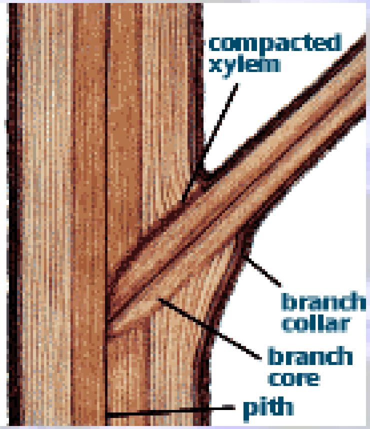
Composites are made from two or more distinct materials that when combined are better (stronger, tougher, and/or more durable) than each would be separately.

The word usually refers to the fiber-reinforced metal, polymer, and ceramic materials that were originally developed for aerospace use in the 1950s.

Although composites are a "high-technology" development, to some extent they mimic the features of living organisms such as the microstructures of wood and bioceramics like mollusk shells. The fibers and matrix of advanced composites may be combined using a variety of fabrication processes, with the choice depending on the desired alignment of fibers, the number of parts to be produced, the size and complexity of the parts, and so on. Perhaps best known for their use in **aerospace** applications, advanced composites are also used by the **automotive**, **biomedical**, and **sporting goods** markets. In addition, these strong, stiff, lightweight materials are seeing increased use in the rehabilitation, repair, and retrofit of **civil infrastructure**--including, for example, as replacement bridge decks and wrapping for concrete columns.

An Example of a Natural Composite

Composites do occur in nature--e.g., in tree trunks, spider webs, and mollusk shells. A tree is a good example of a natural composite, consisting of cellulose (the fibrous material) and lignin (a natural polymer) forming the woody cell walls and the cementing (reinforcing) material between them.



Complements of: http://www.ccm.udel.edu/

university homepage
college homepage
University of Delaware
Center for Composite Materials
sitemap
search

Military Aircraft Drive Development of Advanced Composites

Advanced Composites Usage – 1970’s

Boron/epoxy horizontal/vertical stabilizers (F-15)

Advanced Composites Usage – 1970’s

Boron/epoxy horizontal stabilizers (F-14)

Composites Research – 1970’s

Boron/epoxy tail and fuselage sections (F-111)

Composites Research – 1970’s

Carbon/epoxy fuselage component (F-5)

Composites Usage – 1980's

Carbon/epoxy wing, fuselage, control surfaces (AV-8B, Harrier)

Composites Usage – 1980's

Carbon/epoxy wingskins, control surfaces (F/A 18)

Composites Usage – 1990's

Carbon/epoxy wingskins, stabilizers, fuselage skins, control surfaces, internal structure (F 22)

Advanced Composites Usage – 2000's

White Night Launch Assist Vehicle



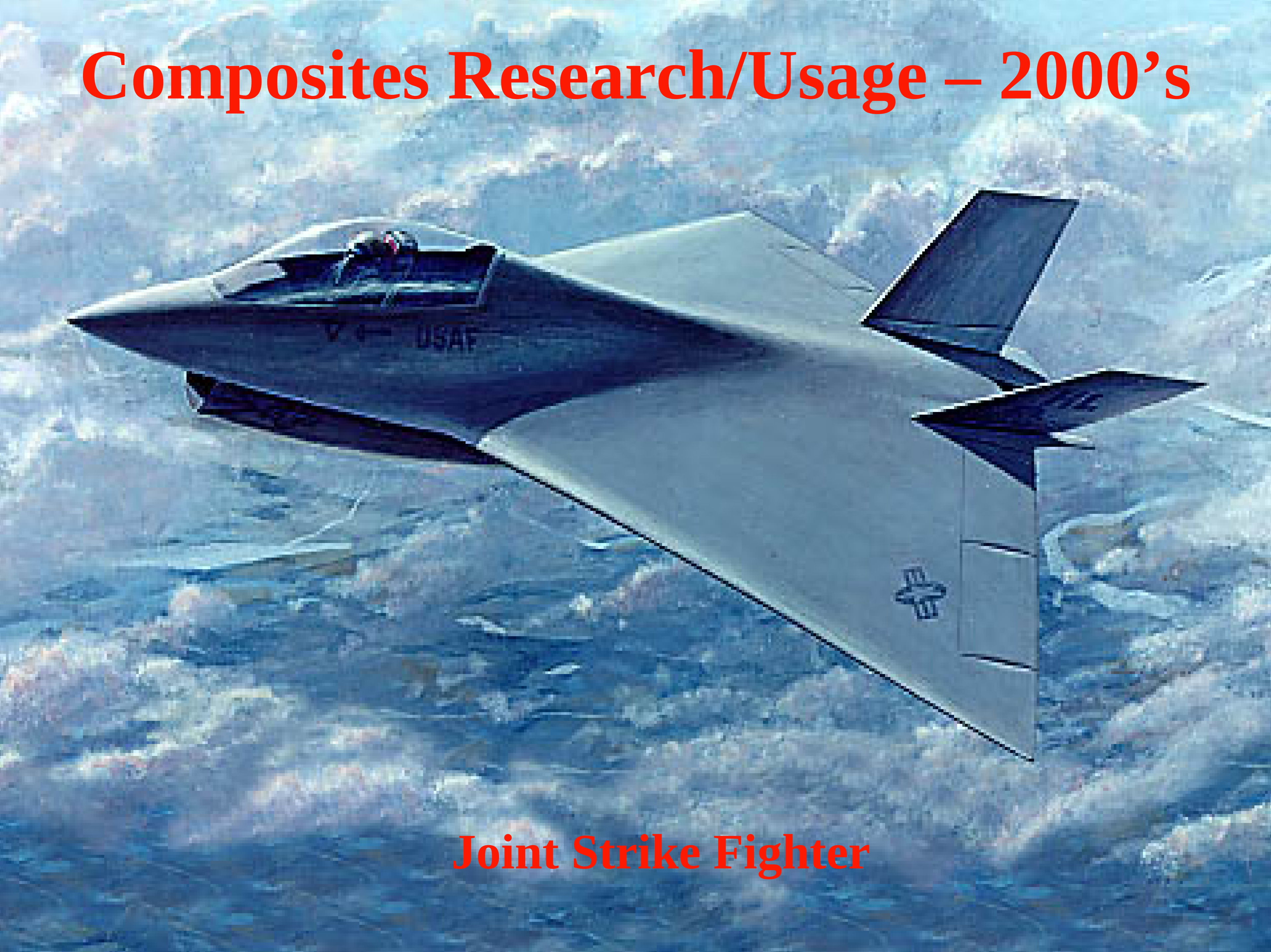
Aircrew
Brian Binnie   Pete Siebold
Mike Melvill Doug Shane

SpaceShipOne
WHITE KNIGHT

SCALED
COMPOSITES

Scaled Composites, LLC
1624 Flight Line, Mojave CA 93501
Info@scaled.com 661-824-4541

Composites Research/Usage – 2000’s



Joint Strike Fighter

General Characteristics of Some Composites

Advantages

- High Mechanical Properties
- Flexibility of Design Options
- Ease of Fabrication
- Light Weight
- Corrosion Resistant
- Impact Resistant
- Excellent Fatigue Strength
- **Ideal for structural applications that require high strength-to-weight and stiffness-to-weight ratios**

Disadvantages

- Brittle Failure Mechanisms
- High Material Costs
- High Manufacturing Costs
- Temperature Limitations
- Actual Mechanical Properties not Always as Good as Expected
- Mechanical Properties Very Process Dependent
- **Conventional composites limited to in-plane loads**

Composites References (Books)

[B1] Agarwal and Broutman, *Analysis and Performance of Fiber Composites,* Wiley and Sons, 1990.
[B2] Carlsson and Pipes, *Experimental Characterization of Advanced Composite Materials,* Prentice-Hall, Englewood Cliffs, NJ, 1987.
[B3] Christensen, R. M., *Mechanics of Composite Materials*, John Wiley and Sons, 1979.
[B4] Cogswell, F. N., *Thermoplastic Aromatic Polymer Composites,* Butterworth Heinemann, 1992.
[B5] Daniel & Ishai, *Engineering Mechanics of Composite Materials*, Oxford University Press, 1994.
[B6] De Wilde and Blain, (editors), *Composite Materials Design and Analysis*, Computational Mechanics Publishers, 1990.
[B7] Gibson, R. F., *Principles of Composite Material Mechanics*, McGraw-Hill, Inc., 1994.
[B8] Hamermesh, C. L. (Ed.), *Composites for Commercial Applications Technology Transfer Examples,* SAMPE, Covina, CA, 1992.
[B9] Hull, D., *An Introduction to Composite Materials*, Cambridge University Press, 1981.
[B10] Ishida, H., ed., *Characterization of Composite Materials,* Butterworth-Heinemann, 1994.
[B11] Jones, R. M., *Mechanics of Composite Materials*, McGraw-Hill, 1975.
[B12] Kelly, A. (ed.), *Concise Encyclopedia of Composite Materials*, Pergamon Press, 1994.
[B13] Lambie, J., *Composite Construction for Homebuilt Aircraft*, Aviation Publishers, 1984.
[B14] Lekhnitskii, S. G., *Theory of Elasticity of an Anisotropic Body*, Mir Publishers, Moscow, 1981.
[B15] Lubin, George (editor), *Handbook of Composites*, Van Nostrand Reinhold Company, 1982.
[B16] Mallick, P. K., *Fiber-Reinforced Composites*, Marcel Dekker, Inc., New York, 1993.
[B17] Marshall, A.C., *Composite Basics*, Marshall Consulting, Walnut Creek, CA, 1994.
[B18] Marshall and Demuts (editors), *Optimum Design of Composite Structures*, Elsevier Applied Science, 1990.
[B19] Meyer, R.W., *Handbook of Pultrusion Technology*, Chapman & Hall, New York, NY, 1985.
[B20] No author, *Aircraft Bonded Structure*, IAP, Inc, Casper, WY, 1985.
[B21] No author, *Moldless Composite Homebuilt Sandwich Construction*, Rutan Aircraft Factory Inc., 1983.
[B22] Pendleton and Tuttle, eds., *Manual on Experimental Methods for Mechanical Testing of Composites*, SEM, Inc., 1989.
[B23] Rutan, B., *Building the Rutan Composites*, VHS Video Tape, 91 min., Wick's Aircraft Supply.
[B24] Schwartz, M. M. (ed.), *Composite Materials Handbook*, McGraw-Hill, 1992.
[B25] Strong, A. B., *Fundamentals of Composites Manufacturing: Materials, Methods, and Applications*, SME, Dearborn, MI, 1989.
[B26] Strong, A. B., *High Performance and Engineering Thermoplastic Composites*, Technomic Publishing, Lancaster, PA., 1993
[B27] Swanson, S. R., *Introduction to Design and Analysis with Advanced Composite Materials*, Prentice Hall, 1997.
[B28] Tsai, S. W., *Theory of Composites Design*, Think Composites, Dayton, 1992.
[B29] Tsai and Hahn, *Introduction to Composite Materials*, Technomic Publishing Co., Inc., 1980.
[B30] Vinson and Sierakowski, *The Behavior of Structures Composed of Composite Materials*, Kluwer Academic Publishers, Boston, 1987.
[B 31] Warner, S. B., *Fiber Science*, Prentice Hall, 1995.
[B32] Wendle, B. C. *What Every Engineer should Know About Developing Plastics Products*, Marcel Dekker, Inc, New York, 1991.
[B33] Whitney, Daniel and Pipes, *Experimental Mechanics of Fiber Reinforced Composite Materials*, Prentice-Hall, Inc., 1984.

This is just a partial list of composites related books.

Composites References (Journals)

Partial List of Composites Related Technical Journals:

1. *AIAA Journal*, (American Institute of Aeronautics and Astronautics)
2. *Composite Structures*, Applied Science Publishers, Essex, England.
3. *Composites*, Butterworth Scientific, Surrey, England.
4. *Composites Engineering*, Pergamon Press, Oxford, England.
5. *Composites Manufacturing*
6. *Composites Science and Technology*, Elsevier Applied Science Publishers, Essex, England.
7. *Composites Technology Review*, (ASTM)
8. *Computers and Structures*
9. *Engineering Failure Analysis*
10. *Engineering Fracture Mechanics*
11. *Experimental Mechanics*, (SESA)
12. *International Journal of Composite Structures* (British)
13. *International Journal of Fracture*
14. *Journal of Advanced Materials*, (SAMPE), Covina, CA.
15. *Journal of Applied Mechanics*, (ASME)
16. *Journal of Composite Materials*, Technomic Publishing Co., Lancaster, Pa.
17. *Journal of Composites Technology and Research*, (ASTM), Philadelphia, Pa.
18. *Journal of Engineering Materials and Technology*, (ASME)
19. *Journal of Reinforced Plastics and Composites*, Technomic Publishing Co., Lancaster, Pa.
20. *Journal of Thermoplastic Composite Materials*
21. *Materials & Design*, Butterworth Heinemann
22. *Polymer Composites* (SPE)
23. *SAMPE Journal*, Society for the Advancement of Materials and Process Engineering, Covina, CA.

Composites References
(Trade Magazines & Websites)

Trade Magazines (Offer free subscriptions)

1. *Composites Design & Application (CDA)*, Published by the Composites Institute of the Society of the Plastics Industry CI/SPI.
2. *Composites Technology*, Ray Publishing.
3. *High Performance Composites*, Ray Publishing.

Related Websites:

- http://www.compositesworld.com/
- http://www.ccm.udel.edu/
- http://www.wwcomposites.com/
- http://mil-17.udel.edu/
- http://plastics.about.com/
- http://www.netcomposites.com/
- http://www.advmat.com/
- http://www.sampe.org/
- http://www.a-c-m.com/
- http://www.egr.msu.edu/cmsc/
- http://www.compositesone.com/
- http://www.wicksaircraft.com/

MEG 461/661
Course Introduction

Composites Related Topics

- Materials Science
- Metallurgy
- Polymer Science
- Fracture Mechanics
- Applied Mechanics
- Experimental Mechanics
- Adhesives
- Design
- Mechanical Joints
- Anisotropic Elasticity
- Process Engineering
- Materials Engineering
- X-ray Diffraction
- Ultrasonic Scanning
- Numerical Analysis
- Chemical Engineering
- Optimization

Composites Related Courses at UNLV

- **Introductory Course (MEG 461/661)**
  - Taught every 2 years
- **Advanced Laminate Analysis (MEG 795)**
  - Only taught one time
- **Experimental Mechanics (MEG 470/670)**
  - Taught about once every 4 years
- **Manufacturing (MEG 495/695)**
  - Only taught one time
- **Design Specific (MEG 491, 497/498)**
  - Many composites oriented design projects over the years
    - HPV frames, HPV fairings, SAE supermileage vehicle, World's largest frisbee, custom bicycle frame, bicycle forks, golf shaft, baseball bat, race car fuel tank, model airplanes, solar airplane, …

Topics Covered In MEG 461/661 Introduction to Composite Materials

- (10 %) Material Options
- (10 %) Composite Material Performance
- (10 %) Manufacturing Options
- (50 %) Analysis Methods
  - Unidirectional Composite Analysis
  - Off-Axis Lamina Analysis
  - Multi-Layered Laminate Analysis
- (20 %) Applied Design or Research Project

Objectives of MEG 461/661 Introduction to Composite Materials

Course Objectives

The overall goal of this course is to learn the important aspects of fiber reinforced materials and be able to answer the following questions:

- **What materials are primarily used to make composite materials?**
- **How are the materials and structures manufactured?**
- **How do you analyze the materials and structures to determine failure and deformations?**
- **How do you design composite structures to optimize structural performance?**
- **What are the key contemporary issues being addressed by the composites technical community?**

Students completing this course will be able to answer these questions.

MEG 461/661 Introduction to Composite Materials
Course Syllabus Spring 2005

Dates	Chap	Topics	Homework Due Dates	Quiz
F 1/21	1 2	Introduction, Course Outline Fibers / Projects		
F 1/28	2	Fiber & Matrix Properties, Density and Voids	**HW #1**, **Ch 1**: 2, 4, 5, 8, 9	
F 2/4	3	Fiber-Matrix Interaction Fiber Reinforced Lamina	**HW #2, Ch 2:** 2, 3, 4, 8, 12, 13, 16, 18	**Quiz 1**
F 2/11	3	Lamina Analysis	**Project Proposals Due**	
F 2/18	3	Laminate Analysis	**HW #3, Ch 3:** 1, 3, 6, 10, 16, 18, 19, 22	**Quiz 2**
F 2/25	3	Catch-up, Software Sample calculations		
F 3/4	4	Static Mechanical Properties Fatigue & Impact Properties	**HW #4**, **Ch 3**: 25, 31,38, 40	**Quiz 3**
F 3/11	4	Environmental & Creep Properties Fracture & Damage Tolerance	**HW #5**, **Ch 4**: 1, 3, 4, 6, 10	
F 3/18	5	Manufacturing Issues: Molding, Pultrusion, Winding	**HW #6**, **Ch 4**: 15, 18, 21, 27, 30, 34	**Quiz 4**
F 3/25		**Spring Break**		
F 4/1	6	Design Issues Failure Predictions	**HW #7**, **Ch 5**: 2, 6, 8, 9, 10	**Quiz 5**
F 4/8	6	Laminate Design Considerations Design Examples		
F 4/15	6	Application Examples	**HW #8**, **Ch 6**: 2, 4, 7, 9, 12, 15, 17, 19, 22	**Quiz 6**
F 4/22		Design or Special Topics		
F 4/29		Design or Special Topics		
F 5/6		SAMPE Conference, Long Beach May 1-5	**Project Reports Due**	
F 5/13		**Final Exam 10 AM – 1 PM**		

Homework, Quizzes, Grading

Homework:

Homework assignments are due at the beginning of class on the dates specified on the previous page. The problems and due dates may be changed during the semester. Any changes will be announced in class; it is your responsibility to be aware of these changes.

All calculations in HW problems are to be completed with software such as:

MathCad, Matlab, MS-Excel, …

Quizzes:

A series of in-class, closed book quizzes will be given throughout the semester. The quizzes will consist of several short answer questions covering topics from the reading assignments in the textbook, class lectures, and homework assignments. The quizzes may have some problem solving questions requiring the use of a calculator. The questions asked on the quizzes will focus primarily on recent topics covered in class. The quizzes will be given at the beginning of class and will last from 20-60 minutes.

GRADING:

Quiz 1-6	60 %	(10 % Each)
Homework Assignments	10 %	
Design/Research Project	30 %	

Design/Research Project Schedule

February 11, 2005 **Design/Research proposal due**

What are the geometric constraints, weight limits, approximate loading conditions (applied loads and supports), special restrictions, etc. Submit a short report defining your problem; include questions, which need answers in order to complete the design. Include rough sketches of your design problem. How will the work be divided between each group member. Each person must be in charge of a significant portion of the project. Submit a preliminary schedule for the semester.

May 6, 2005 **Submit complete design report**
Follow the outline below.

Design/Research Project Requirements

1. **Group names, project title, subtasks**

   You must have a minimum of 2 people per group and a maximum of 4. Each person should be responsible for a specific part of the project/report.

2. **Concise statement of the problem that clearly defines what you are trying to accomplish**

   There can be 3 general types of problems or a combination of the three:

   a) **Structural analysis and design of a composite component**

   b) **Fabricate and test a composite component**

   c) **Literature review of a contemporary composites research topic**

3. **What are the design constraints?**

   a) **Geometric limitations, weight limitations, etc., loading conditions**

4. **What are the design criteria? (How will you compare different design options?)**

   a) **strength, cost, stiffness, etc**

5. **Analysis / Fabrication / Review of literature**

   Material options, manufacturing options (prototype vs. production), recommended testing, test results (if possible), stress analysis, assumptions made for stress analysis, software used, assumptions used about loading conditions, confidence level in your assumptions and analysis, error estimates, etc.

6. **Summary and recommendations**

7. **Well formatted list of references (examples below)**

   All references should be cited in the body of the text. There should be a minimum of 10 references per group member for any type of project. A research literature review project should have a minimum of 10 journal publication references per group member.

Example Format for Report

1. **Title Page**
   A. Title of project
   B. Author
   C. Mail box number
   D. Group members
   E. Date submitted

2. **Abstract**
   A. Objective
   B. Brief summary of procedure
   C. Summary of results

3. **Introduction**
   A. Literature survey
   B. Detailed description of the problem
   C. Discuss design procedure, options, selection criteria

4. **Analysis Methodology**
   A. Discuss methods and assumptions used
   B. Include sketch's and free body diagrams
   C. Use text to describe your equations
   D. Include description of experiments (if appropriate)

5. **Results**
   A. Include tables or graphs based on your analysis
   B. Discuss results shown in tables or graphs
   C. Select final design

6. **Conclusions**
   A. Discuss the significance of your results
   B. Did you meet your objectives?
   C. How could you improve the design or the analysis

7. **References**

8. **Appendices**
   A. Sample Calculations
   B. Raw Data

Example Format for References (Style 1)

The reference list can be listed alphabetically as shown below. Cite references by author last name with publication year in parenthesis as shown below.

Example body text:
… Thermal analysis was conducted using methods described by Chamis (1981). The results are…

Corresponding list of references in alphabetical order:

Alther, G. A. "A Significant Role for Composites in Energy-Efficient Aircraft", Proceedings of the 36th Annual Conference, Reinforced Plastics/Composites Institute, February 16-20, 1981.

Ashley, S. "Cheetah Sprints to World Record", Mechanical Engineering, February 1993, pp 56-59.

Bicos, A. S. and Springer, G. S. "Design of a Composite Box Beam", J. of Composite Materials, Vol. 20, 1986, pp 86-109.

Buesking, K. and Rubinsky, J. "Material Design of Racing Catamaran Structural Beams", Proceedings of the 38th Annual Conference, Reinforced Plastics/Composites Institute, February 7-11, 1983.

Chamis C.C. "Prediction of Composite Thermal Behavior Made Simple", Proceedings of the 36th Annual Conference, Reinforced Plastics/Composites Institute, February 16-20, 1981.

Chamis C.C. "Design Procedures for Fiber Composite Structural Components: Rods, Beams, and Beam Columns", Proceedings of the 38th Annual Conference, Reinforced Plastics/Composites Institute, February 7-11, 1983.

Daines, J. V. "Design and Fabrication of Crashworthy Composite External Fuel Tanks", Proceedings of the 38th Annual Conference, Reinforced Plastics/Composites Institute, February 7-11, 1983.

Example Format for References (Style 2)

The references are listed in the order that they are cited in the text of the report. Cite references in the text using a number in brackets, [12]. Include the numbers in the list of references.

Example body text:
… The bicycle frame that was fabricated for this class only weighed 3 pounds, which was lighter than any other on record that could be found [8].

Corresponding list of references:

[1] O'Brien, K., Crincoli, J. F. and Kauffman, R. L. "Long Strand, Fiber-Reinforced, Thermoplastic Engineering Resins for Unique Combinations of Stiffness, Toughness and Injection Moldability", Proceedings of the 43rd Annual Conference, Composites Institute, February 1-5, 1988.

[2] Hauser, R. L. and Mund, H. "How to Strengthen and Stiffen Composite Panels", Proceedings of the 36th Annual Conference, Reinforced Plastics/Composites Institute, February 16-20, 1981.

[3] Levin, S. C. "Composites and Bicycles: Market Diversification in Action", Proceedings of the 38th International SAMPE Symposium, May 10-13, 1993.

[4] Weingart, O. "Winding for the Wind", Proceedings of the 36th Annual Conference, Reinforced Plastics/Composites Institute, February 16-20, 1981.

[5] Hart-Smith, L. J. "How to Calculate In-Plane Strengths of Fiber-Polymer Composite Laminates", SAMPE Journal, Vol. 28, No. 6, 1992, pp 25-35.

[6] Hopkins, M. W., Principe, F. S., and Kelleher, K. J. "Beyond Materials: DuPonts Aerodynamic Bicycle Wheel", Proceedings of the 35th International SAMPE Symposium, April 2-5, 1990.

[7] Howarth, C. S, Balonis, R. and Ko, F. K. "The Design and Manufacture of Composite Intensive Vehicles", Proceedings of the 35th International SAMPE Symposium, April 2-5, 1990.

[8] Kubomura, K., et al. "The Lightest Composite Monocoque Bicycle Frame", Proceedings of the 35th International SAMPE Symposium, April 2-5, 1990.

ERRATA

Book Corrections

Chapter 2

Page 86: Prob. P2.3
Change the term inside parenthesis to (t + 1).

Chapter 3

Page 123: Equation (3.27)
Change the left hand side to γ_{12} instead of n_{12}.
Page 131: Example 3.3
Change the units of ρ_f and ρ_m to g/ml.
Page 141: Stiffness matrix [Q] should be numbered Eq.(3.58).
Page 192: line 2
Change "titantum" to "titanium"

Chapter 4

Page 237: Equation (4.17)
The corrected version of Eq. (4.17) is

$$\gamma_{12} = 0.5977\ \epsilon_{g1} - 1.8794\ \epsilon_{g2} + 1.2817\ \epsilon_{g3}.$$

Page 311: Equation (4.43)
Change the denominator inside the parenthesis to c^2.
Page 348: Problem P4.1
1. In part(b), change Eq. (3.33) to Eq. (3.31).
2. Change the transverse strain values for 45° angle to -0.00113, -0.0021, -0.0029, -0.0038, -0.0048.

Page 354: Problem P4.23
1. Change $[0\&90]_s$ to $[0/90]_s$.
2. In parts (b) and (c), change 501/3 to 50%.

Page 357: Problem P4.29
The laminate thickness is "c" instead of "s".
Page 359: Problem P4.34
The specimen width is 25 mm.

Book Corrections (continued)

Chapter 5

Page 367: Equation (5.6)
Delete the minus sign inside the parenthesis.

Page 431: Problem P5.7
Change the units of E_1 and E_2 to cal/mol instead of kcal/mol.

Chapter 6

Page 506: Problem P6.10
Change the subscript "vt" to "ut".

Page 508: Problem P6.18
Change the beam length to 0.1m instead of 1m.

Chapter 7

Pages 511 and 526: Tables 7.1 and 7.3
Change the unit of Modulus (in parenthesis) to Msi.

Chapter 1

Major Classifications of Composites

- Polymer Matrix
  - Material Systems
    - Thermoset & Thermoplastic Resin Systems
    - Glass, Carbon, Aramid Reinforcing Fibers
  - Product Classifications
    - Engineering Composites (lower cost, injection molded parts, fiberglass tooling and components)
    - Advanced Composites (high performance and higher cost materials)
- Carbon Carbon Composites
- Metal Matrix
- Ceramic Matrix
- Reinforced Concrete

Composite Materials Mechanical Property Highlights

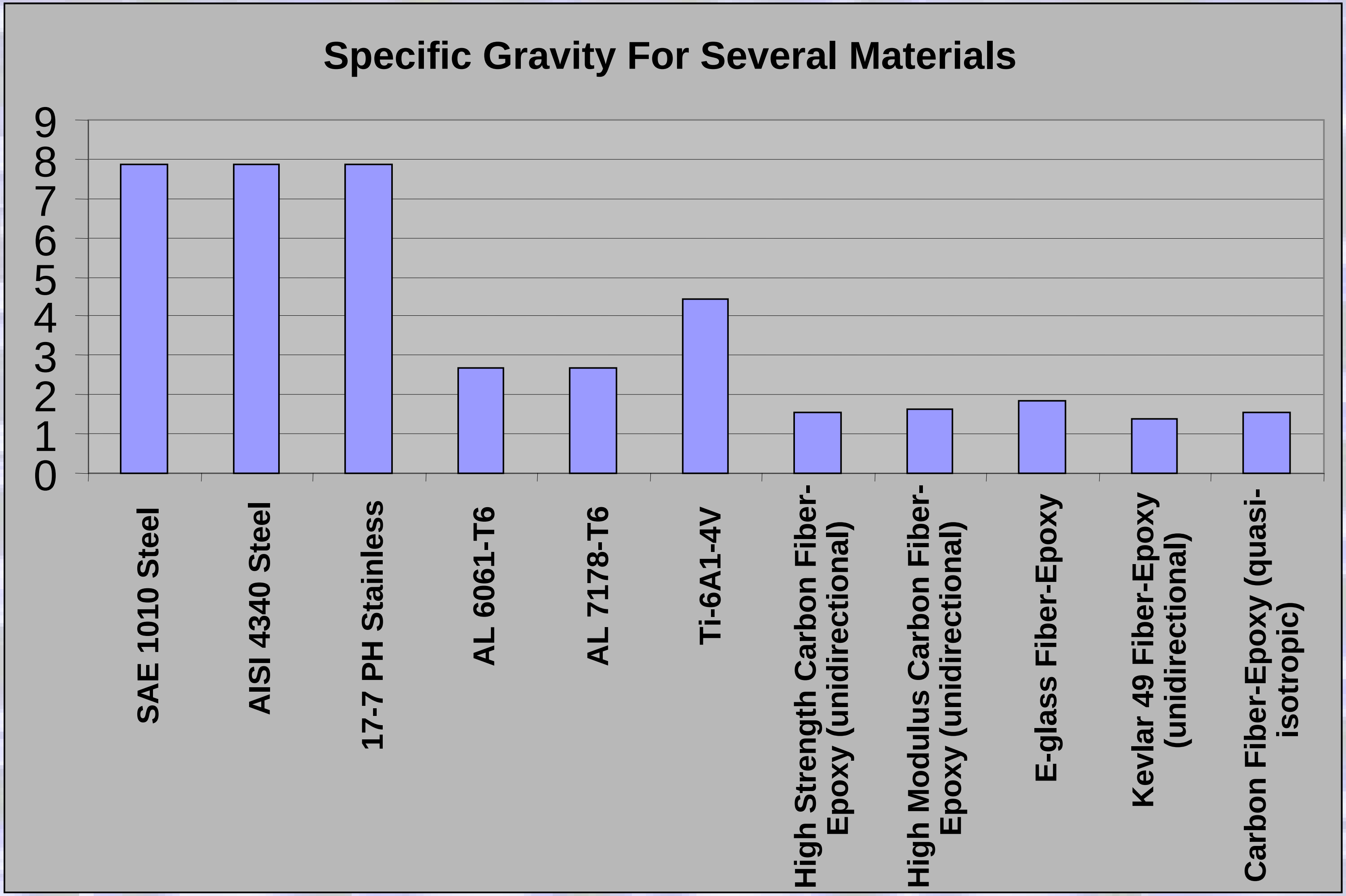
Material Property Definitions

- **Specific Gravity** = $\rho_{material}/(\rho_{water})$
  - ρ_{water} = 1000 kg/m^3 = 1 g/cm^3 = 1.94 slug/ft^3
- **Specific Weight** = ρg
- **Tensile Modulus**: $E = \sigma/\varepsilon$
- **Shear Modulus:** $G = \tau/\gamma$
- **Specific Tensile Modulus** = $E/\rho g$
- **Specific Tensile Strength** = $\sigma/\rho g$
- **Axial Stiffness** = EA (E*cross-sectional area)
- **Flexural Stiffness or Flex. Modulus** = EI
- **Torsional Stiffness or Torsional Rigidity** = GJ

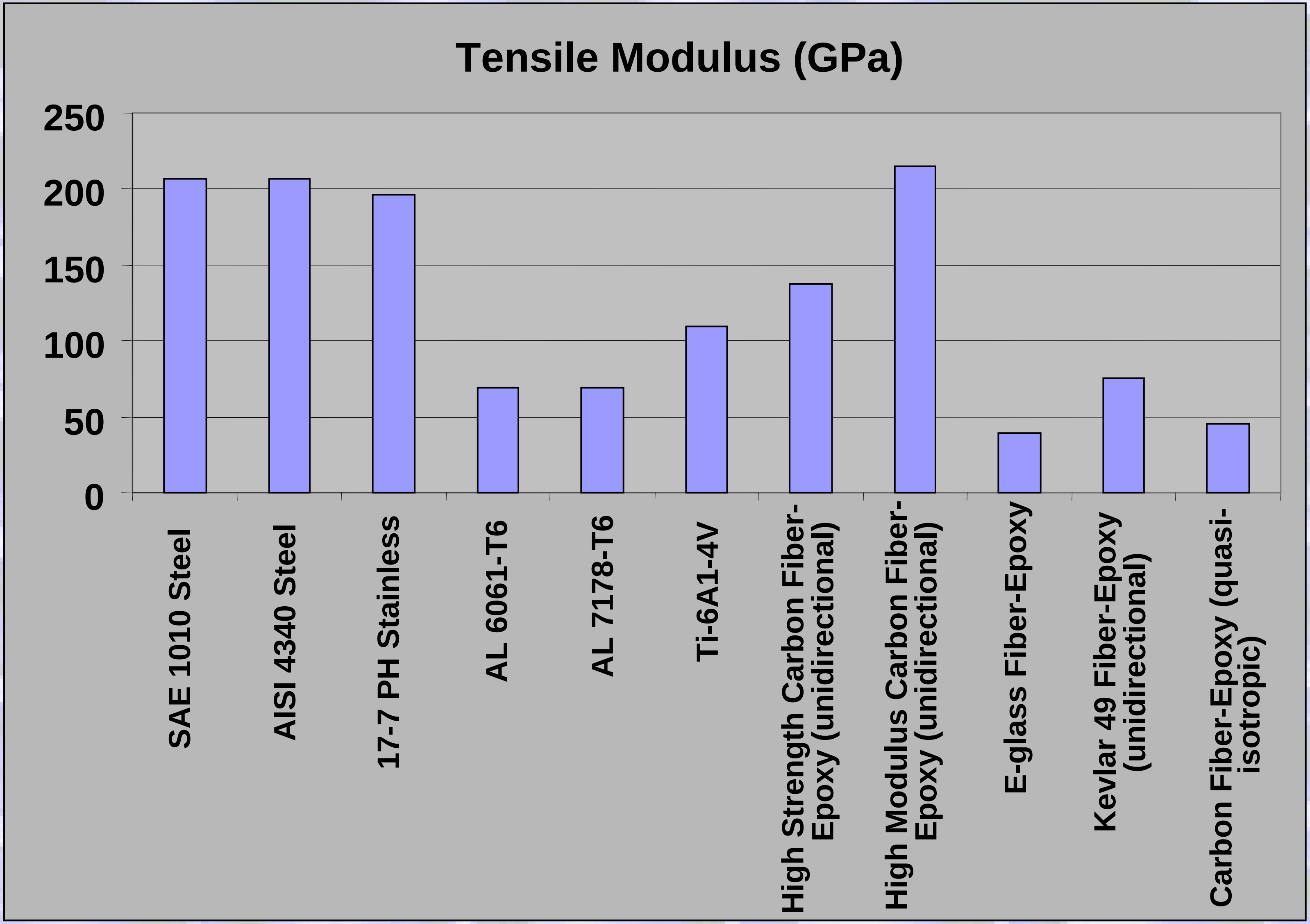
Tensile Properties of Metallic and Structural Composite Materials

	Specific Gravity	Tensile Modulus (GPa)	Tensile Strength (MPa)	Yield Strength (MPa)	Specific Modulus (m)	Specific Strength (m)
SAE 1010 Steel	7.87	207	365	303	2.68	4.72
AISI 4340 Steel	7.87	207	1722	1515	2.68	22.3
17-7 PH Stainless	7.87	196	1619	1515	2.54	21
AL 6061-T6	2.7	68.9	310	275	2.6	11.7
AL 7178-T6	2.7	68.9	606	537	2.6	22.9
Ti-6A1-4V	4.43	110	1171	1068	2.53	26.9
High Strength Carbon Fiber-Epoxy (unidirectional)	1.55	137.8	1550		9.06	101.9
High Modulus Carbon Fiber-Epoxy (unidirectional)	1.63	215	1240		13.44	77.5
E-glass Fiber-Epoxy	1.85	39.3	965		2.16	53.2
Kevlar 49 Fiber-Epoxy (unidirectional)	1.38	75.8	1378		5.6	101.8
Carbon Fiber-Epoxy (quasi-isotropic)	1.55	45.5	579		2.99	38

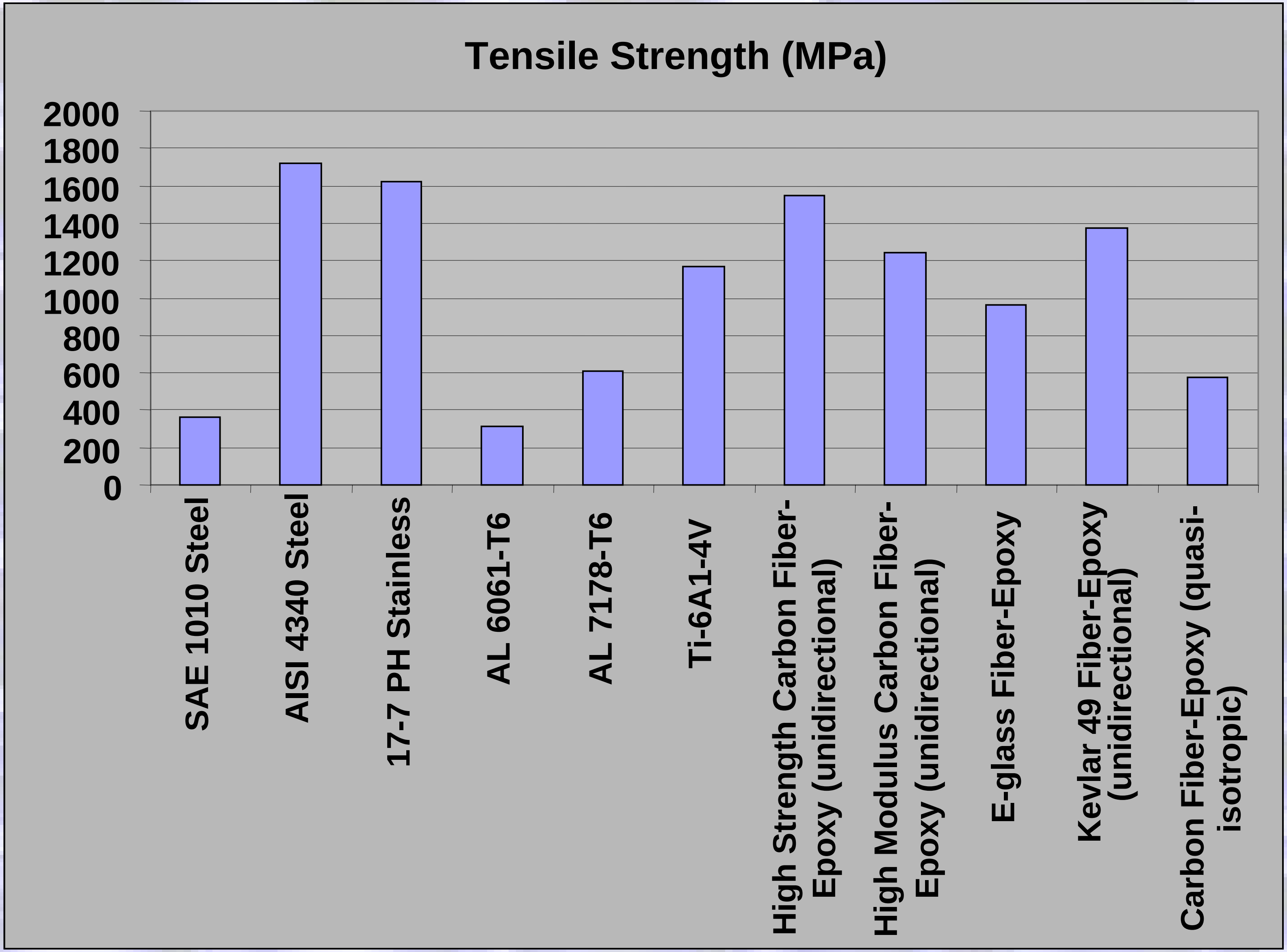
Specific Gravity For Several Materials



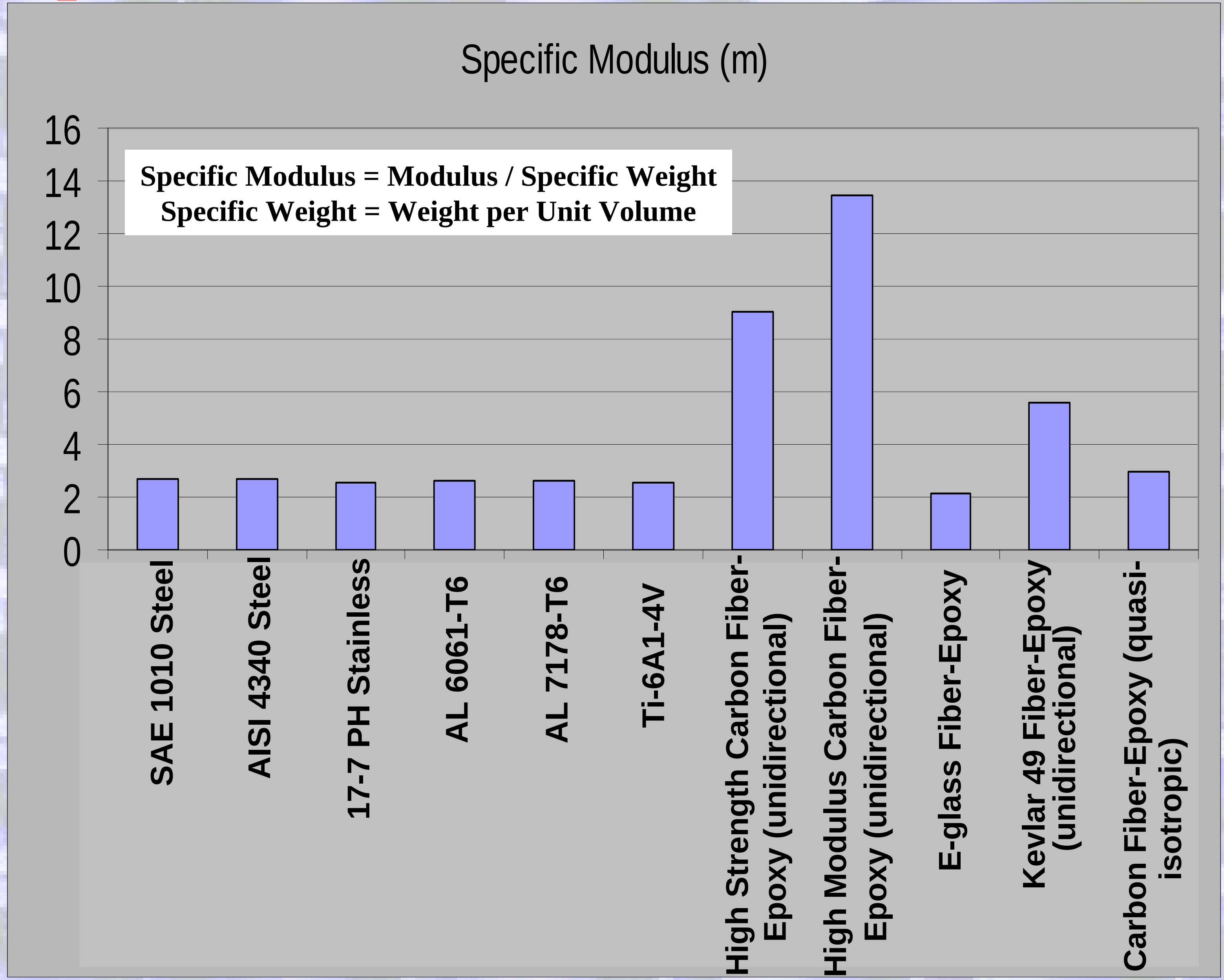
Tensile Modulus for Several Materials



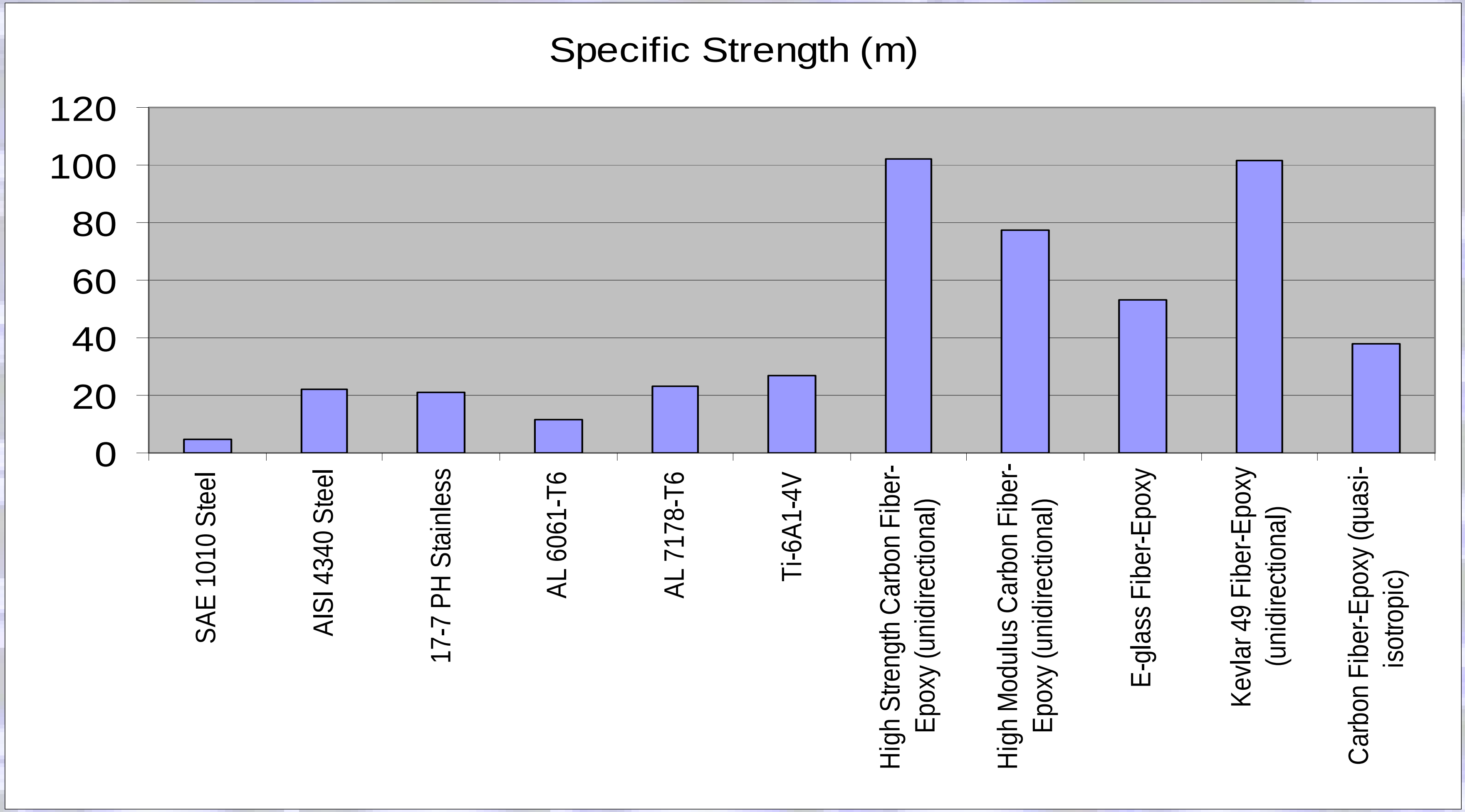
Tensile Strength for Several Materials



Specific Modulus for Several Materials



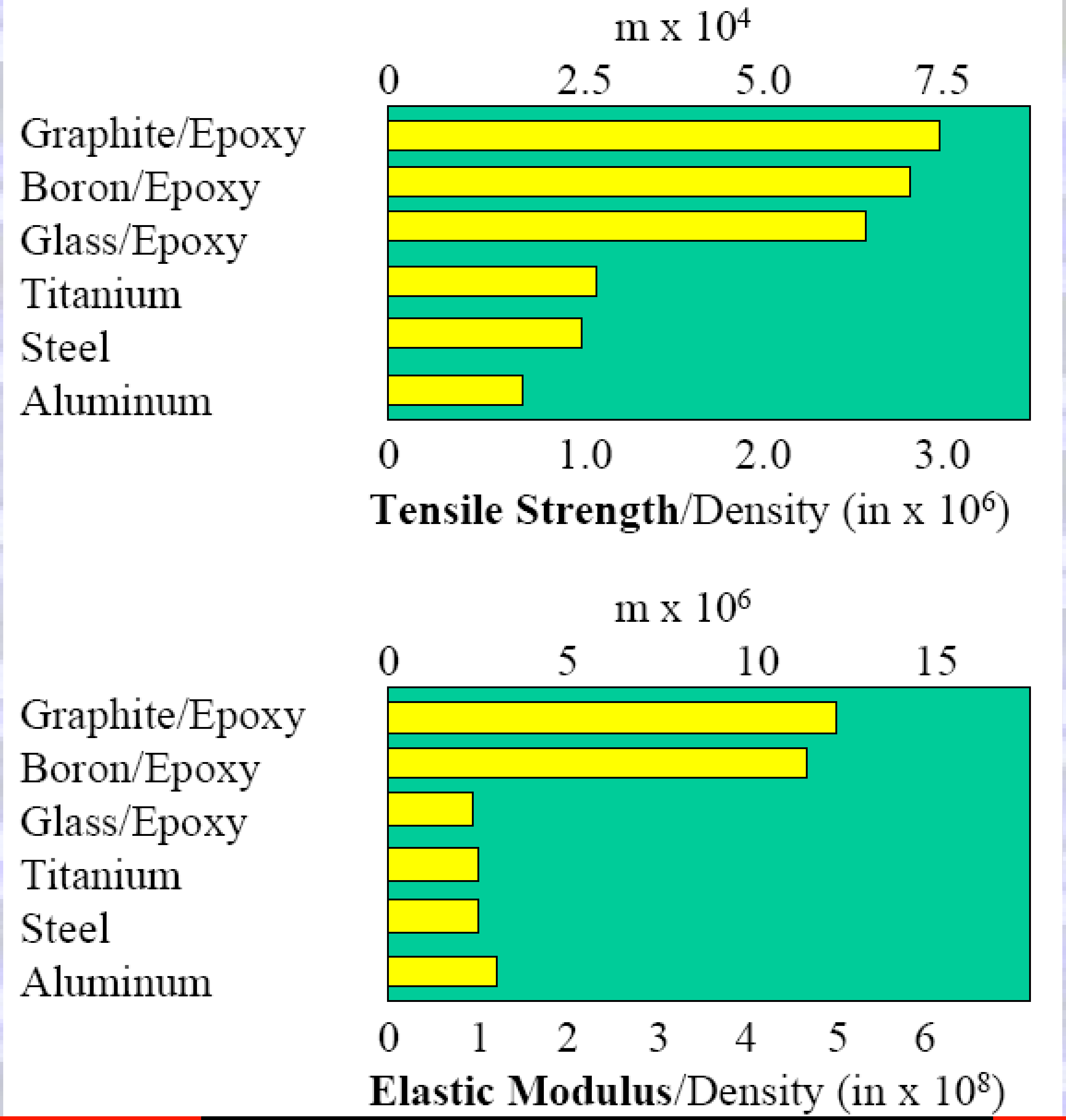
Specific Strength for Several Materials



Specific Strength = Strength / Specific Weight

Specific Weight = Weight per Unit Volume

Specific Strength & Specific Modulus

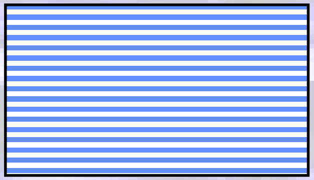


Materials Found in Polymer Composites

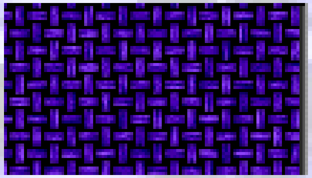
Materials Found in Composites

- Reinforcing Fibers (or particles)
- Matrix (holds fibers together)
- Others may include
  - Coatings
    - Improve bonding and load transfer at the fiber-matrix interface
  - Fillers
    - Added to polymers to reduce cost and improve dimensional stability

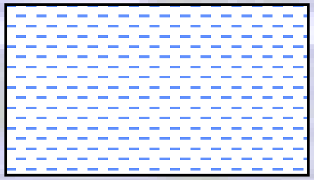
Basic Building Blocks of Fiber-Reinforced Composites



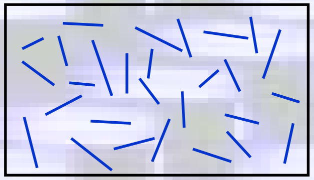
Unidirectional Continuous



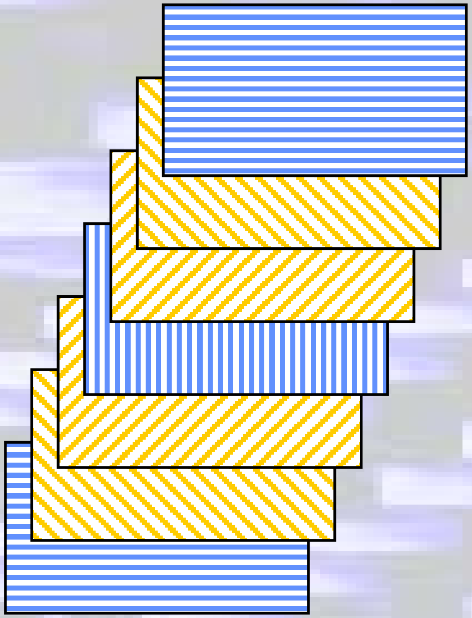
Bi-directional Continuous (e.g. woven fabrics)



Unidirectional Discontinuous



Random Discontinuous



Lamina with different fiber orientations (or different materials) are stacked to make laminates.

Materials are formed into layers called lamina (ply, layer).

Lamina can be 0.004 - 0.04 inches thick.

Relative Amounts of Material?

- Examine a small piece of composite material about the size of your little finger.
  - It is primarily made up of fibers, resin, & an interface between the two.
  - It has a volume of about 0.5 in^3
  - Assume a fiber volume fraction of 60%
  - Each fiber diameter is about 7 μm
- This composite contains approximately:
  - 100 miles of fiber (L.V. to Death Valley)
  - 0.2 in^3 of resin (thimble)
  - 32 ft^2 of interface (area of a large dining room table)

Influence of Constituents on Properties of Unidirectional Composites

Composite Property	Fibers	Matrix	Interface
Tensile Properties			
Longitudinal Modulus	S	W	N
Longitudinal Strength	S	W	N
Transverse Modulus	W	S	N
Transverse Strength	W	S	S
Compressive Properties			
Longitudinal Modulus	S	W	N
Longitudinal Strength	S	S	N
Transverse Modulus	W	S	N
Transverse Strength	W	S	N
Shear Properties			
In-Plane Shear Modulus	W	S	N
In-Plane Shear Strength	W	S	S
Interlaminar Shear Strength	N	S	S

Key: S = Strong Influence, W = Weak Influence, N = No Influence