Aerospace Structural Mechanics

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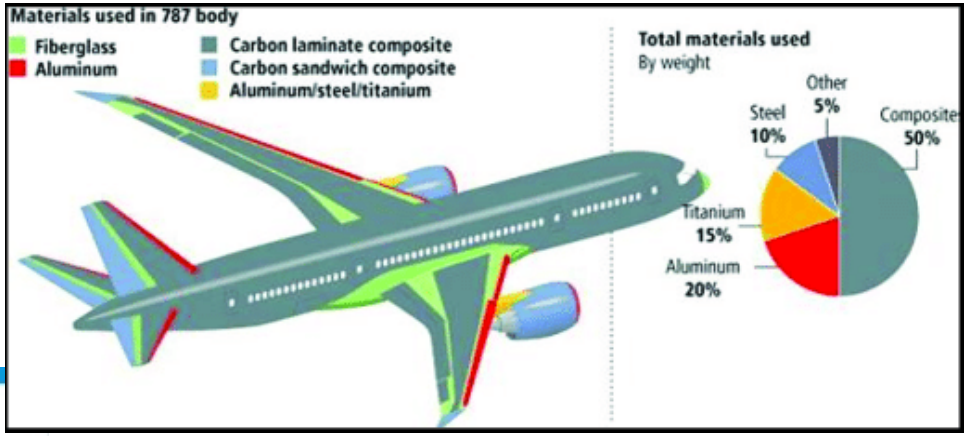
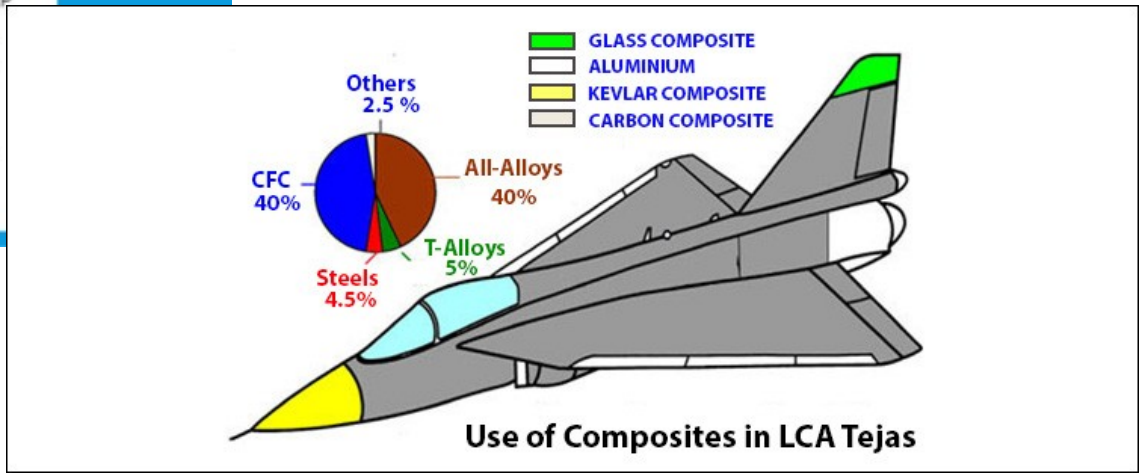
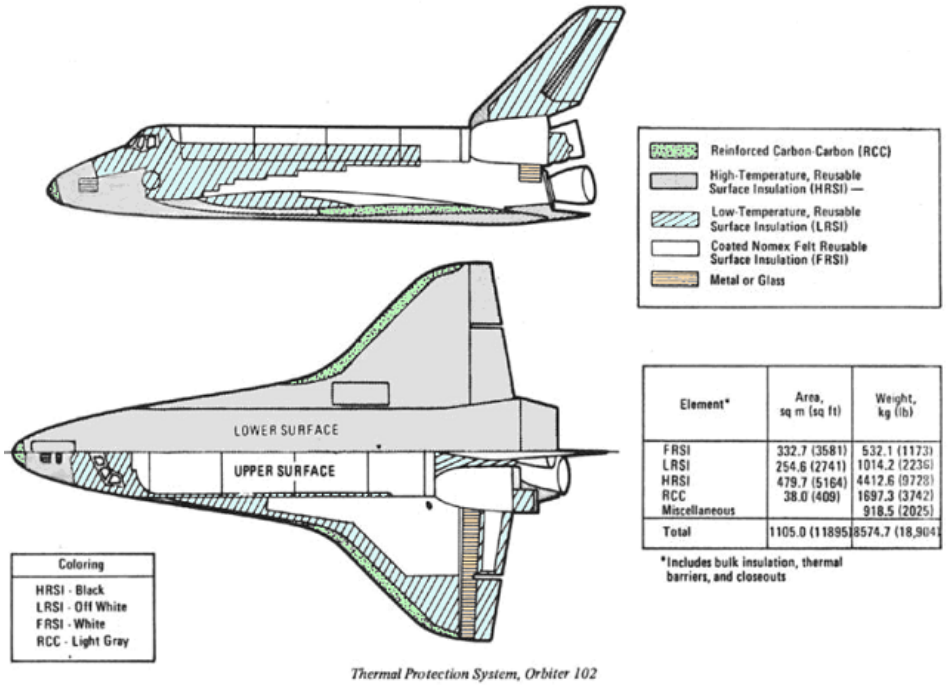
Materials in Aerospace Structures

- Metals/Metallic alloys: Al alloys, Ti, Ni-supperalloys etc.
- Ceramics: aluminum oxide, silicone nitrade etc.
- Polymers: thermoplastics and thermsetting plastics
- Composites: metal matrix and fiber reinforced





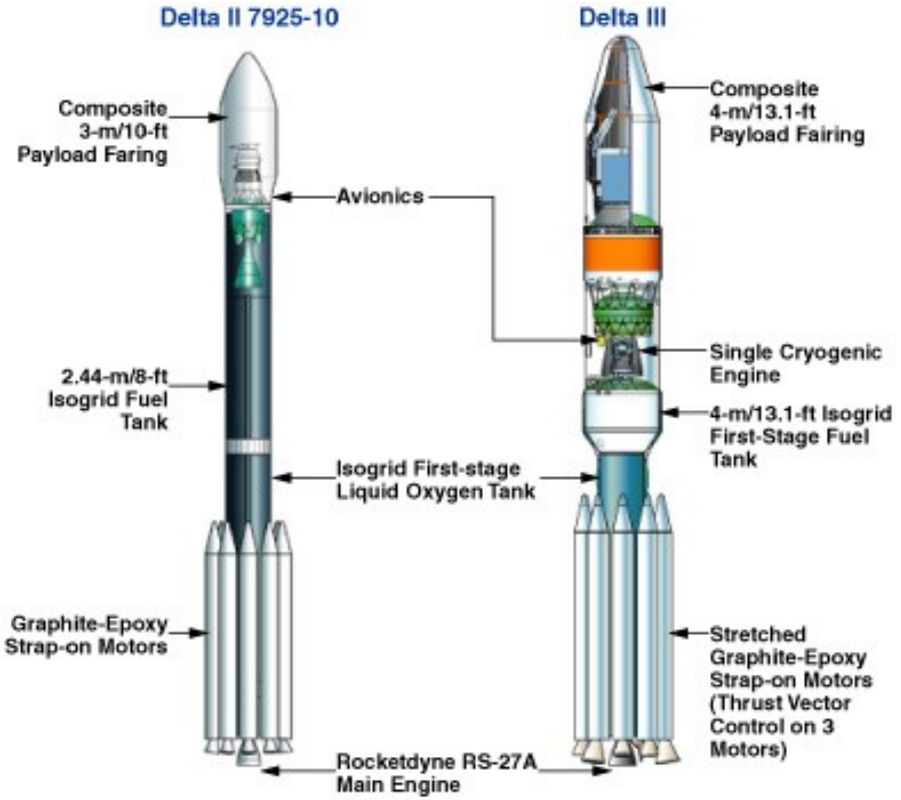
Materials in Aerospace Structures

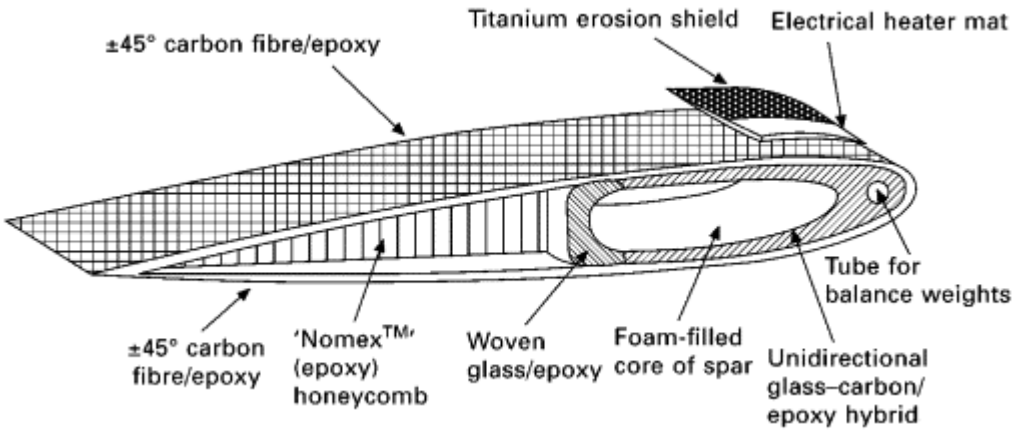


Element*	Area, sq m (sq ft)	Weight, kg (lb)
FRSI	332.7 (3581)	532.1 (1173)
LRSI	254.6 (2741)	1014.2 (2236)
HRSI	479.7 (5164)	4412.6 (9728)
RCC	38.0 (409)	1697.3 (3742)
Miscellaneous		918.5 (2025)
Total	1105.0 (11895)	8574.7 (18,904)

*Includes bulk insulation, thermal barriers, and closeouts

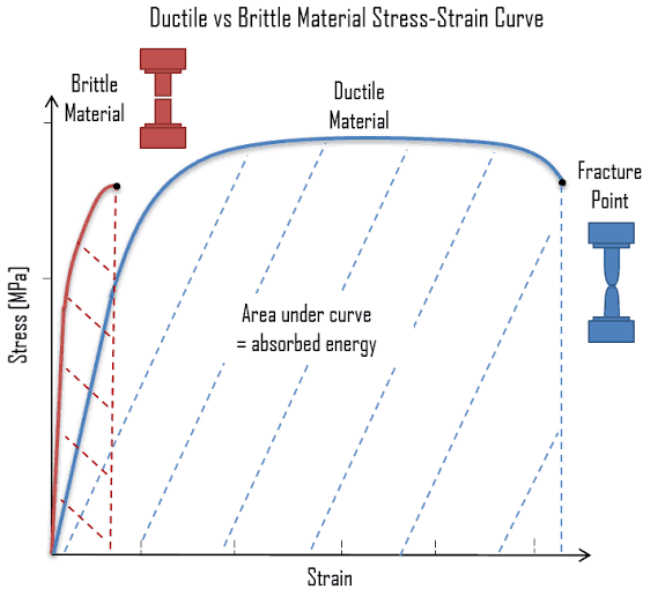
Thermal Protection System, Orbiter 102

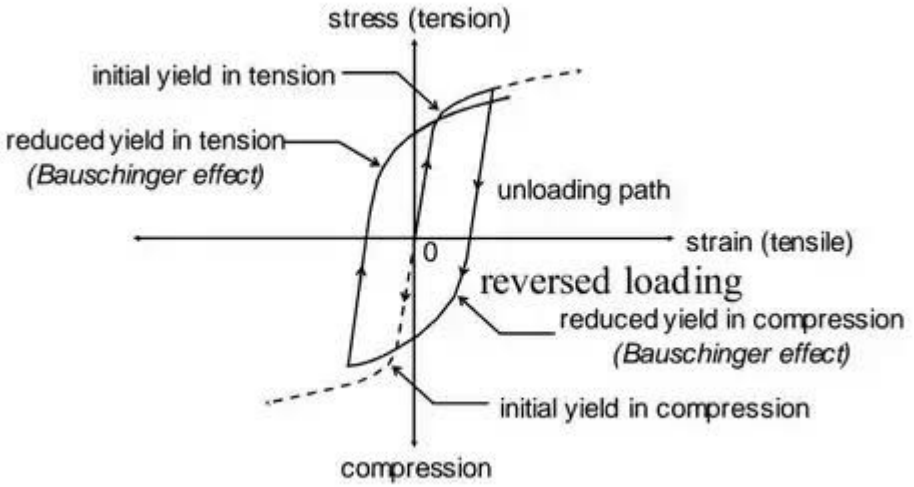




Types of materials

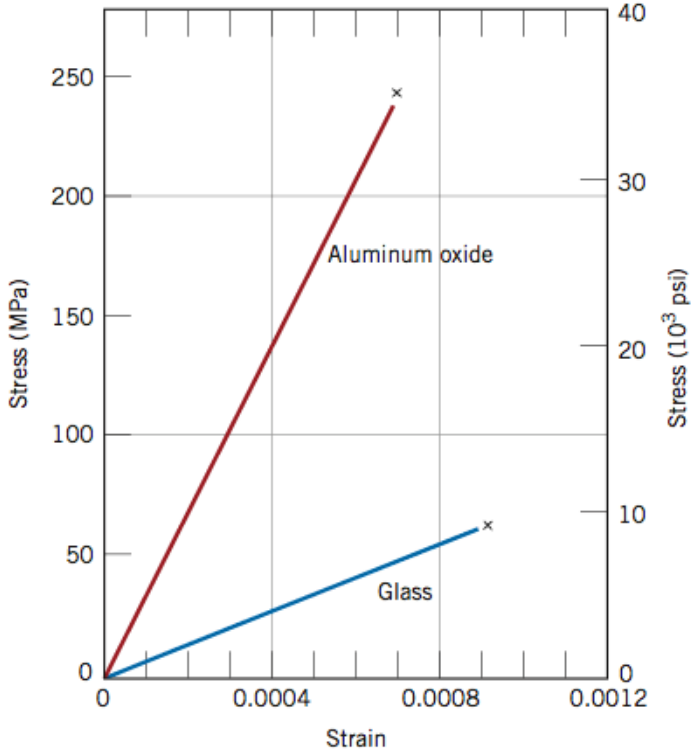
- Metallic materials: '*They are normally combinations of metallic elements. They have large numbers of nonlocalized electrons; that is, these electrons are not bound to particular atoms. Many properties of metals are attributable to these electrons. They are quite strong and malleable. Additionally, they are good conductors of of electricity and heat. They are not transparent to visible light. They have lustrous appearance after polish.*'





Types of materials

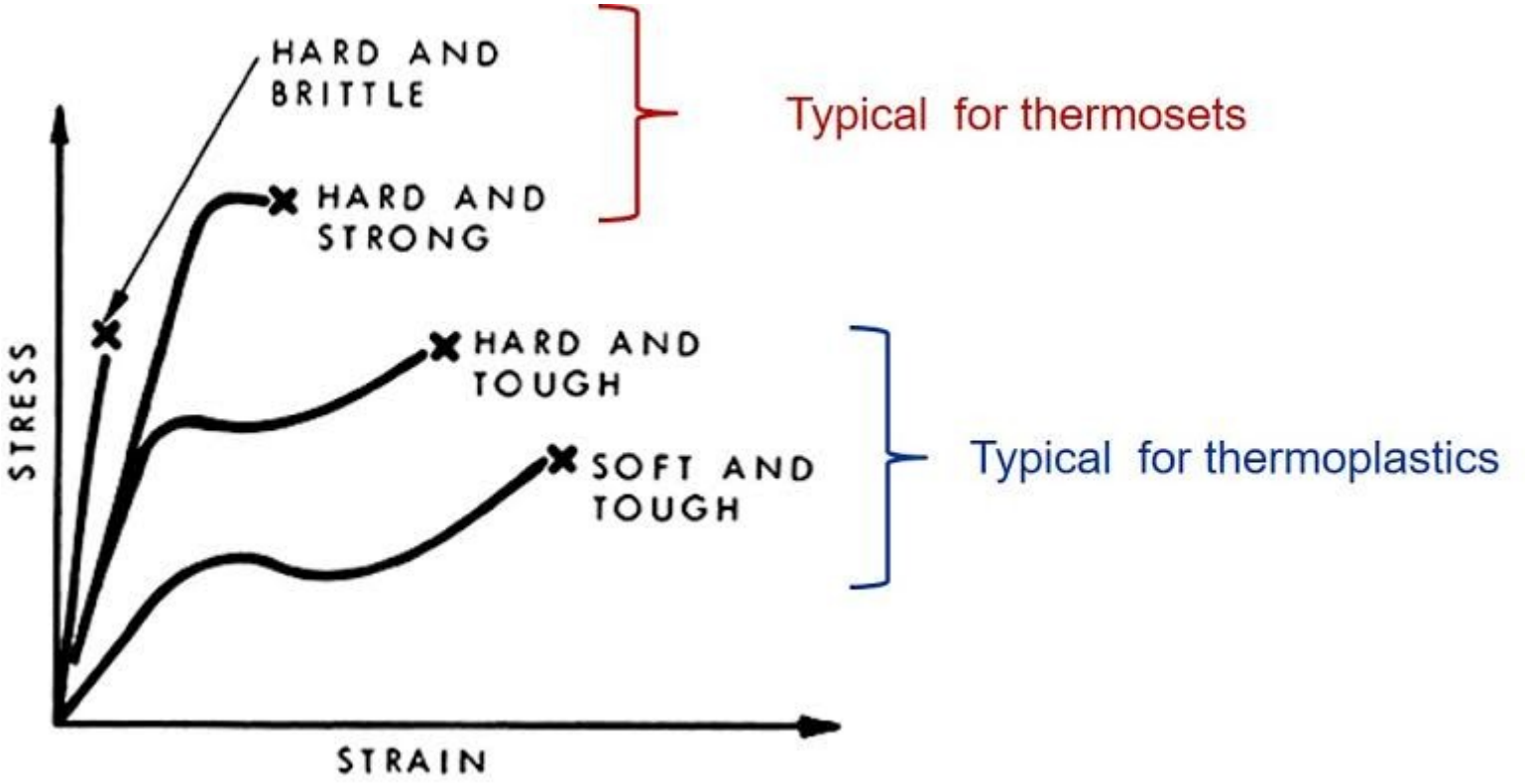
- Ceramics: *They are compounds between metallic and nonmetallic elementsl they are most frequently oxides, nitrides, and carbides. They are typically insulative to the passage of electricity and heat, and are most resistant to high temperatures and harsh environments than metals and polymers. They are hard but very brittle.*



Applications:
a. Components and engine exhaust
b. Space Vehicle insulating tiles
c. Aircraft windshields (glass)
d. Nose cones and high-temperature coatings (in ultra high speed flying objects) etc.

Types of Materials

- Polymers: *They inlcude familiar plastic and rubber materials. Many of them are organic compounds that are chemically based on carbon, hydrogen, and other nonmetallic elements; furthermore, they have very large molecular structures. They have low densities and may be extremely flexible.*



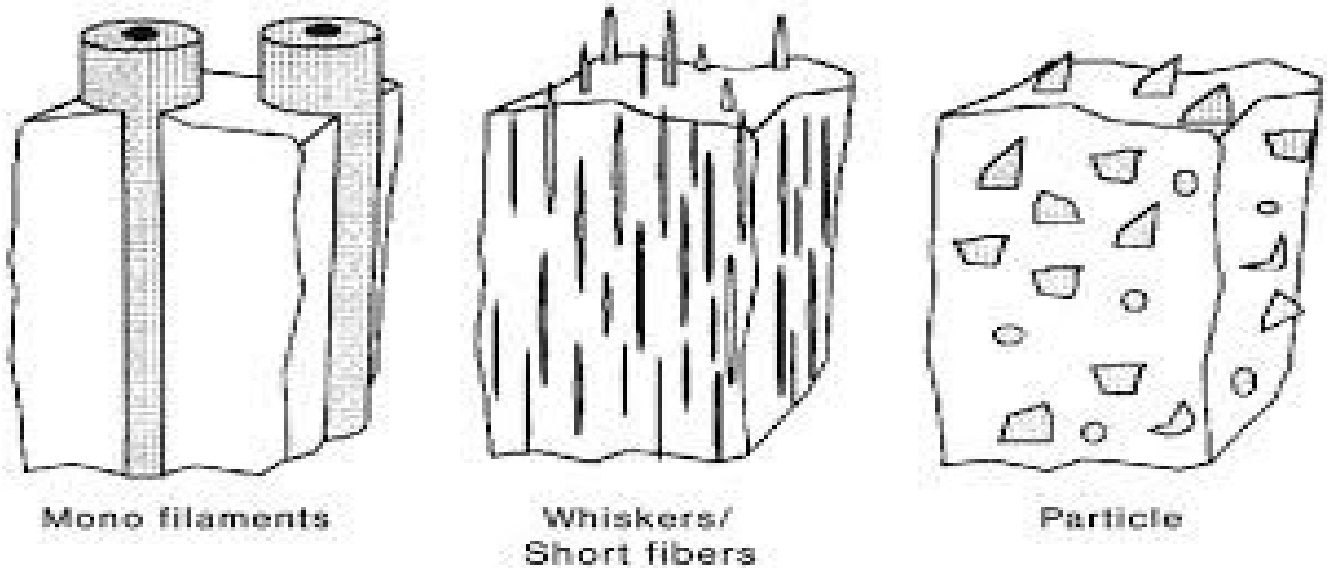
Composite Materials

Definition: Consist of two or more separate materials combined in a structural unit

Main Ingredients: matrix material and fillers

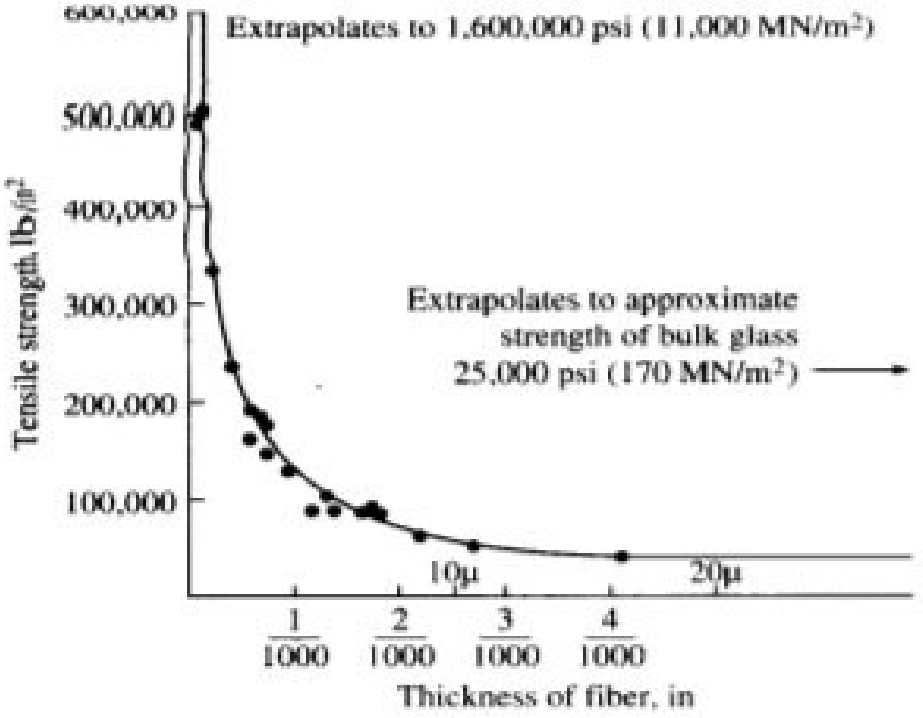
Matrix materials: metals and polymers

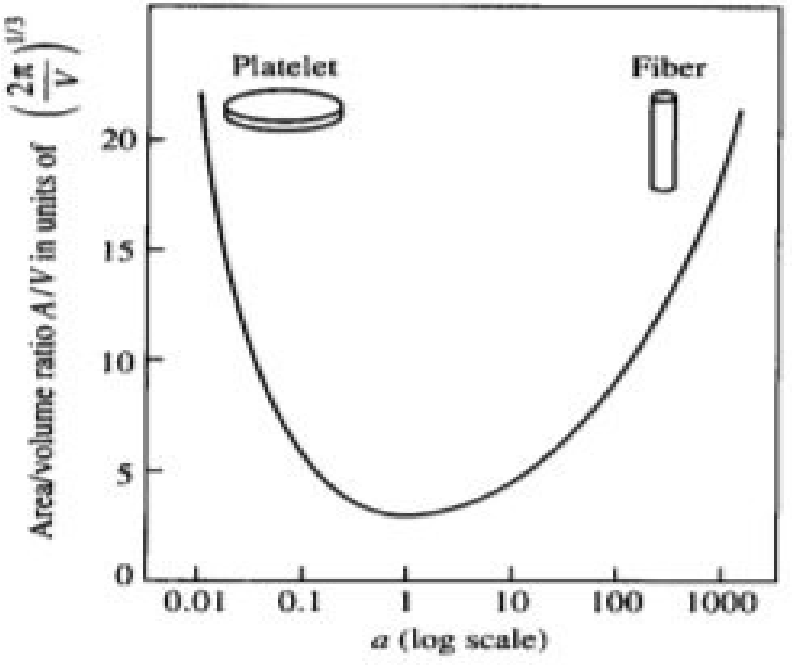
Fillers: fibers (macro/nano), particles, flakes etc.



Why fiber configuration is a popular filler?

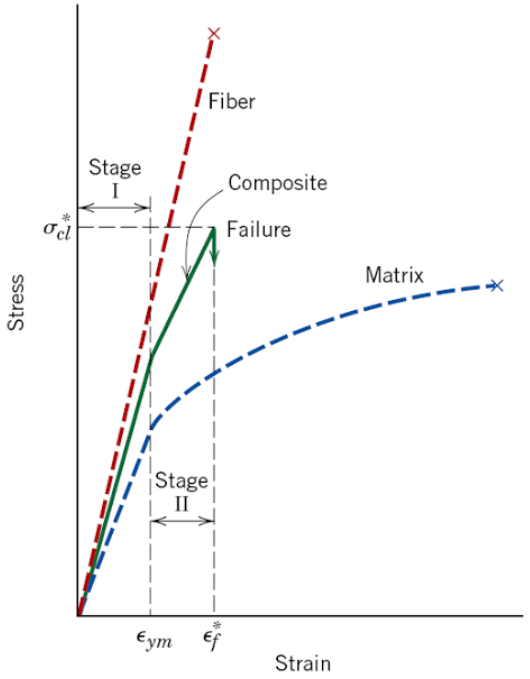
- Materials are stronger and stiffer in fiber form
- Geometrical configuration is efficient from the point of view of interaction with the binder or matrix
- Disadvantages of fibers: cannot support compression and weak transverse mechanical properties





Why matrix?

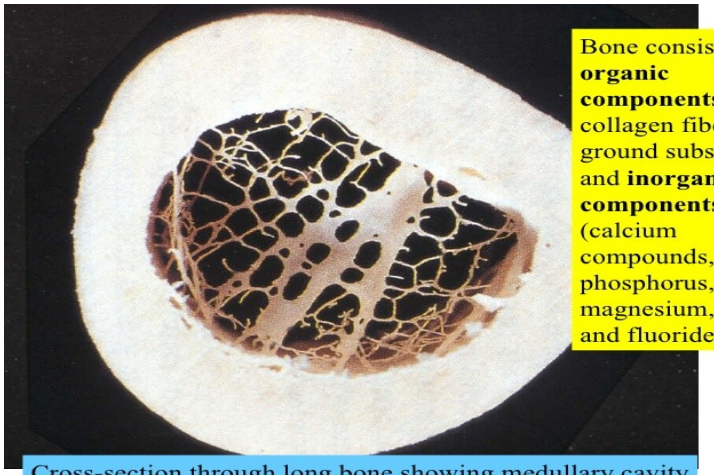
- Necessary to hold or bind the fibers together as a structural unit
- Protects the fibers from extermal damage and environmental attack
- Transfers and distributes the load
- Contributes to ductility , toughness and electrical insulation
- Ex: polymers, metals and ceramics



Typical stress-strain response of fiber, polymer matrix and composite

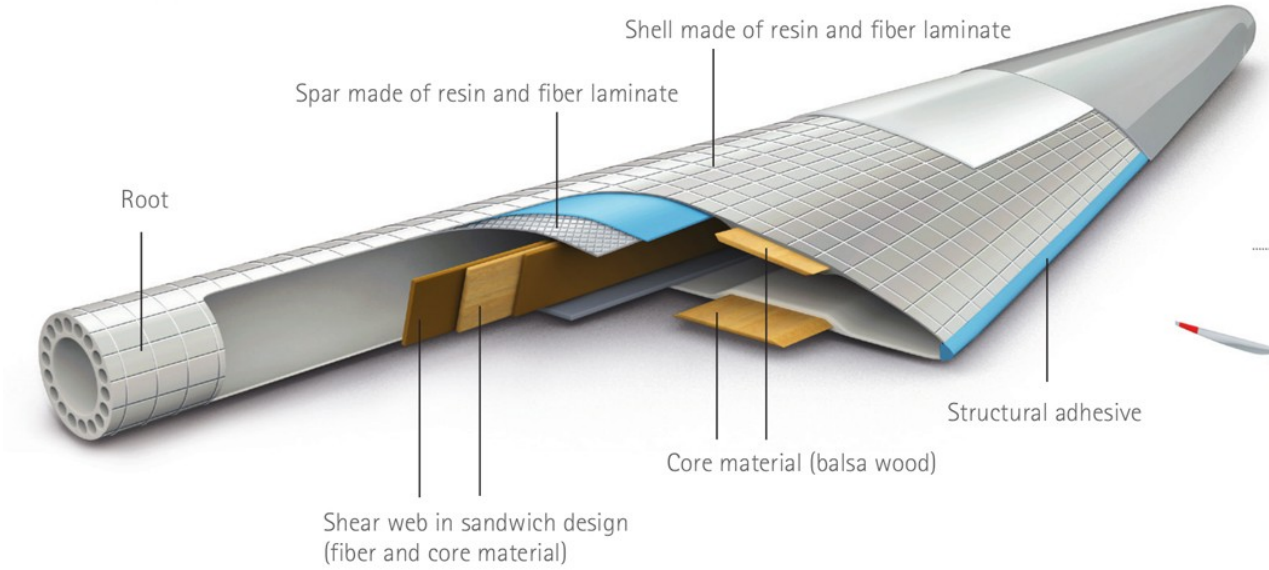
Natural and man-made composites

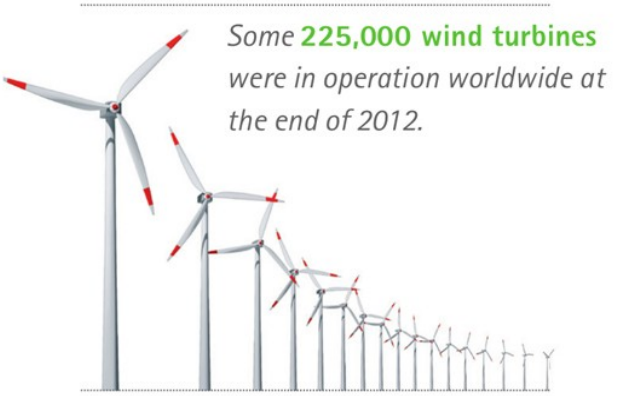
- Natural: Bone, ivory, balsa etc.
- Man-made: CFRP, GFRP etc.



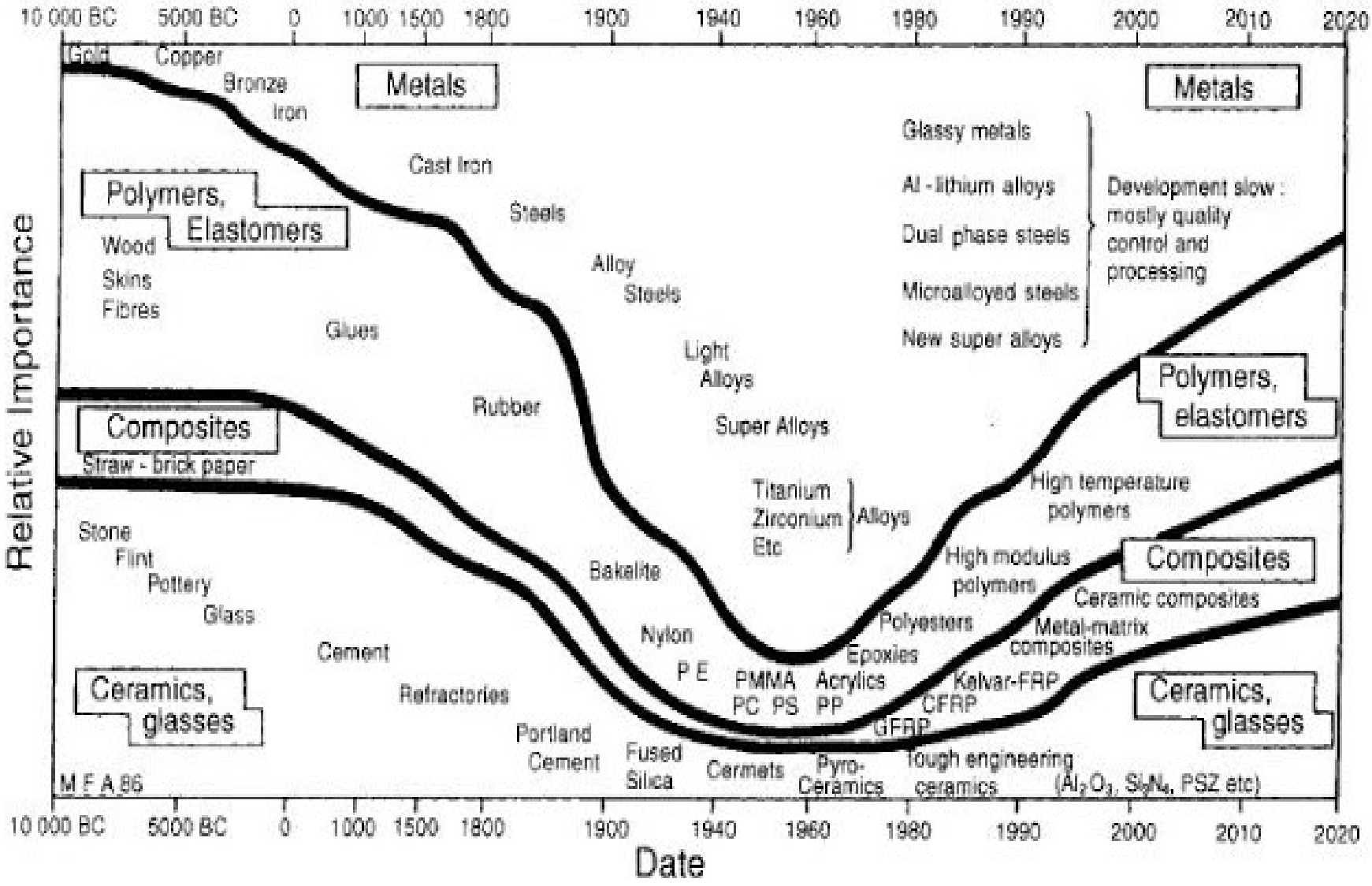
Bone consists of **organic components** (cells, collagen fibers, and ground substance) and **inorganic components** (calcium compounds, phosphorus, sodium, magnesium, sulfate, and fluoride).

Cross-section through long bone showing medullary cavity





Relative Importance of Materials

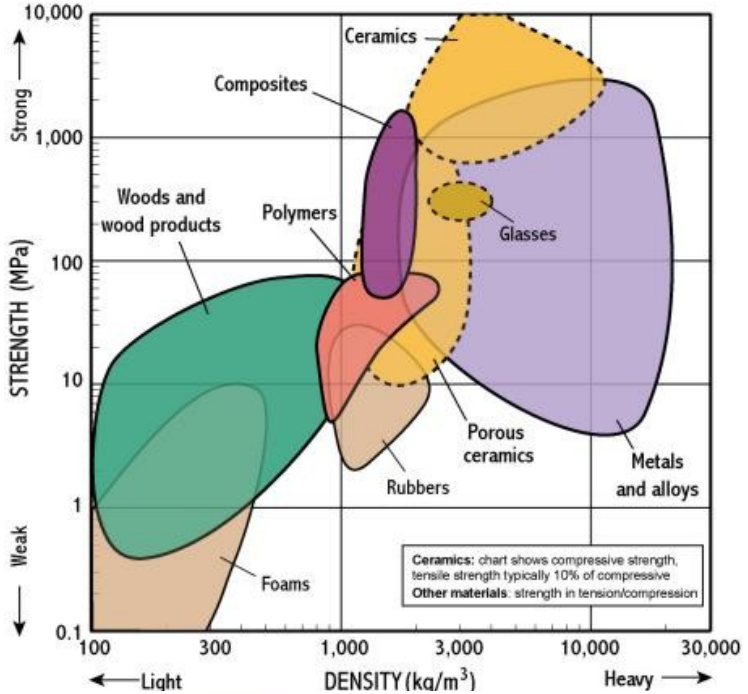


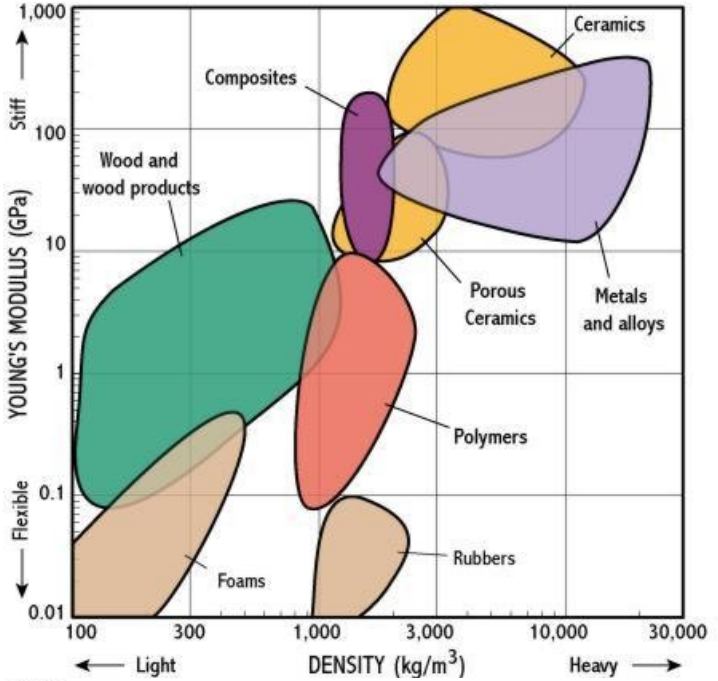
Typical properties of composites as compared to metallic materials

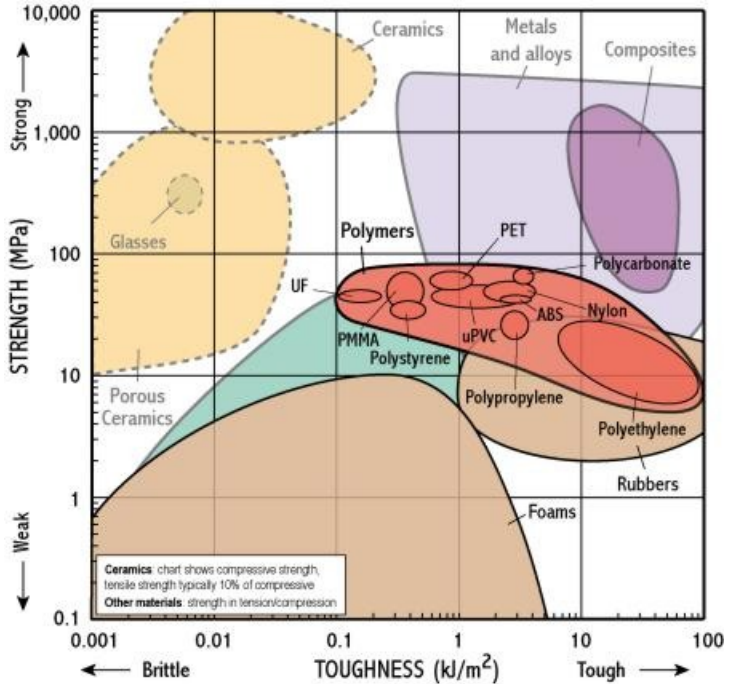
Material	Specific Gravity, S	Tensile Modulus, E (GPa)	Tensile Strength, Xt (MPa)	Compressive Strength, Xc (MPa)	Specific tensile modulus, E/S	Specific tensile strength, Xt/S	Specific compressive strength, Xc/S
Steel	7.8	206	400-2500	400-2500	26.4	50-320	50-320
Al alloy	2.8	69	55-700	55-700	24.6	20-250	20-250
Ti alloy	4.5	103	360-1400	360-1400	22.9	80-310	80-310
GFRP	2.0	40	1650	1400	20.0	825	700
CFRP	1.6	140	1450	1050	87.5	906.3	656.3

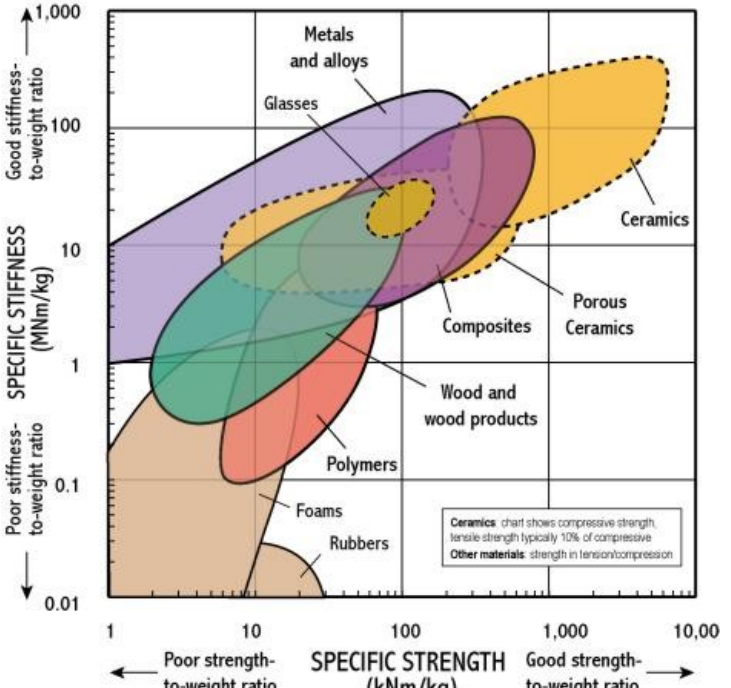
CFRP: Carbon fiber reinforced plastic GFRP: Glass fiber reinforced composite

Typical Material Property Charts





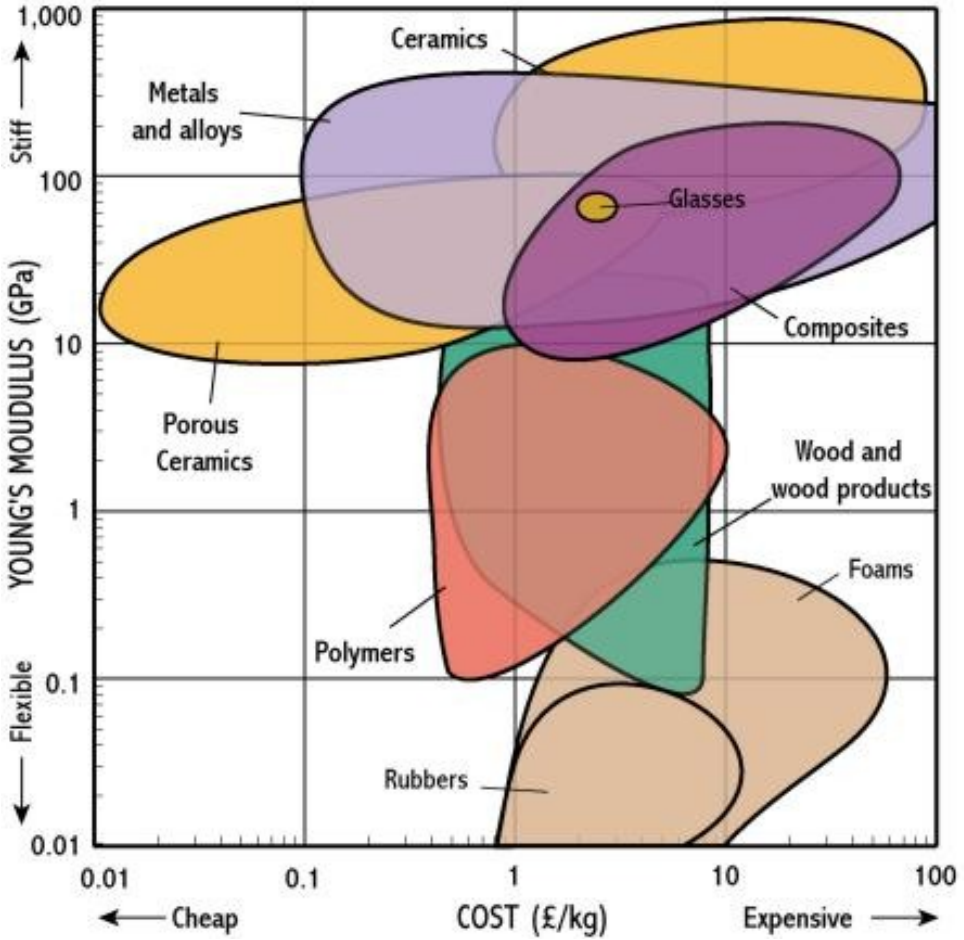


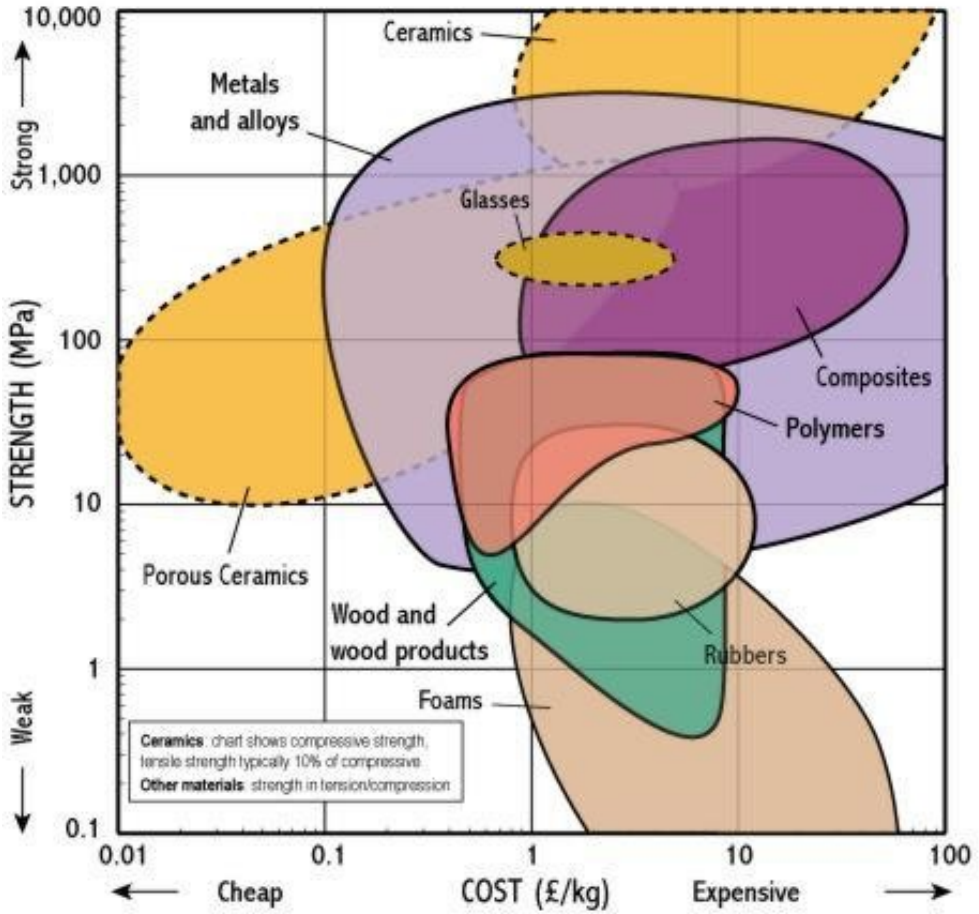


Desirable properties of aerospace materials

- Hight strength to weight ratio
- High stiffness to weight ratio
- Fracture toughness
- Fatigue resistance
- Creep resistance
- Resistance to corrosion
- Ductility
- Ease of fabrication
- Cost

Better properties...but at what cost?



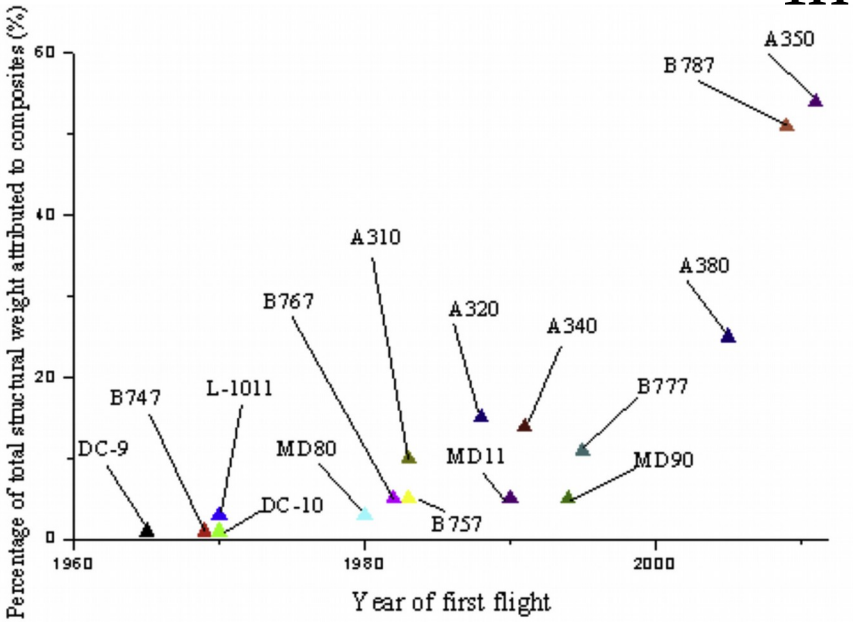


Performance of various materials for specific structural applications

- Strength Design: ultimate strength/density
- Stiffness Design: sqrt (E/density)
- Buckling Design: E/(density)^3

How does the composite materials compare with other materials on all three design index?

How does composite materials effect aerospace industry?



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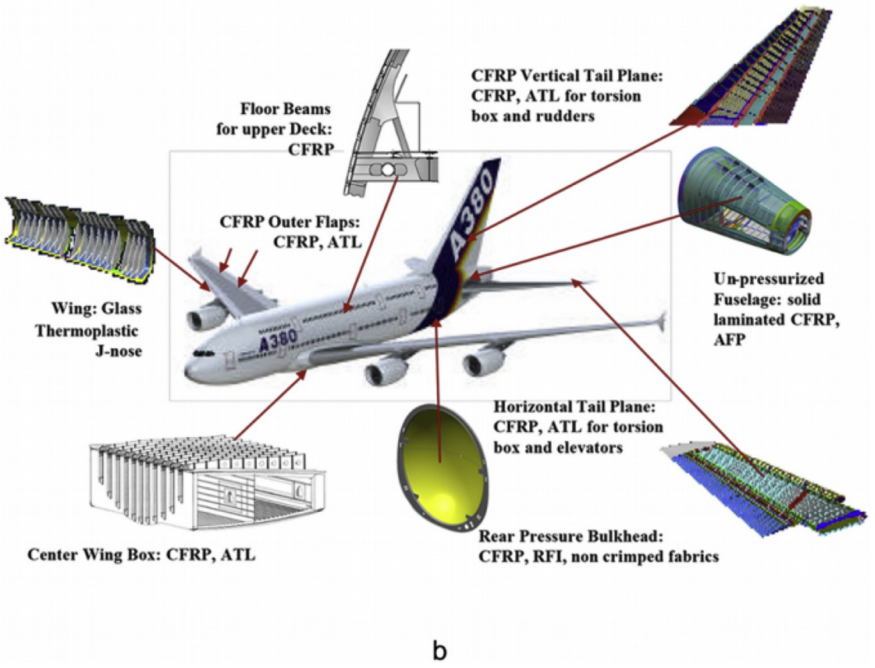

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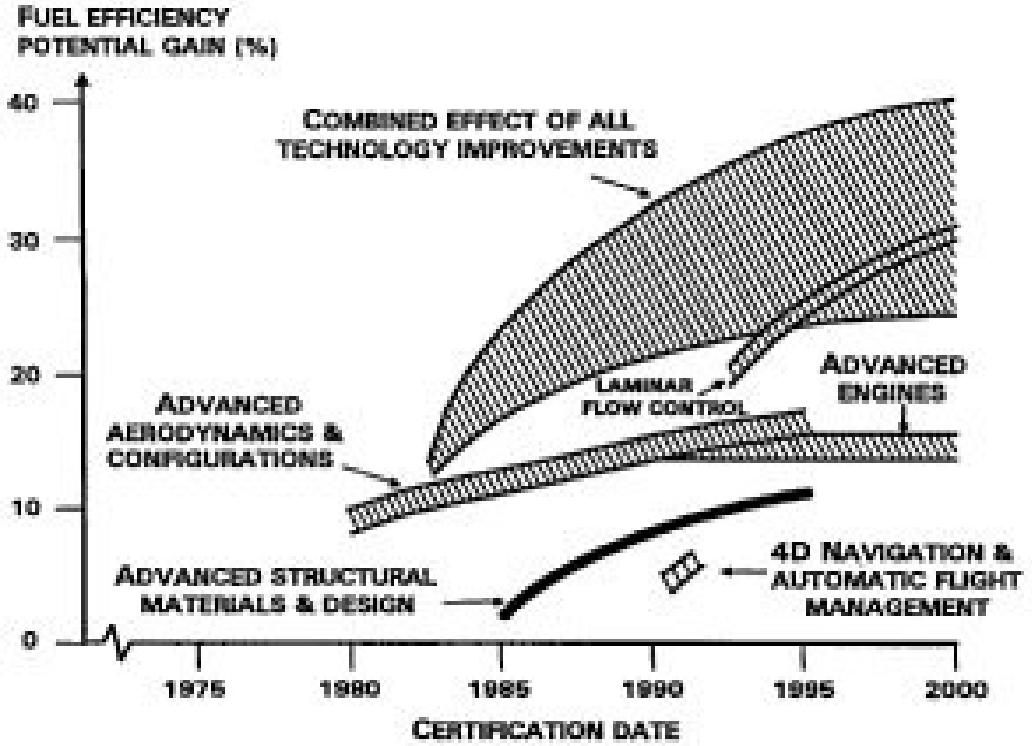

Example illustrating weight saving

- A cantilever beam of rectangular cross-section and made of Al alloy is to be replaced by a CFRP beam having the same length 'L' and width 'b', and it must have the same tip deflection 'w' under the same tip load 'P'. Compare the thicknesses and weights of the two beams.

Activities at leisure

- Find out the materials used in Boeing 787 aka 'Dreamliner'.
- Use of composite materials in space structures (launch vehicle, satellites etc.)
- Applications of composite materials in fields other than Aerospace Engineering.