

# **MSE200**

## **Lecture 21 (CH. 12.4,12.5, 12.6,12.10)**

### **Composite Materials**

**Instructor: Yuntian Zhu**

**Objectives/outcomes: You will learn the following**

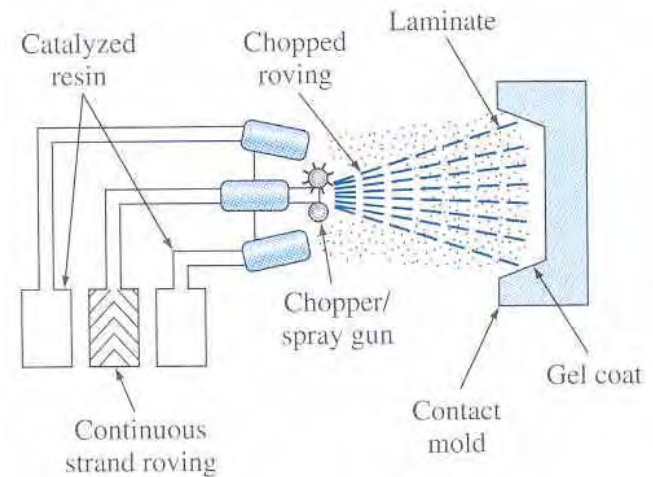
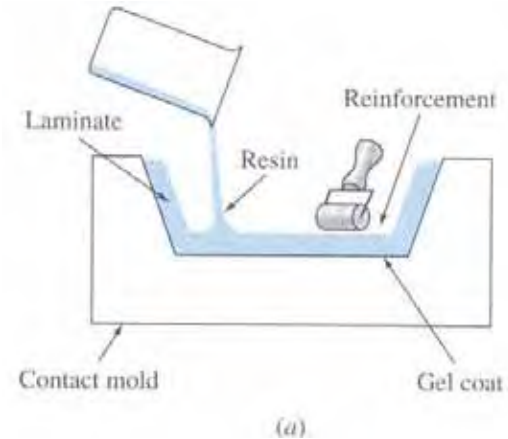
- Processing of polymer fiber composites**
- Metal matrix composite**
- Concrete**
- Ceramic fiber composite**

## Principle of composites

- Polymer and Metal matrix composites:
  - Improve the strength and stiffness
  - Requirements:  $E_f > E_m$ ,  $\sigma_f > \sigma_m$
- Ceramic matrix composites:
  - Improve the toughness
  - Requirements: more complex

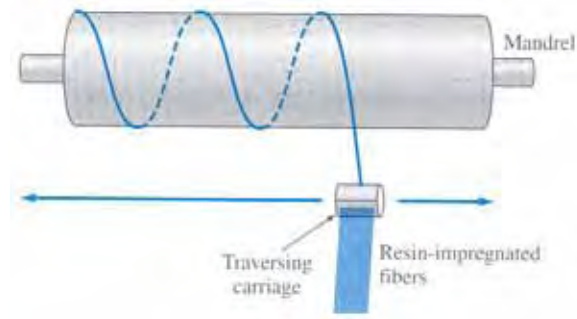
# Open Mold Process for Fiber Reinforced Plastics

- **Hand lay-up process:**
  - Gel coat is applied to open mold.
  - Fiberglass reinforcement is placed in the mold.
  - **Base resin** mixed with catalysts is applied by pouring **brushing or spraying**.
- **Spray-up process:** Continuous strand roving is fed by chopper and spray gun and chopped roving and **catalyst resin** is deposited in the mold.



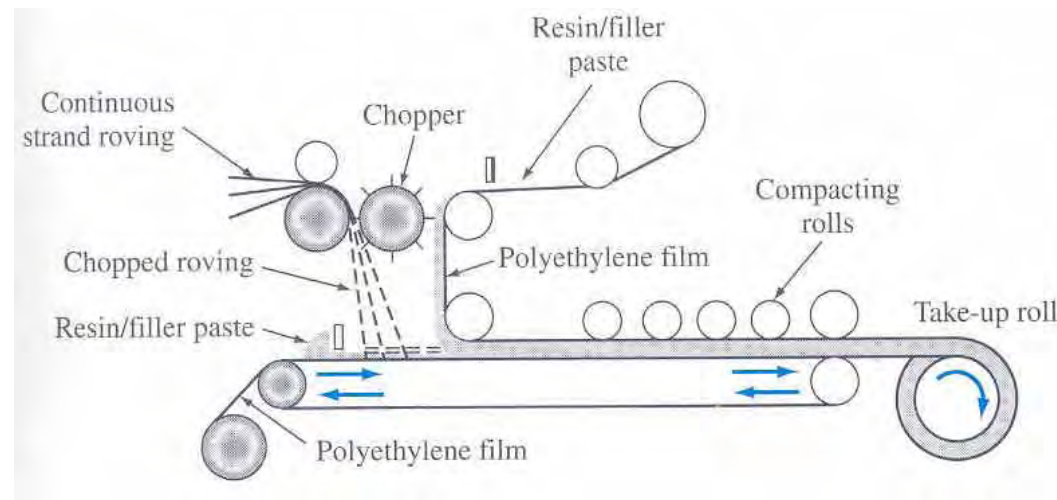
# Vacuum Bag-Autoclave and Filament Winding

- **Vacuum bag-autoclave process:**
  - Long thin sheet or prepeg carbon-fiber epoxy material is laid on the table.
  - The sheet is cut and **laminates** are constructed.
  - Laminates are put in **vacuum bag** to remove entrapped air and **cured in autoclave**.
- **Filament winding:**
  - Fiber reinforcement is fed through resin bath and **wound** around suitable **mandrel**.
  - Mandrel is cured and mold part is **stripped** from mandrel.



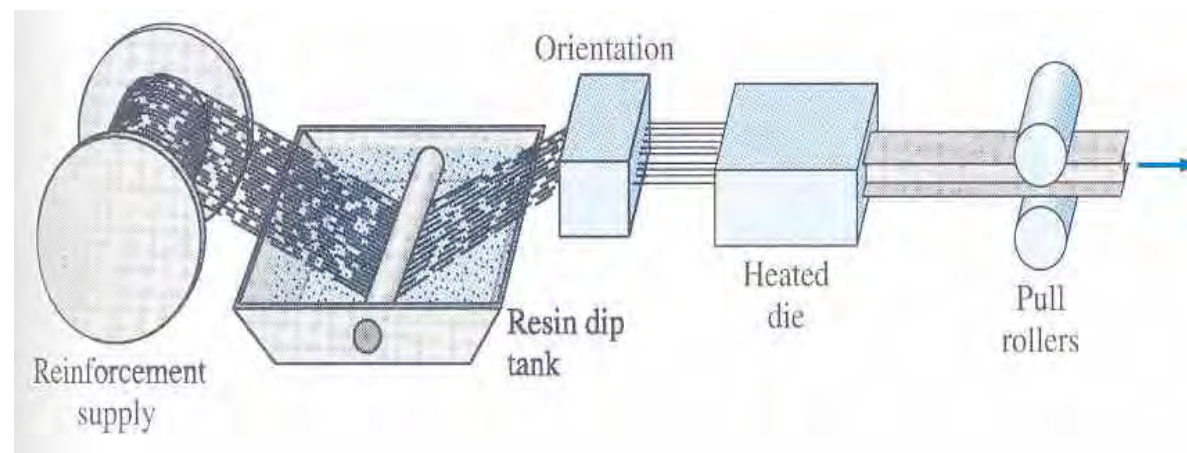
# Closed Mold Process

- **Sheet molding compound process:**
  - Continuous strand fiberglass roving is chopped and deposited on a layer of **resin-filler paste**.
  - Another layer of paste is deposited on first layer.
  - Sandwich is **compacted and rolled** into rolls
- The rolled up sheet is stored in a **maturation** room for 1-4 days.
- The sheets are cut into proper size and **pressed** in hot mold (149<sup>0</sup>C) to form final product.



# Continuous protrusion

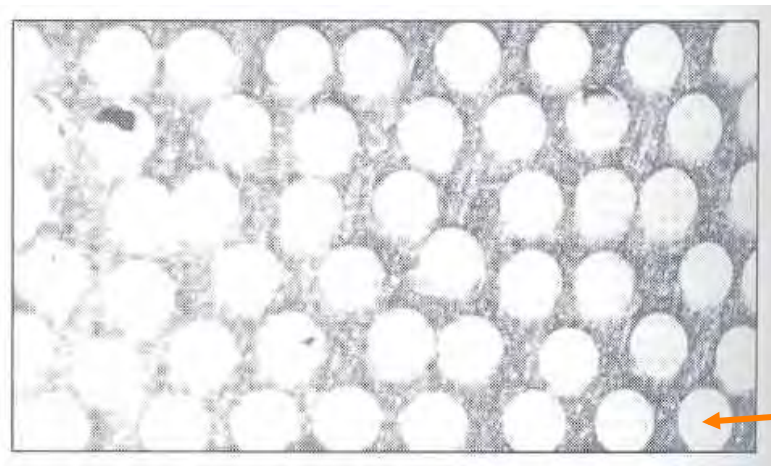
- **Continuous strand fibers are impregnated in resin bath, fed into **heated die** and **drawn**.**
- **Used to produce beams, channels, and pipes.**



<http://video.google.com/videosearch?q=composite+material&hl=en&site=search=>

## Metal Matrix Composites (MMCs)

- **Continuous fiber reinforced MMCs:** Continuous fibers are reinforced in metal matrix – used in **aerospace**, auto industry and sports equipments.
- **Example:-** Aluminum alloy – Boron fiber composite



**Boron fiber**

# Concrete

- **Low tensile strength**, less ductile
- **High compressive strength**
- Concrete is a **ceramic composite** composed of **coarse granular** material embedded in hard matrix of **cement paste**.
- Concrete = 7-15% **Portland cement**, 14-21% water, 1/2 - 8% air, 24-30% fine aggregate and 31-51% coarse aggregate.

# Types of Portland Cement

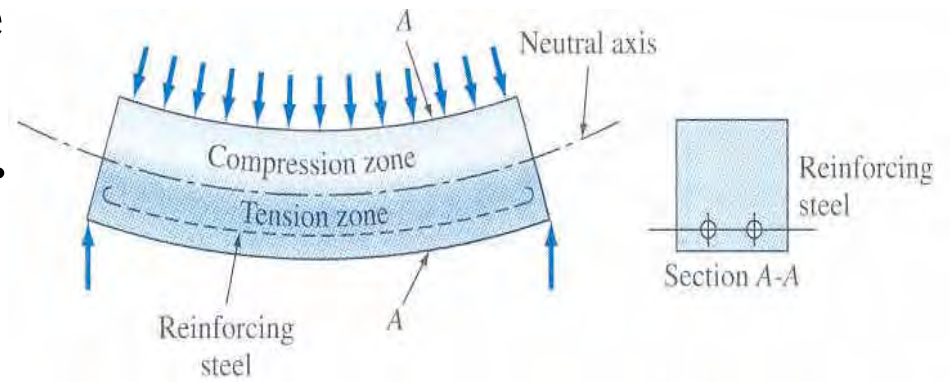
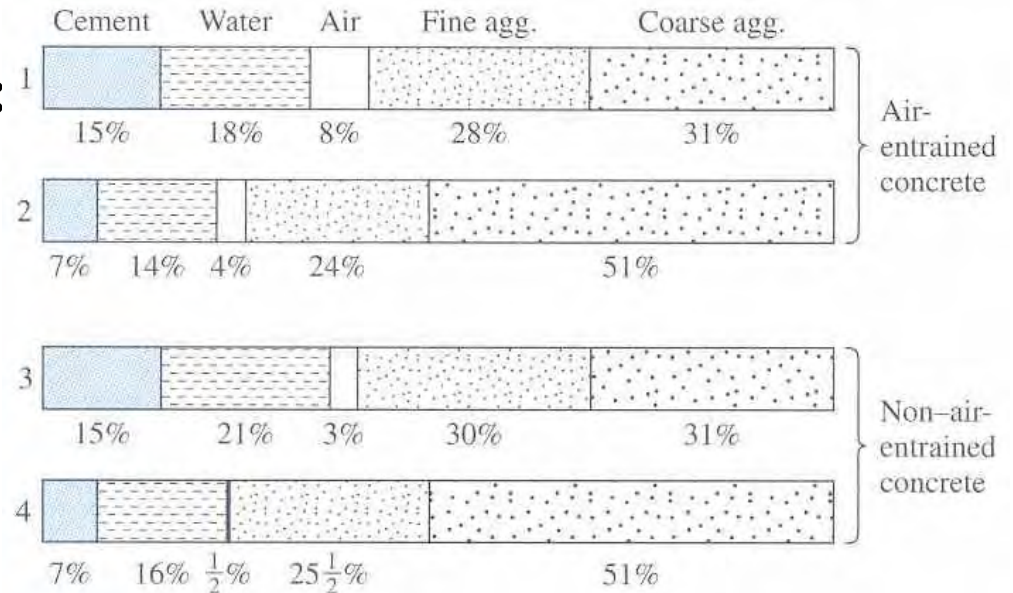
- Types of Portland cement differ by **composition**.
- **Type I**: Used when high sulfate attack from soil and water, and high temperature are absent.
  - **Examples**: Sidewalks, buildings, bridges.
- **Type II**: Used in case of moderate sulfate attack as in case of drainage.
- **Type III**: Early strength type for quick use.
- **Type IV**: Low heat of hydration type and used when rate and heat generated must be minimized.
- **Type V**: Used for heavy sulfate attack as in case of groundwater.

# Proportioning Concrete Mixture

- Facts to be considered:**

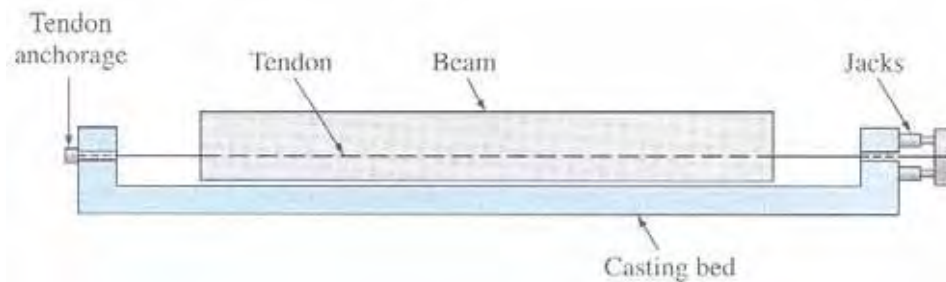
- **Workability**
- **Strength and durability**
- **Economy of production**

- Water to cement ratio determines compressive strength.**
- Steel reinforcements are used to improve tensile properties as in bending.**

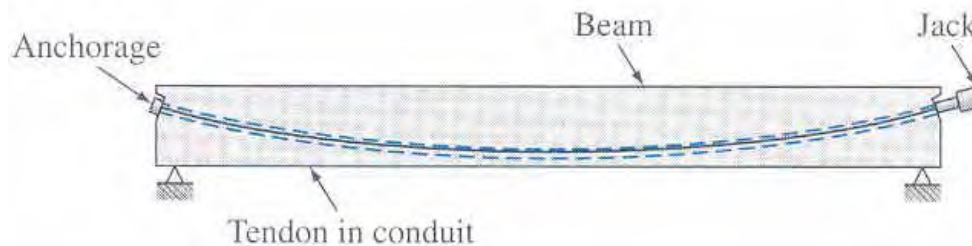


# Prestressed Concrete

- **Compressive stress are induced to improve tensile properties by introducing **tensioned reinforcements** (tendons).**
- **Pretensioned concrete:** The tendon is first stretched and concrete is poured on the tendon.



- **Posttensioned concrete:** Steel reinforcements are used to improve tensile properties as in bending.



## Ceramic-Matrix Composites (CMCs)

- **Continuous fiber reinforced CMCs:**
  - SiC fibers are woven into mat and SiC is **impregnated** into fibrous mat by *chemical vapor deposition*.
  - Used in heat exchanger tube and thermal protection system.
- **Discontinuous and particulate reinforced CMCs:**
  - **Fracture toughness** is significantly increased.
  - Fabricated by common process such as *hot isostatic pressing*.

## Toughening Mechanisms in CMCs

- Toughening is due to fibers **interfering** with crack propagation.
  - **Crack deflection:** Up on encountering reinforcement, crack is deflected making propagation more meandering.
  - **Crack bridging:** Fibers bridge the crack and help to keep the cracks together.
  - **Fiber pullout:** Friction caused by pulling out the fiber from matrix results in higher toughness.