

MECH 1905 Buildings for Contemporary Living Building Systems

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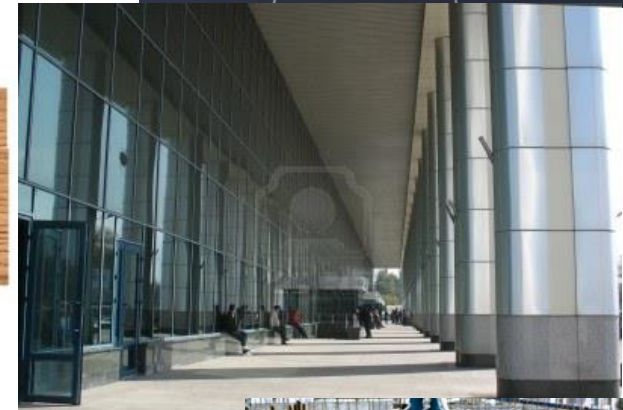
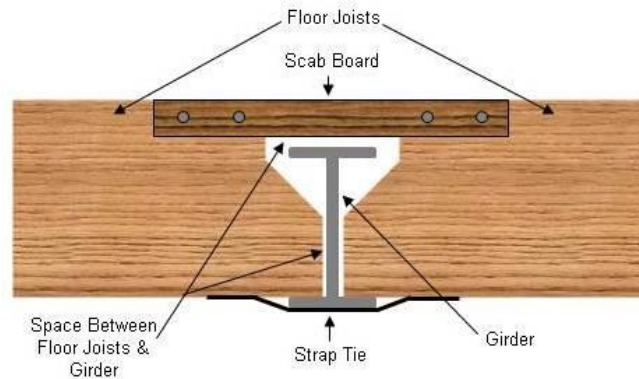
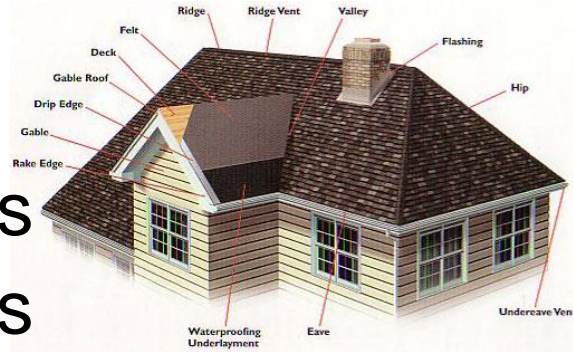
Contents

- Structural Systems
 - Foundation
 - Building Envelope
 - Ceiling and Flooring
- Water System
- Heating, Ventilation and Cooling (HVAC)
- Electricity and Lighting
- Fire Protection
- Elevators



Structural Systems

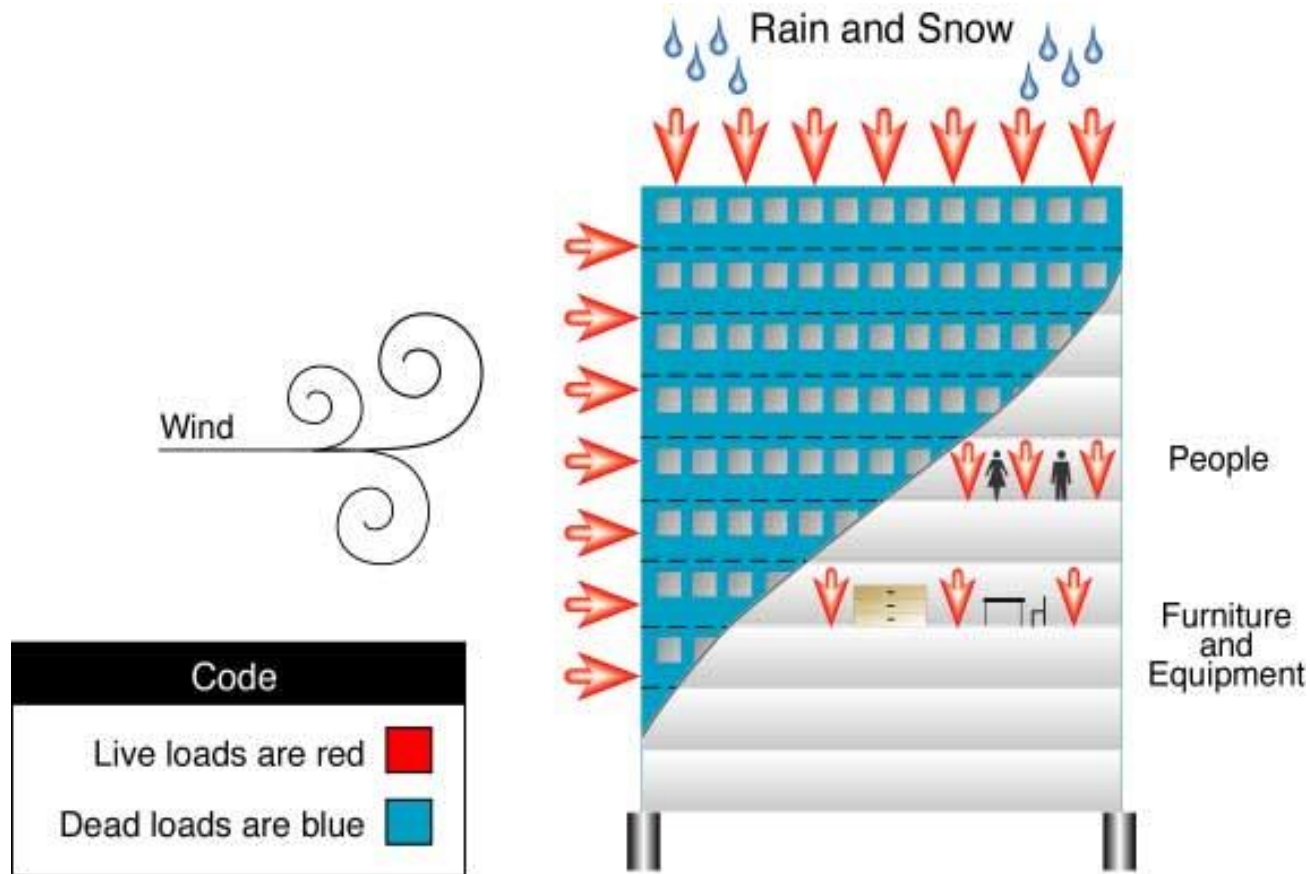
- Floor and Roof
- Beams and Girders
- Columns and Walls
- Foundation



- *Together – they make the frame*



Loads on Buildings

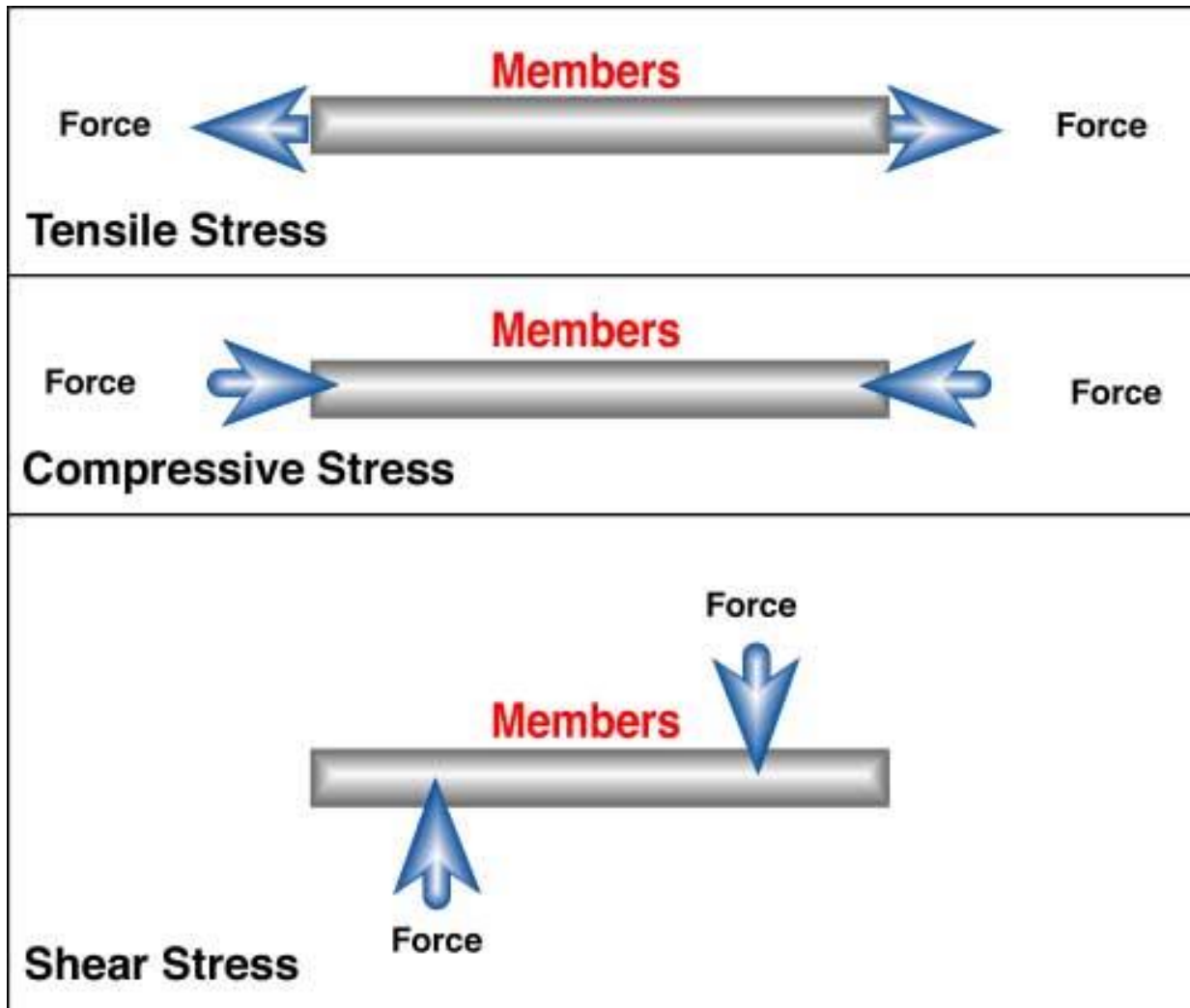


Live loads are variable; dead loads are fixed.

Support Loads

- Dead Loads
 - Architectural Construction
 - Mechanical Equipments
 - Utilities
 - Sprinkler Systems
- Live Loads
 - People
 - Furnishings
 - Machinery
 - Moveable Walls
 - Rain, Snow, Ice
- Snow Loads
- Wind Loads
 - Pressure on windward side
 - Suction on leeward side
 - More as you get higher
- Seismic Loads
 - Earthquakes - shaking
- Vibration Loads
 - Traffic, heavy trucks
 - Subway
 - Airports
- Shock Loads
 - Suddenly applied
 - 9/11

Stresses on Members (1)



Stresses on Members (2)

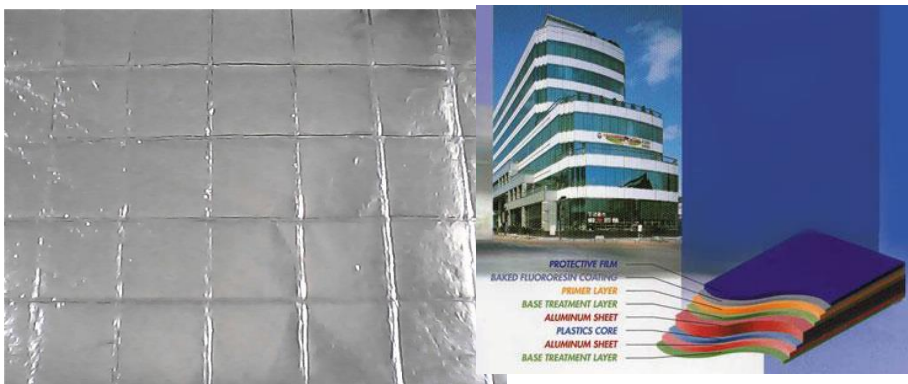
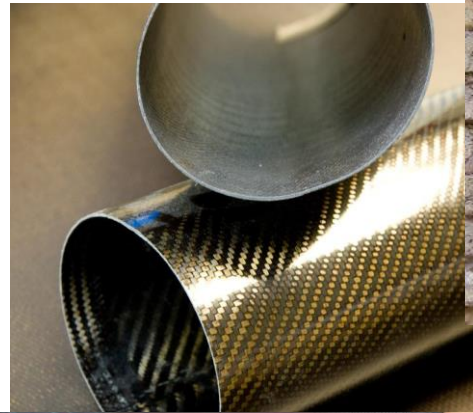
- Compressive stress compacts material, decreasing the volume.
 - More weight = more compression.
 - Ductile materials (metal, soil, plastic) yield.
 - Brittle materials rupture.
- Aspect ratio (ratio between width and length)
 - Ratios greater than 2:1 will buckle
 - Due to “elastic instability”

https://youtu.be/l_HlbF4EoJs

Video about buckling of mechanical structure

Fire Resistance

- Hourly ratings (1-4)
- Rating = amount of time the element, component or assembly can contain the fire
- Rated ceilings need clips

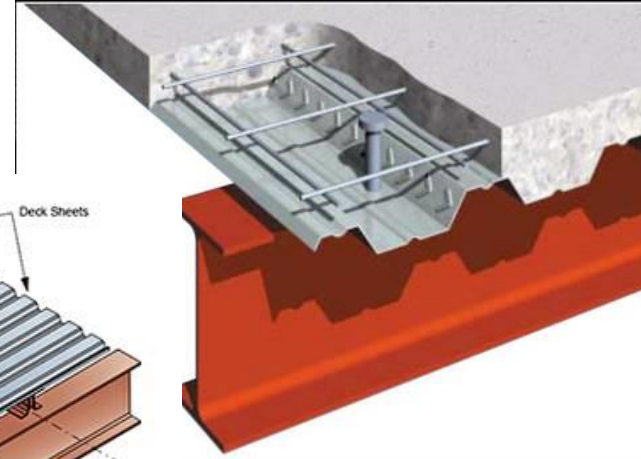
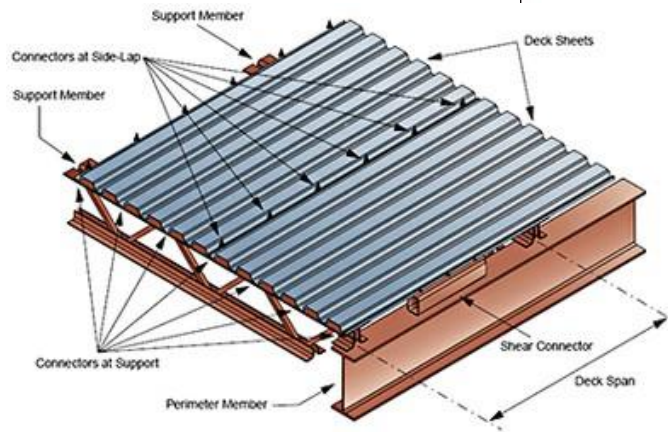


- Structural system and individual members will need to comply with code required ratings.

Floor Systems

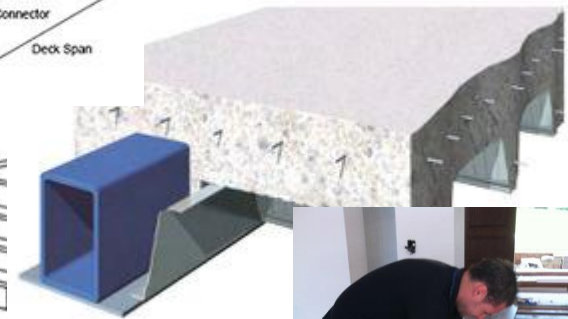
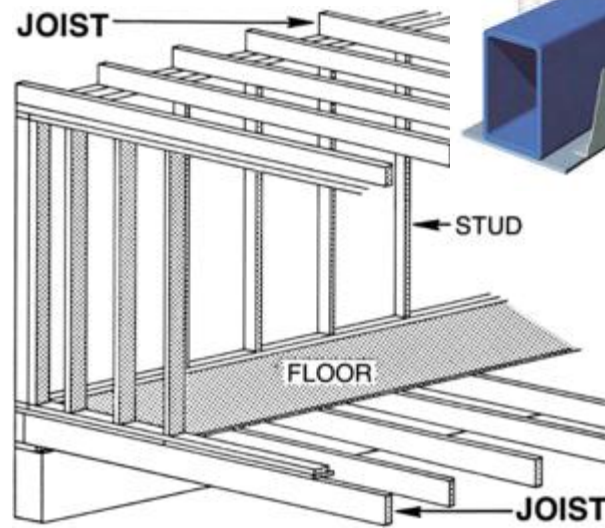
- Steel and Concrete Decks

- Cellular Steel
- Composite Steel
- Open Web Joist
- Concrete Slab
- Slab On-Grade



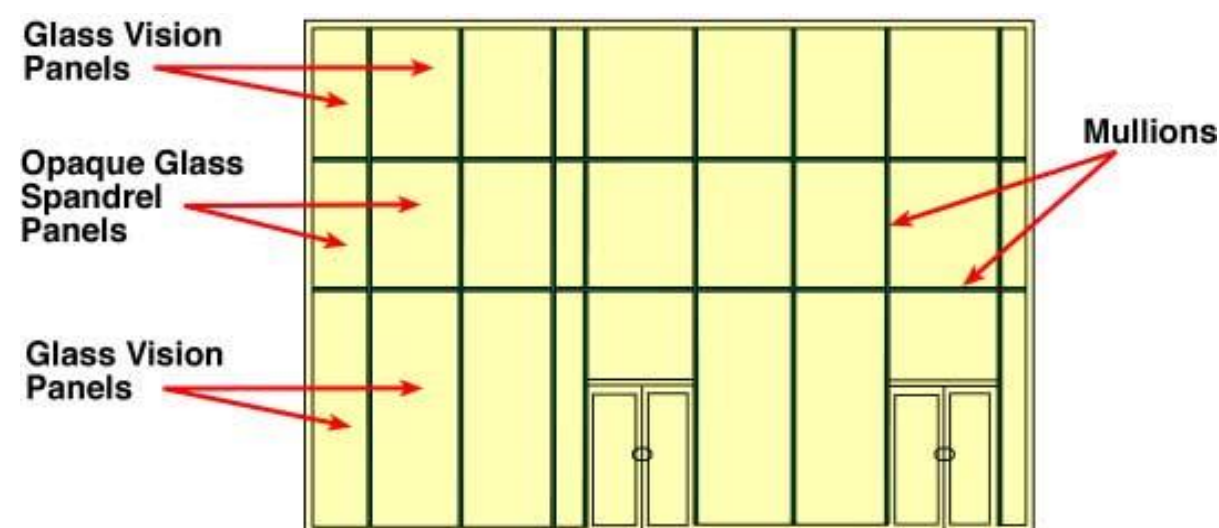
- Wood Floor

- Deck on Joists
- Solid Timber



Building Walls

- Exterior Walls
- Curtain Walls
- Interior Walls



Steel Frame System

- Load-bearing Wall Construction
 - Like a house
- Frame Construction
 - Most highrises
- Long Span Steel Structures
 - McCormick Place
 - Bridges
- Combination Steel and Concrete Framing



Advantages and Disadvantages of Steel

Advantages

- High Strength
- Uniformity
- Elasticity
- Permanence
- Ductility
- Additions to Existing Structures
- Other advantages
 - Prefabrication
 - Speed
 - Weldability
 - Toughness
 - Reuse
 - Recycle

Disadvantages

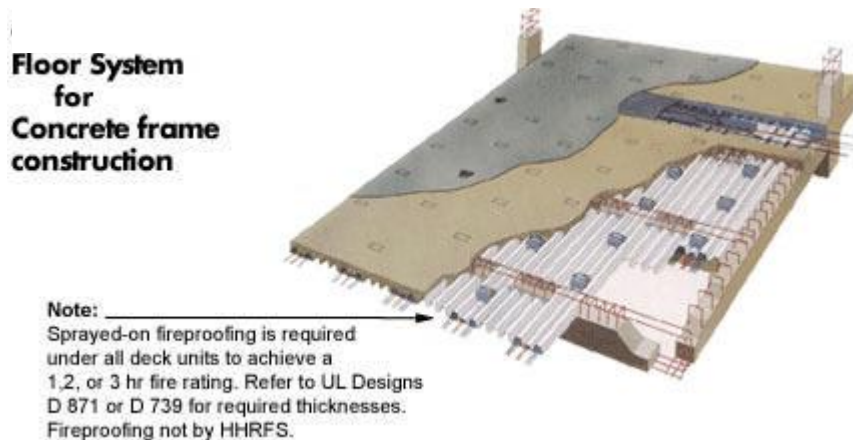
- Fireproofing
 - Encase in concrete or fireproofing
 - Enclose with fire rated materials
 - Intumescent paint
 - Chemically treated water
- Maintenance
 - Paint
 - Rust
 - Connections

<https://youtu.be/VAkTbyENZ5s>

Simulations of World Trade Center 7 Collapse

Concrete Frame Systems

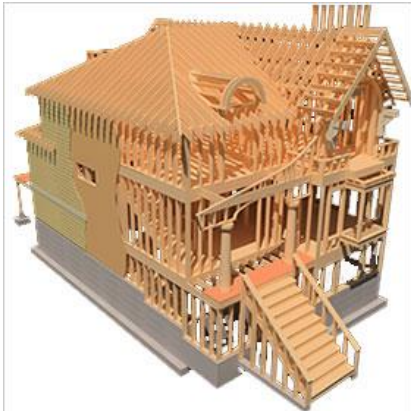
- Reinforced Concrete
 - Add **steel bars** for tensile strength
 - Poured on-site
 - More flexibility
 - More tedious
 - Weathers well



- Precast Concrete
 - Mass production – less expensive
 - Reduced construction time
 - Better quality control
 - Take weather out of the equation
 - Hard to transport
 - Connections more difficult
 - **Caulking/maintenance costs**
 - Heavier – needs larger foundations
 - Reduced continuity between structural members

Wood Frame Systems

- Materials
 - Lumber
 - Plywood
 - Laminated Timber
- Disadvantages
 - Fungus
 - Termites
 - Burns easily
 - Moisture induced movement
- Systems
 - Balloon Framing
 - Platform Framing
 - Post-and-Beam Framing
 - Stressed Skin Construction

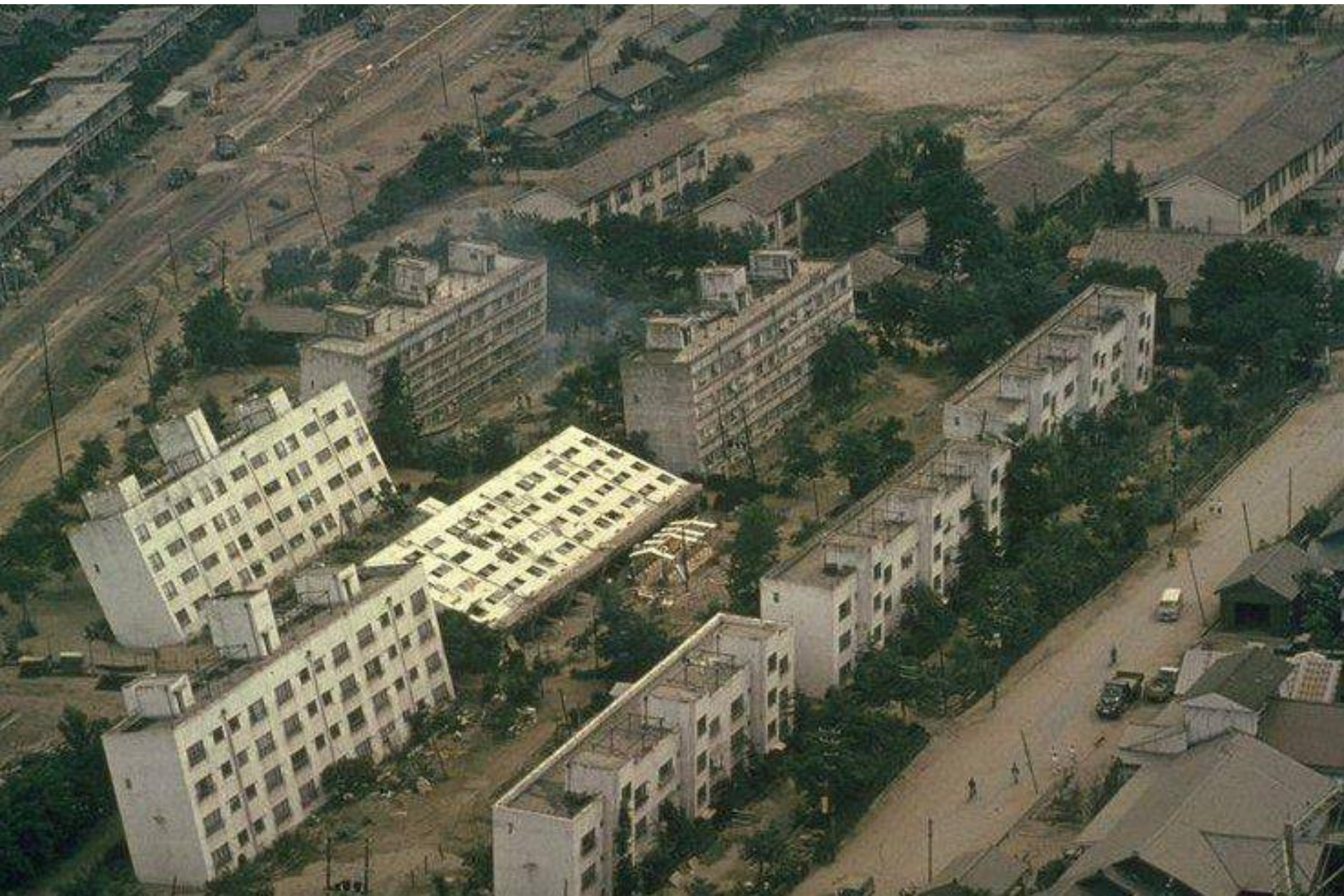


Foundation and Soil

- Foundation is what EVERYTHING sits on
 - Coarse-grained noncohesive soils
 - Fine-grained cohesive soils
 - Organic fibrous soils
- Anything in soil that is or once was alive needs to come out

Soil Concerns

- Moisture
- Frost
- Shifting
 - Settlement
 - Upheaval
 - Sliding
 - Liquefaction



Foundation Systems

- Deep Systems
 - Concrete Piles
 - On site
 - Precast
 - Augered-in-place
 - Tapered
 - Caissons
 - Steel Piles
 - Sheet piles
 - Wood Piles
 - Always wet (tree roots)
 - Always dry
- Shallow Systems
 - Spread footings
 - Mat and Raft systems
 - Trench footings
- Foundation Materials
 - Generally reinforced concrete

Structural Systems Maintenance

- Locate the deterioration
- Determine the cause
 - Neutralize
 - Eliminate
- Evaluate the existing strength
- Evaluate need for repair
- Select & implement repair
- Maintaining Foundations
 - Look for “tell”
 - Water is the enemy
- Maintaining Steel
 - Corrosion
 - Abrasion
 - Connections
 - Fatigue
 - Impact
- Maintaining Concrete
 - Cracking
 - Spalling
 - Disintegration
- Maintaining Wood
 - Water, yes water is still the enemy
 - Insects are the other enemy

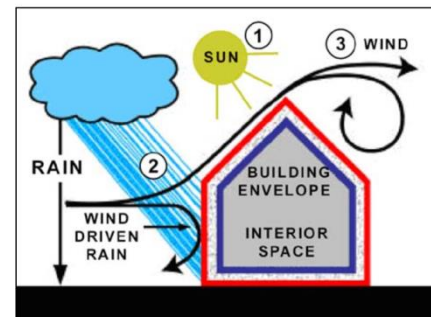
Structural Considerations for Sustainability

- Maximum Solar Access
- Maximize Daylighting
- Reuse of Materials or Structures
- Salvaging Materials
- Recycling Content
- Use Certified Lumber

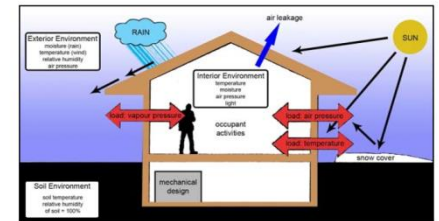
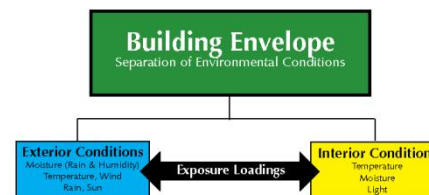


The Building Envelope

- What is blocked:
 - Rain, snow, hail, wind, humidity
 - Heat and cold
 - Dirt, soot, pollen, etc.
 - Bugs and coyotes
 - Noise
 - Fire
 - UV
 - Bad people
- What it let's in:
 - Sunlight
 - Views
 - Good people
 - Natural ventilation



Environmental Separation



Residential High-Rise Envelope Failure – Steel Stud Corrosion

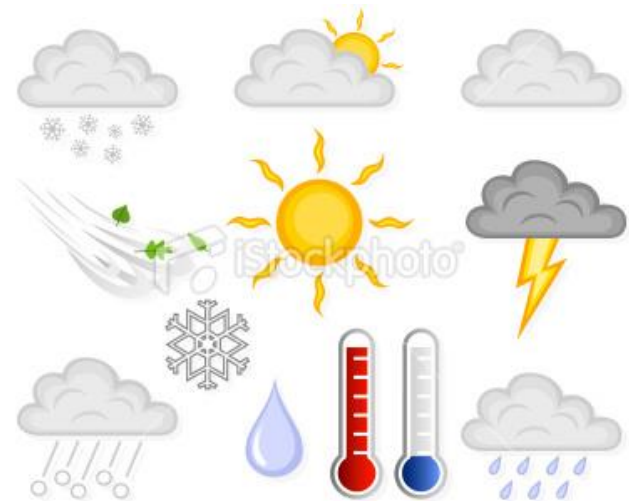
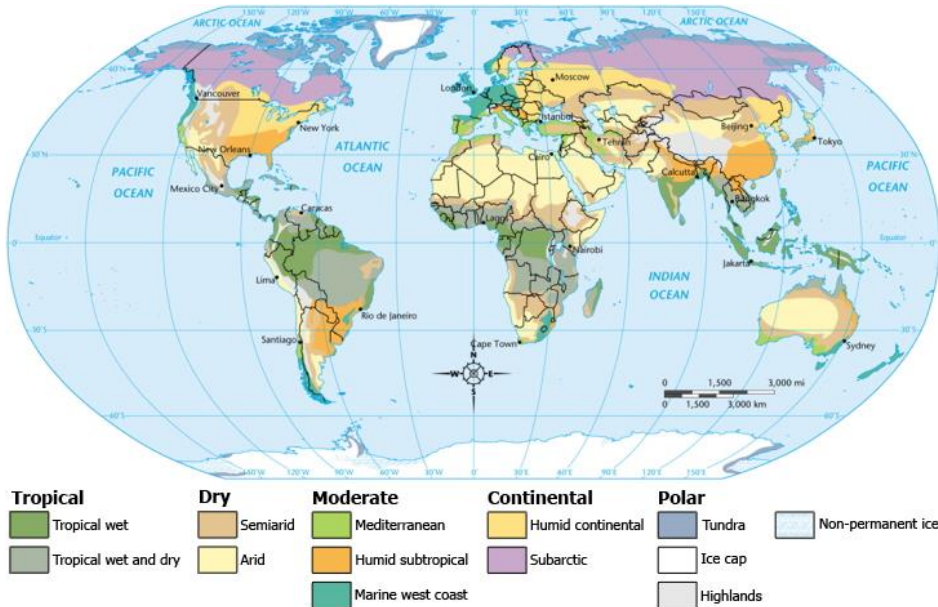
Climate

- Types of Climates

- Cold Climates
- Temperate Climates
- Hot/Dry/Arid Climates
- Warm Humid Climates

- Basic Elements

- Temperature
- Humidity
- Air Movement
- Precipitation
- Cloud Cover
- Solar Radiation



Design Criteria

- Water Infiltration
- Air Infiltration
- Loads
- Thermal Expansion/
Contraction
- Heat Transfer
- Moisture Migration
- Sound Attenuation
- Building Maintenance
- Building Codes



Factors Contributing to Premature Building Decay

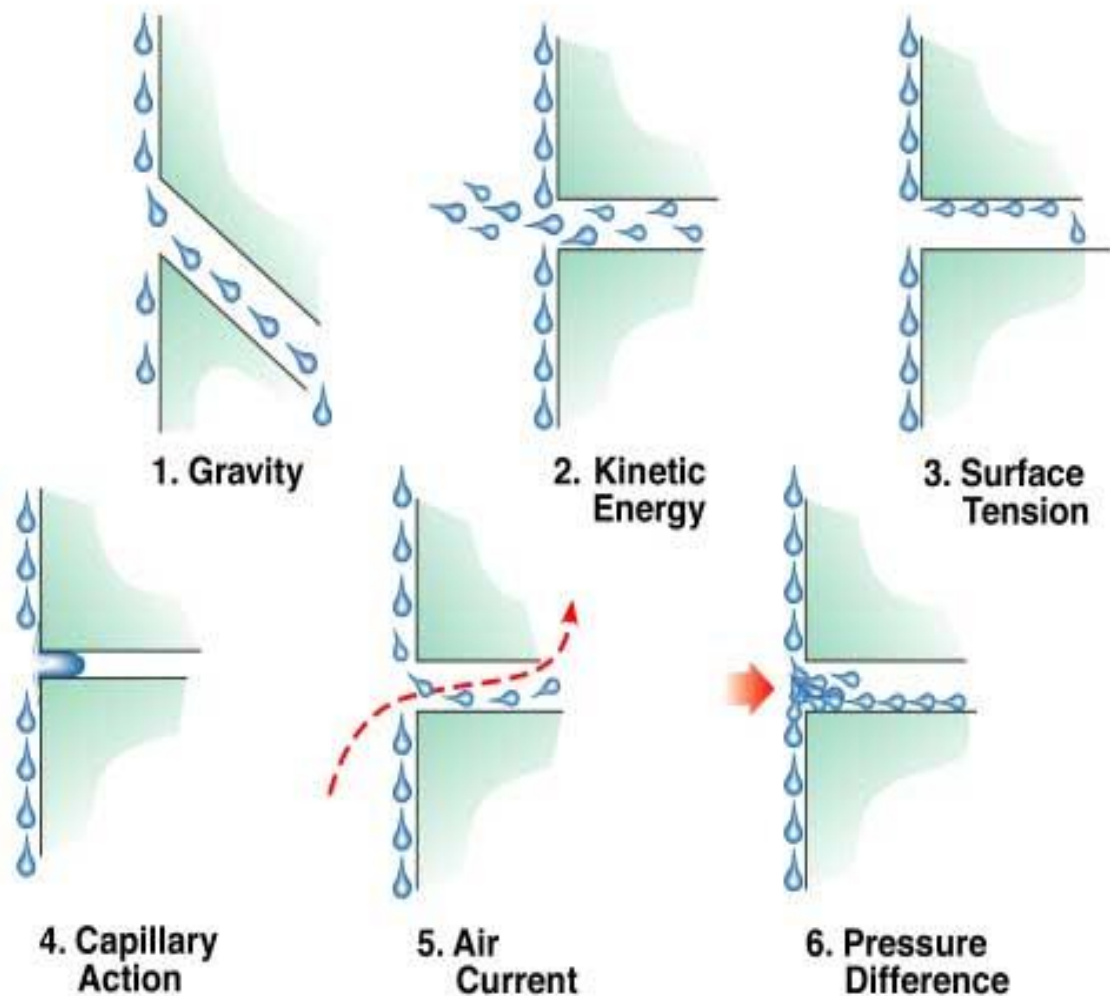
1. Design deficiencies
2. Poor material selection
3. Improper construction
4. Deferred maintenance
5. Applied forces
6. Weight
7. Vibrations
8. Pollution
9. Vandalism
10. Air (Oxygen)
11. Temperature – extremes
12. Wind pressure
13. Water



WATER is the ENEMY

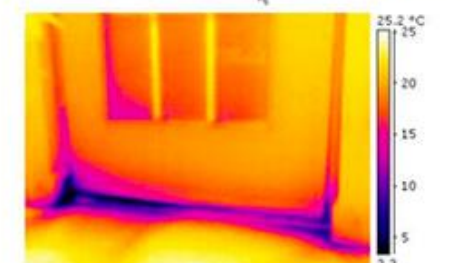
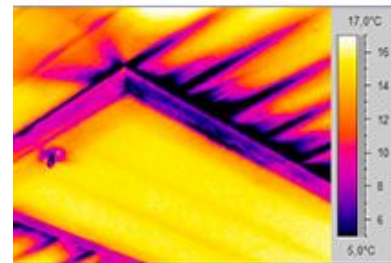
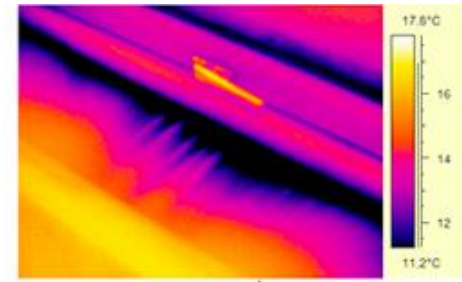
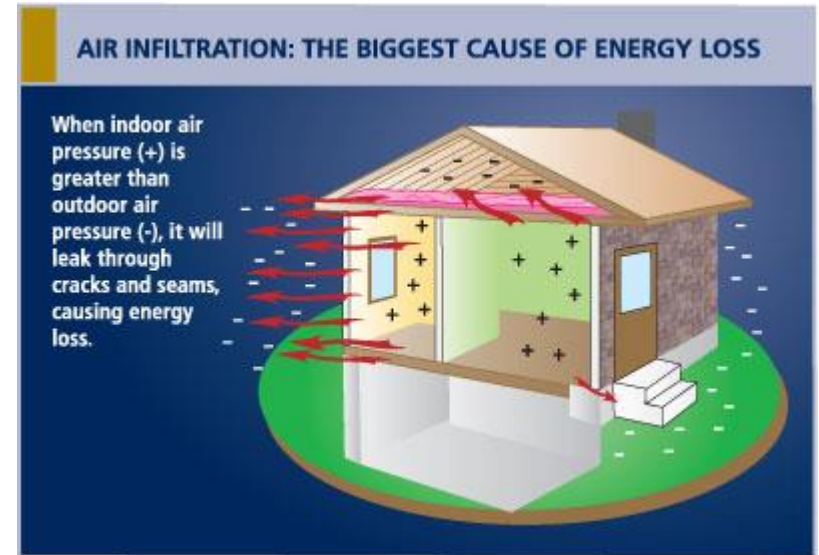
- Gravity
 - Sloped joints
- Kinetic Energy
 - Wind driven rain
- Surface Tension
 - Water moves horizontally
- Capillary Action
 - Tiny joints
- Air Currents
 - Most buildings suck in
- Pressure Drops
 - Mind your weeps

Six Causes of Water Intrusion and Damage



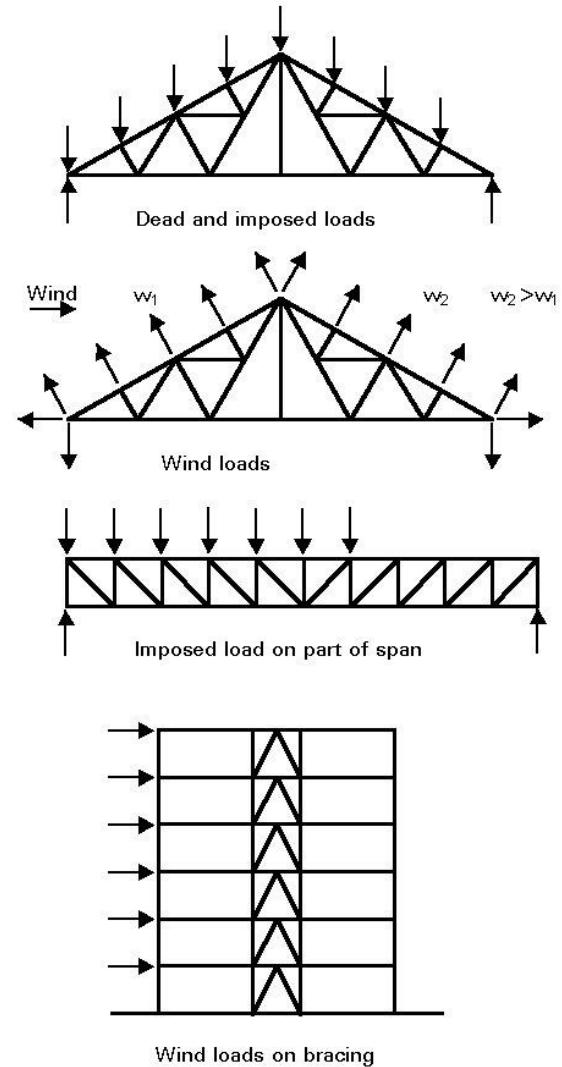
Air Infiltration

- Sash
 - “...tore open the shutter and threw up the sash.”
- Weatherstripping
 - Gaskets
- Stack Effect
 - Warm air rises and rises
- Air Infiltration Tests
 - ASTM E-283
 - 0.06 cf/m or less



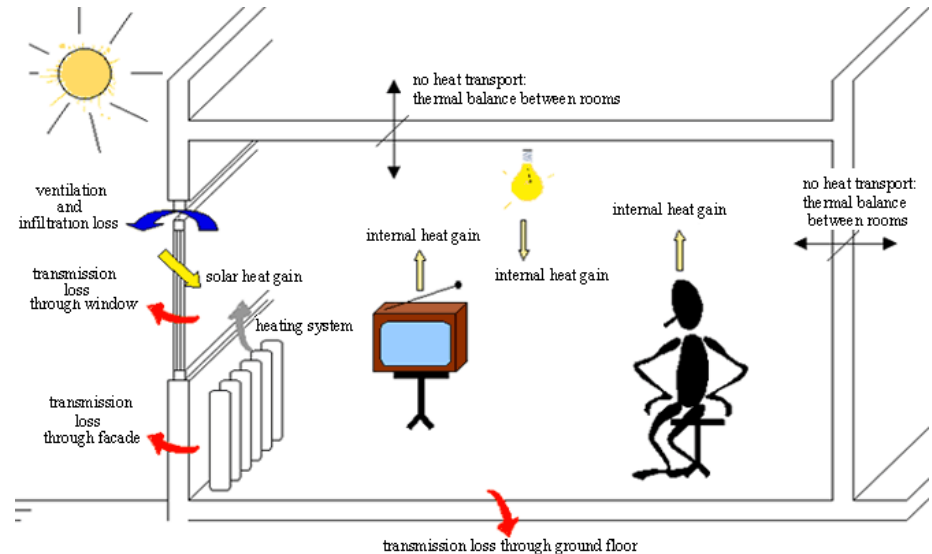
Loads

- Wind Loads
 - Positive pressure windward
 - Negative pressure leeward
 - Movement in taller buildings
- Seismic Loads
 - Shake Rattle and Roll
 - Connections and anchors

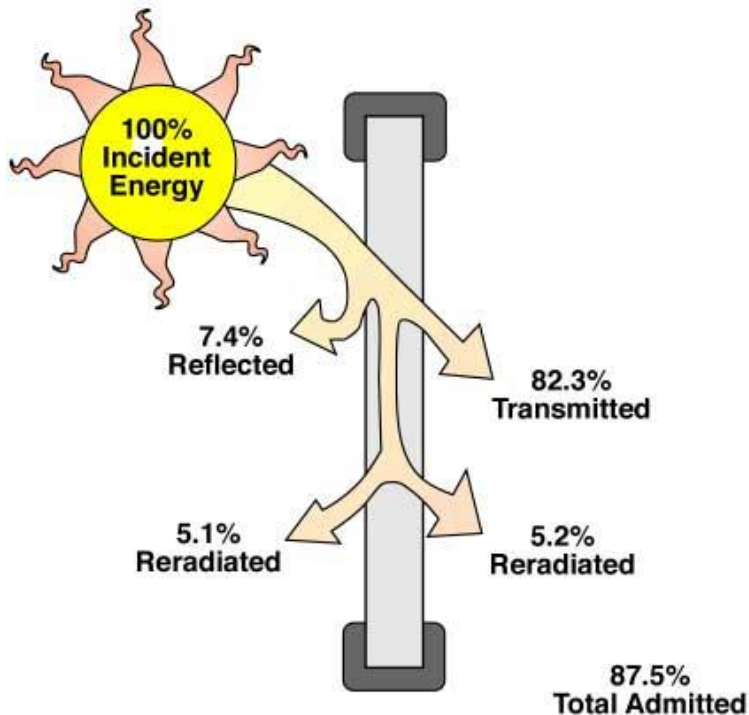


Heat

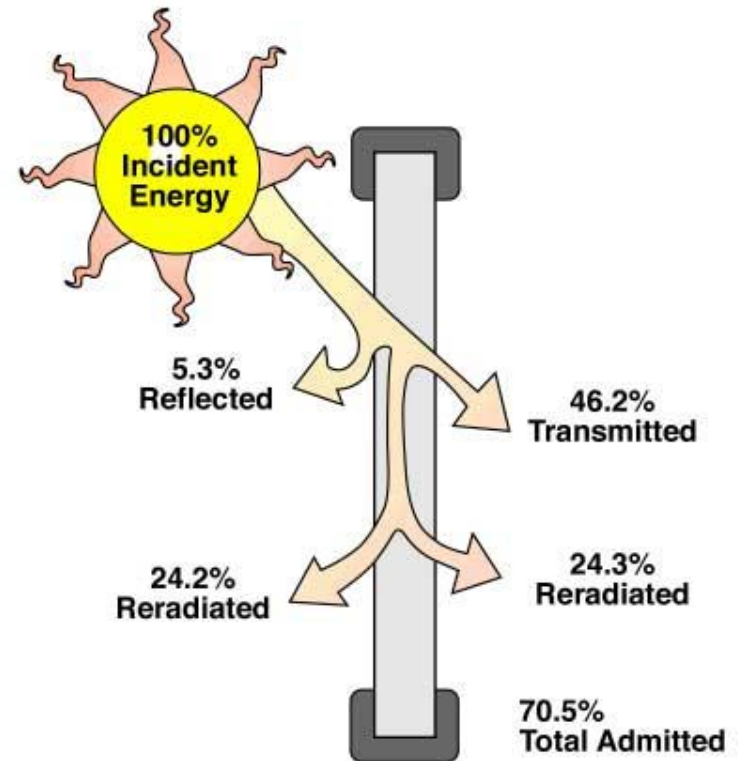
- Thermal Expansion and Contraction
 - Aluminum twice masonry
- Heat Transfer
 - U-value
 - Ability of a system to transmit heat
 - Inverse of R-value
 - Thermal breaks
 - Curtain connects to structure
 - Panels connect to framing
 - Wall assemblies
 - Within panels themselves
 - If everything else is sealed



Solar Energy Transmission Through Glass



Clear Glass



Heat-Absorbing Glass

Moisture Migration

- To Prevent Condensation
 - Provide a vapor retarder on the interior of the wall to prevent humid air from entering the wall system
 - Insulate internal surfaces
 - Provide venting for water vapor
 - Weep system
- Condensation – function of temperature and Relative Humidity



Ceilings and Flooring

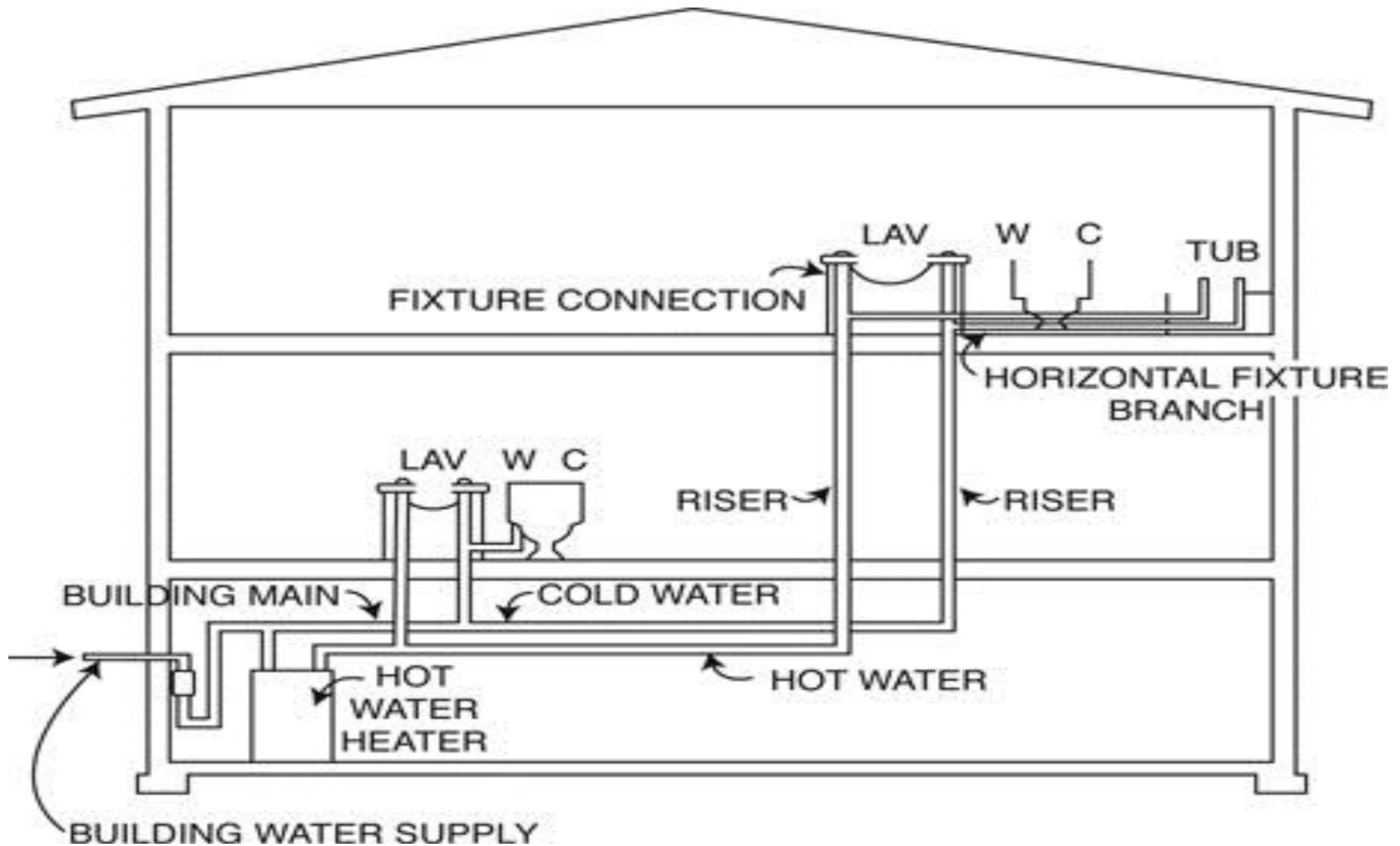
Ceilings

- Generally the upper limit for a space.
- Area between ceiling and deck is the plenum.
- Ceiling panels.
- Ceiling maintenance.
 - Always follow manufacturer's recommendations.
 - Painting reduces acoustics.

Flooring

- Function and Cost
- Appearance and Style
- Durability and Noise
- Comfort and Safety
- Installation and Maintenance
- Weight and Measurement

Water System



Water System

— Major components —

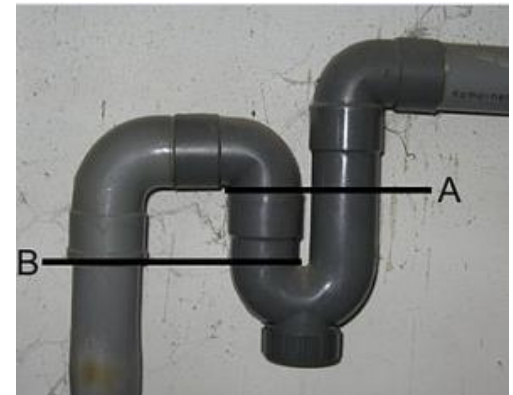
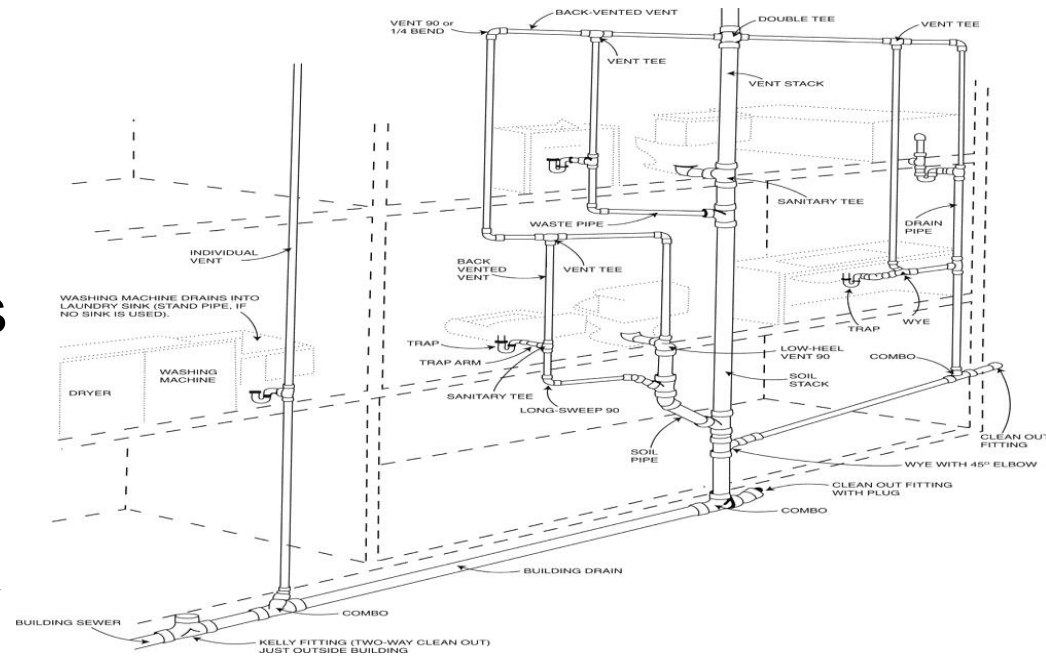
- Meter
- Piping for water
 - Older systems may have used cast iron
 - Delivery
 - Copper
 - Soldered joints
 - Polyvinyl chloride (PVC)
- Hot water heater
 - Electric
 - Gas
 - Fuel oil
 - Equipped with safety valve
- Drain system
 - Removes **black water** from toilets
 - Removes **gray water** from showers, tubs, and washers
- Piping for drainage
 - Vent and drain system
 - Acrylonite butadiene styrene (ABS)
 - Polyvinyl chloride (PVC)
- Appliances

Water System

— Drainage —

- Drain system
 - “P” traps prevent methane or sewer gas from entering buildings
 - P trap water can evaporate
 - May be the explanation for some unknown odor calls
 - May be eliminated by running water into drain

P trap = a barrier to prevent sewer gas from rising up through drain and toilet into building



Water System

— Plumbing —

- Substantial water requirements in commercial structure
- Requires larger systems than residential
- High rise buildings require pumps above the 7th floor
- Paint schemes indicate what is in pipes
 - The hotter the contents, the brighter the color:
 - Steam—orange
 - Heat—yellow
 - Water—blue
 - Sewage—brown or black
 - Fire protection—red

Heating, Ventilation and Cooling (HVAC)

- Forced air and heat pumps are common in use today
 - Heated by either fuel oil or gas
 - Heat pumps use the unit's ability to remove moisture from the atmosphere and convert it to heated air
 - Same duct work used for air conditioning systems
- Air conditioners use refrigerant pumped into coils
- Air flows over coils
- Chilled air is blown by a fan
- Return air may come from a plenum space above a dropped ceiling

Heating, Ventilation and Cooling (HVAC) — Insulation

- Insulation enhances efficiency of HVAC systems
- Fiberglass is the most modern of insulation materials
- Installed in wall cavities
- Service people should repair HVAC systems to reduce fire department liability



Electricity and Lighting (1)

- Produced by central station
- Transmitted by wires to transformers and to the residential or commercial user
- Electricity enters a structure at the service point or drip line
 - It comes in **220 volts** in Hong Kong and energizes the service box
 - The box is rated by the amperage available for use
- **Volt** is the unit that measures the potential difference in electrical force or “pressure” between two points on a circuit
- **Ampere** is the unit used to measure the amount of current
- **Watt** is the unit of power
 - $\text{volts} \times \text{amperes} = \text{watts}$
- **Watt-hour** is the unit of energy

Electricity and Lighting (2)

- Lighting energy consumption
 - 20 - 45% in commercial buildings
 - 3 - 10% in industrial plants
- Significant energy savings can be realized with a minimal capital investment
 - Daylighting
 - Efficient lighting devices
 - Task lighting
 - Controls



Electricity Bill

- Electricity bills show how many **units** of electricity you used
- 1 unit = 1 kilowatt-hour, **kWh** (an amount of energy)
- **1 kWh** = amount of electrical energy used by a 1 kW appliance left on for 1 hour

$$\text{Total Cost} = \text{Power} \times \text{Time} \times \text{Cost of 1 kWh}$$

(kW) (hrs)

- Note: 1 kW = 1,000 W; 1 hr = 3,600 secs

CLP General Service Tariff (2016)

- Based on bimonthly meter-readings.
- Aggregate of the following items:

a) Energy Charge

Total Bimonthly Consumption Block	Rate (Cents/Unit)
Each of the first 400 units (0 – 400)	82.2
Each of the next 600 units (401 – 1,000)	95.6
Each of the next 800 units (1,001 – 1,800)	111.4
Each of the next 800 units (1,801 – 2,600)	142.2
Each of the next 800 units (2,601 – 3,400)	165.1
Each of the next 800 units (3,401 – 42,00)	175.5
Each unit over 4,200	176.7

b) Fuel Cost Adjustment is 24.3 cents per unit

c) Energy Saving Rebate applicable to a bill with total bimonthly consumption of 400 units or less

Total Bimonthly Consumption Range	Rebate Rate (Cents/Unit)
1-200 units	17.2 cents per unit on total consumption
201- 300 units	16.2 cents per unit on total consumption
301- 400 units	15.2 cents per unit on total consumption

Electricity Bulk Tariff (2016)

- Customers whose present or expected monthly consumption is not less than 20,000 units may apply to the Company in writing for supply under Bulk Tariff.
- Demand Charge: Based on the monthly maximum demand in kilovoltamperes (kVA):
 - On-Peak Period:
 - Each of the first 650 kVA - HK\$ 68.4
 - Each kVA above 650 kVA - HK\$ 65.4
 - Off-Peak Period (9 pm to 9 am; Sundays and Public Holidays):
 - Each off-peak kVA up to the on-peak billing demand - HK\$ 0.0
 - Each off-peak kVA in excess of the on-peak billing demand - HK\$ 26.8
- Energy Charge
 - On-Peak Period:
 - Each of the first 200,000 units – 70.5 cents
 - Each unit over 200,000 - 68.9 cents
 - Off-Peak Period (9 pm to 9 am; Sundays and Public Holidays):
 - Each unit – 62.8 cents
- Fuel Clause Charge
 - 24.3 cents per unit

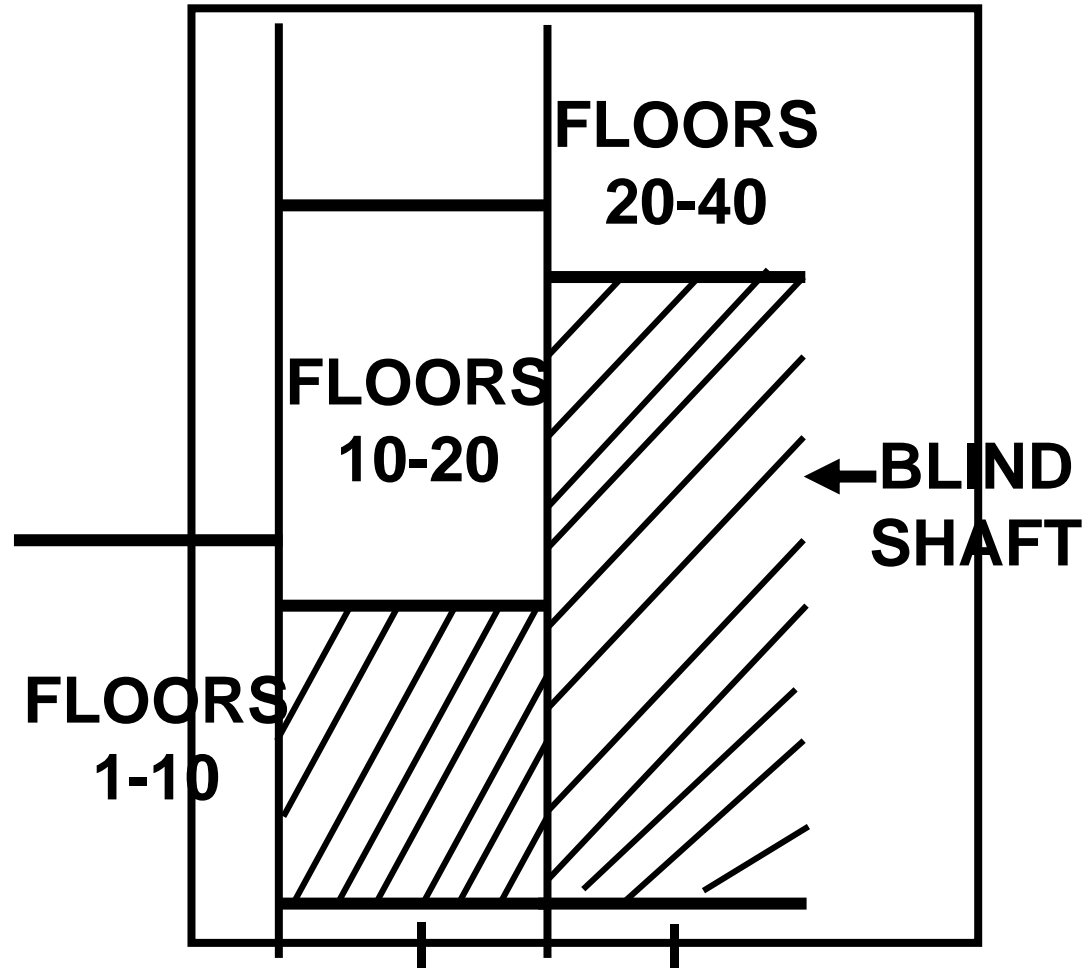
Fire Protection

- More than just **sprinklers**; it is also:
 - Pumps
 - Piping
 - Tanks
 - Valves
 - Hoses and tanks
 - Tanks may have gated discharge valves for fire department use
- For most buildings, external protection begins with standpipe or sprinkler connections
- Allows fire department to pump water into the system to augment building's fire protection systems
- May have multiple connections that may or may not be interconnected

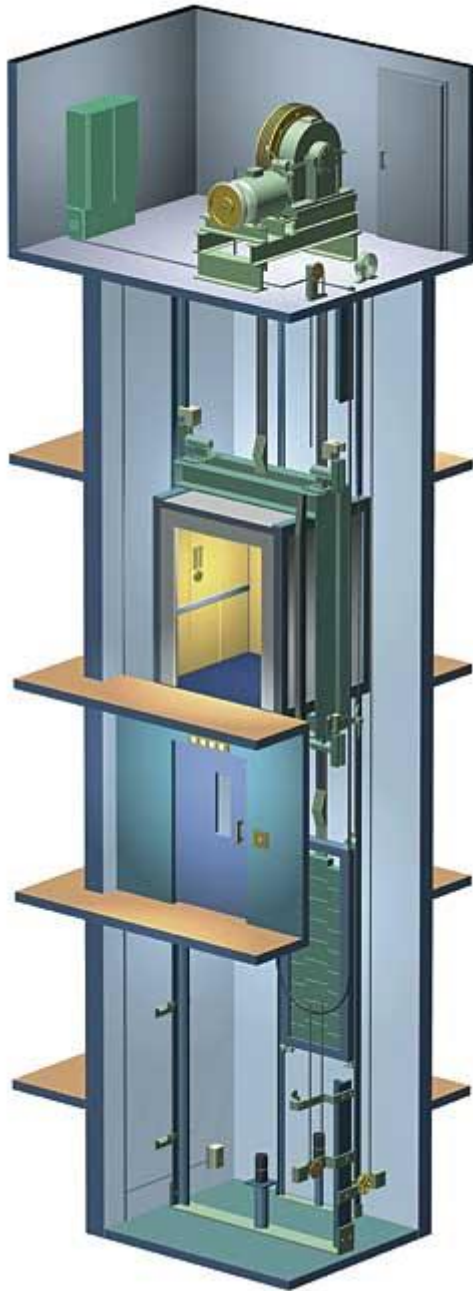
Elevators/Lift (1)

- Powered in two main ways, traction or hydraulic
 - Car is essentially a cage of light metal supported on a structural frame
 - Cables are attached to the top member
 - Car is fixed to shaft by rail shoes

Elevator Shafts



Elevators (2)

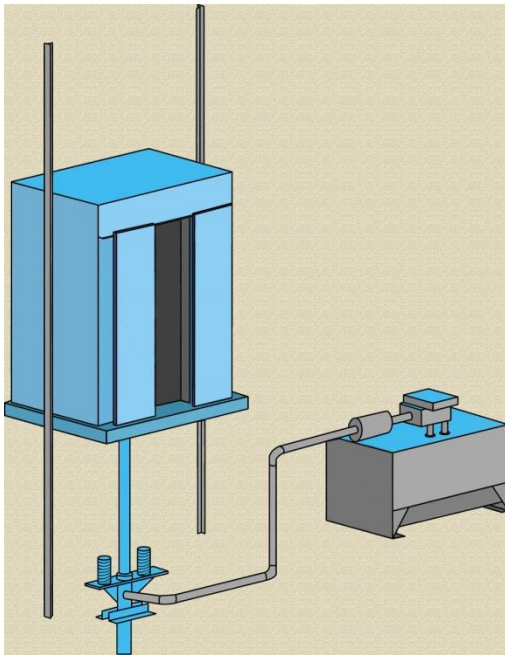


- Cables
 - Cables lift and lower the car in the hoistway
- Machine room
 - Elevator machine room is usually directly above the hoistway at the uppermost run of the elevator or bank of elevators
 - Contains the machine-generator set, which powers the elevator machine, the control board, and other control equipment
 - Firefighters should be cautious due to electrical hazards

Elevators (3)

- Hydraulic

- For **inexpensive elevator service**, the use of hydraulics is employed
- Do not need cables, drums, motor generator sets, elaborate controllers, or penthouse equipment



- Hydraulic elevators

- Movement of the elevator is controlled by means of a movable rod (plunger) rigidly fixed to the bottom of the car
- Hydraulic elevator uses a basement machine room
- Requires a **much larger motor and a tank** for the reclaiming and storage of the fluid used to push the rod
- Primarily for low-rise applications under 6 stories
- Fire department should know how elevators behave during a fire or power failure



Smart Elevators: internet connected, predictive maintenance with wireless MEMS sensors <https://tinyurl.com/tm6x8zb>