CONTENT AREA: PRINCIPLES

Building Design

Facts/Rules:
- After an idea is developed for a building, an architect helps consolidate the owner’s thoughts and designs the form of the building. They assemble a group of engineers and specialists to help work out the details and scheme for the building.
- Drawings and specifications are produced to explain how and what the building will be made of.
- A contractor is hired either by negotiation or bid, who then hires subcontractors to complete specific portions of the work (e.g.: casework, electrical, doors/hardware)
- Drawings/spec are submitted to the necessary municipality (city or county, typically) who verifies conformance with building code and local requirements/ordinances.
- The building inspector and design team should observe the work at regular intervals to verify compliance with the construction documents.

Concepts/Goals:
- Designers are able to use a limitless palate of materials and systems to produce a building of any desired form/texture
- Designers are bound by physical limitations (e.g.: size of site, soil bearing capacity, maximum span), budget, and legal restrictions.
- Design professionals need to have a broad understanding of people, climate, physical principles of materials, available technologies, legal restrictions, and contractual arrangements and obligations under which buildings are built.
- Designers must answer several questions when designing a building:
  - What will give the required functional performance?
  - What will give the desired aesthetic result?
  - What is possible legally?
  - What is most economic?
  - How can we build in a sustainable manner?

Design Principles + Design Impact on Human Behavior

Vocabulary:
- Ahwahnee principles: a collective vision of how urban and suburban planning should follow certain fundamental principles regarding community size, integration, transportation, open space, pedestrian paths, native vegetation, water and energy use.

Facts/Rules:
- Typical Human Comfort Zone
  - Winter = 63°F - 71°F
  - Summer = 66°F - 75°F
  - Tolerable humidity = 30% - 60%
  - Uncomfortable humidity = + 75%
• Winds
  Basic Speed = 70 - 80 miles/hour
  Unnoticeable = < 50 feet/minute
  Pleasant = 50 - 100 feet/minute
  Pleasant *and* noticeable = 100 - 200 feet/minute
  Drafty = 200 - 300 feet/minute
  Uncomfortable = + 300 feet/minute
  Pressure varies as the square of the velocity (if velocity doubles, pressure quadruples)

• Pedestrian Circulation
  Area of a person = 3 sf
  Easy movement = 13 sf
  Crowd movement = 7 sf
  No movement = 3 sf
  Sidewalks = 5'-0" wide min
  Collector walks = 6'-0" - 10'-0" wide min

• Noise
  Smallest difference in 2 sounds the human ear can detect is 1 decibel
  Sleeping, studying, whispering = 30 decibels
  Conversation, comfort = 50 - 60 decibels
  Safety Threshold = 85 decibels
  Rock Band! = 90 - 100 decibels

  Trees thin out high frequency noises
  Each increase of 10 decibels the human ear perceives as 10x loud.
  Typically doubling the distance between source and ear reduces level by 6 decibels
  On freeways, doubling the distance between source and ear reduce level by 3 decibels
  Winds add “white noise” that blurs any one sound frequency.
  Walls close to a noise source reduce high frequency, but midway between the source and the ear does nothing.

Concepts/Goals:
  The best thing we can do as architects is to get involved in the art and business of buildings. We must learn how materials feel in the hand, how they look installed, how they're manufactured, worked, and put in place, how the perform, and how the they deteriorate over time.

Processes:
  • Address Human Elements
    • Senses: sight, sound, smell and touch give an impression of size, shape, and material. Taste probably isn’t an issue...unless you’ve got willy wonka walls :)
    • Style: follow conventional and acceptable solutions to maintain consistency and harmony within space and surrounding context
    • Culture: different cultures use buildings differently (separation of women/men, sanitary standards, layout of spaces for rituals, feng shui, vastu shastra, etc.)
  • Address building organizational values
    • Behavioral Interests: desired spaces to perform tasks
    • Circulation: ease of movement around site and building
    • Health: reduce stressors (noise, crowding, sun glare, sick building syndrome)
    • Adaptability: allow for future changes, modifications, and flexibility
    • Cost: use regular forms, plans, and compact arrangements
• Design principles that increase personal safety in public areas
• Design for the needs of the local residents to encourage a well used space.
• Concentrate activities in a limited number of areas
• Promote foot traffic by providing shortcuts/inviting features to encourage new routes
• Visible into public space and evening lighting
• Protected play area for small kids with comfortable seating for parents

Building Systems + Their Integration

Vocabulary:
• **Post**: long, sturdy piece of timber or metal set upright in the ground used to support
• **Beam**: a member that supports loads perpendicularly to its longitudinal axis
• **Simple Beam**: rests on a support at each end and ends are free to rotate
• **Cantilever Beam**: supported at one end and restrained from rotation at that end
• **Overhanging Beam**: rests on 2+ supports and has one or both ends cantilevered beyond the support
• **Fixed End Beam**: fixed against rotation at both ends
• **Frame**: a structural system that supports other components of a physical construction
• **Truss**: a framework, typically consisting of rafters, posts, and struts, supporting a roof, bridge, or other structure
• **Gage line**: standard dimension from corner edge of an angle to centerline of bolt holes. depends on size of angle
• **Arch**: a curved symmetrical structure spanning an opening and typically supporting the weight of a bridge, roof, or wall above it.

Facts/Rules:
• The physical properties of of the four common structural materials help determine the appropriate building system to use

<table>
<thead>
<tr>
<th>Material</th>
<th>Allowable Tensile Strength</th>
<th>Allowable Compressive Strength</th>
<th>Density</th>
<th>Modulus of Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td>700 psi</td>
<td>1,100 psi</td>
<td>30 pcf</td>
<td>1,200,000 psi</td>
</tr>
<tr>
<td>Brick Masonry</td>
<td>0 psi</td>
<td>250 psi</td>
<td>120 pcf</td>
<td>1,200,000 psi</td>
</tr>
<tr>
<td>Steel</td>
<td>22,000 psi</td>
<td>22,000 psi</td>
<td>490 pcf</td>
<td>29,000,000 psi</td>
</tr>
<tr>
<td>Concrete</td>
<td>0 psi</td>
<td>1,350 psi</td>
<td>145 pcf</td>
<td>3,150,000 psi</td>
</tr>
</tbody>
</table>

• **Wood**  **(See Materials + Technology Content Area for more in-depth notes)**
  • The oldest and most common system
  • One way structural system (load is transmitted through members in one direction)
<table>
<thead>
<tr>
<th>Type</th>
<th>Width</th>
<th>Spacing</th>
<th>Spans</th>
<th>Top/Bottom</th>
<th>Use</th>
<th>Advantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joists</td>
<td>2” nom</td>
<td>12” or 16” o.c.</td>
<td>20’ to 25’</td>
<td>Bridging supports bottom edge, sheathing holds top in place</td>
<td>Between beams or bearing walls</td>
<td>Tried and true method</td>
</tr>
<tr>
<td>I-Joist</td>
<td>1-3/4” to 3-1/2”</td>
<td>12” - 24” o.c.</td>
<td>8’ to 24’</td>
<td>9-1/2” - 16” depth OSB webs and microllam (thick plywood) flanges connect to wall with hangers</td>
<td>Residential/ light commercial</td>
<td>Efficient strl shape as shop fabrication eliminates common defects</td>
</tr>
<tr>
<td>Glulam</td>
<td>3-1/8”, 5-1/8”, 6-3/4”, 8-3/4”</td>
<td>varies</td>
<td>15’ to 60’</td>
<td>Several layers of timber bonded together with glue and connected with plates and/or bolts</td>
<td>Columns and beams, commercial, public</td>
<td>Can be left exposed, can be tapered or curved</td>
</tr>
<tr>
<td>Plank/ Beam Framing</td>
<td>4” or 6”</td>
<td>4’ or 6’ or 8’</td>
<td>10’ to 20’</td>
<td>Wood decking span between beams, underside finish ceiling</td>
<td>Between girders or bearing walls, residential</td>
<td>Easy to insulate</td>
</tr>
<tr>
<td>Truss</td>
<td>varies</td>
<td>24” o.c.</td>
<td>24’ to 40’</td>
<td>12 - 36” depth made of strand wood members connected with plates</td>
<td>Residential, Commercial, Public</td>
<td>MEP can pass thru</td>
</tr>
<tr>
<td>Box Beam</td>
<td>Up to 30”</td>
<td>varies</td>
<td>50’</td>
<td>Plywood panels glued &amp; nailed to 2x4</td>
<td>Residential, Commercial, Public</td>
<td>Looks like solid timber, custom made</td>
</tr>
</tbody>
</table>

- **Steel (See Materials + Technology Content Area for more in-depth notes)**
  - Most commonly used structural material due to its high strength, availability, adaptability, ductility (can deform and return to original shape/bends before it breaks)
  - Suited for multi-floor construction due to strength and structural continuity
  - Beams span shorter distances of 8’ - 10’
  - Girders span longer distances of 25’ - 40’

- **Concrete (See Materials + Technology Content Area for more in-depth notes)**
  - **Cast-in-place concrete**: typically involves steel reinforcement (rebar), sometime post-tensioning is used
  - **Precast structural members**: high-strength steel cables are pre-stressed/stretched and concrete is poured on top. When concrete reaches minimum allowable strength cables are cut from formwork and compressive stresses are transferred to concrete that resists tension forces of own weight/live load
  - **Post-tensioned concrete**: steel tendons are laid out in desired direction and concrete is poured on top. When concrete is cured tendons are tensioned and force is transferred to the concrete through end anchorages.

- **Beam & Girder system**:
  - Large girders carry intermediate beams which support slabs with spans of 15’-30’
  - Easy to form and construct making it economical
• Slabs can be penetrated (unlike PT slabs that have tendons)

**One Way Concrete Joist system (pan joists):**
• Prefab metal pan forms are used to create frame to support light/medium loads
  with spans of 20’ - 30’ and depths of 1’ - 2’
• Formed with prefab metal pan forms spaced 24” – 36” apart in one direction

**Two Way Concrete Joist system:**
• Like One Way Joist but with beams in each direction
• Typically used in rectangular bays where distance between columns is equal (or
  close to) in both directions

**Flat plate system:**
• Basically a Two-Way slab with no supporting beams, only columns.
• Reinforced slab spans in both directions directly into columns at 25’ with 6” - 12”
  thickness
• Typically used for light loads, short spans, when floor-floor height must be
  minimized, and/or when simple under-side of slab appearance is required
• Has low shear capacity and low stiffness

**Drop panel system:**
• Like a Flat Plate system, but the slab thickness is increased around the columns
  for greater shear failure resistance.
• Used with greater live loads or larger spans.

**Flat slab system:**
• A two way slab with column capitals, drop panels, or both with spans of 30’

**Waffle slab system:**
• ribs formed with reusable prefab metal/fiberglass forms and span up to 40’
• Provides the largest spans of conventional concrete floor systems

**Lift-slab system:**
• Floor/roof slabs are cast on top of the previous and then jacked up to the desired
  height

**Singe tee/double tee system:**
• Prestressed ribs (one or two) with a 2” topping slab connected.
• Typically used for larger spans

**Masonry (See Materials + Technology Content Area for more in-depth notes)**
• System has high compressive strength and is weak in tension and bending.
• Advantages include strength, flexibility, appearance, fire resistance, sound insulation,
  doesn’t weather (much), and can be used as a thermal mass for passive solar energy
• Horizontal joints are reinforced at 16” o.c. to strengthen walls and control cracking.
• Joints tie multi-wythe walls together and anchor veneer facing to structural backup
  wall

**Single Wythe Masonry Walls:**
• One unit thick
• Non structural wythe of brick is called veneer
• No requirements for reinforcing or grouting and rely on a substrate for support

**Double Wythe Masonry Walls:**
• Two units thick
• Material for both wythes may be the same and may be grouted/reinforced or
  ungrouted

**Cavity Walls:**
• Two masonry skins (eg: brick exterior and CMU interior) with hollow space
  between
• Cavity is used for drain water out of wall through weep holes
  • May be grouted and reinforced or ungrouted
  • A cavity wall is a double wythe wall, but a double wythe wall is not always a cavity wall (kinda like, a square is a rectangle, but a rectangle isn’t always a square)

• **Composite Construction**
  • Two or more materials designed to act together to resist loads (reinforced concrete construction is the most typical example)

• **Arches**
  • Have hinged or fixed supports (though fixed are less common)
  • Arches are usually top hinged to allow it to remain flexible and avoid developing high bending stresses under live loading and loading due to temperature changes and settlement
  • Hinged arch is primarily subjected to compressive forces
    • Conceptually, uniform loads supported across the span form a parabola
    • Actually, no arch is subject to just one set of loads...there’s always compression and bending stresses
    • Supports have vertical reactions and horizontal actions
  • Three hinged arches have an additional hinged connection at apex which makes structure statically determinate  (two hinged/fixed arches are statically indeterminate)
  • Generally, loads acting on an arch force it to spread out
  • Ultimate goal of arch design is that thrust must be resisted
    • For a given span thrust is inversely proportional to the rise/height of the arch
    • If rise is reduced by one half, the thrust doubles
  • Tie rods: hold two lower portions together
  • Foundations are designed to to prevent thrust
  • Shape of arch selected for aesthetic appeal not always ideal shape for loading
  • Typical arch spans:
    • Wood:  50’ – 240’
    • Concrete:  20’ – 320’
    • Steel:  50’ – 500’

• **Trusses**
  • Trusses need to be designed so member is symmetric on both sides of centroid axis in the plane of the truss
  • Typical depth-to-span ratios range from 1:10 to 1:20
  • Typical spans: 40’ - 200’ and typical spacing: 10’ - 40’ o.c.
  • Residential & light commercial trusses are smaller, 2x4 or 2x6 members at 24”o.c.
  • Flat trusses require less overall depth than pitched trusses
  • Roof loads transferred from decking to purlins attached to truss at panel points
  • If concentrated loads between panel points or uniform loads applied to top chords, member must be designed for axial loading as well as for bending...Like beams
  • Compression in top chord & tension in bottom chords
  • Forces in a parallel chord truss increase towards center
  • If concentrated loads or uniform loads on any chord member between panel points, member must resist bending stresses
  • Steel trusses with double angles back-to-back with 3/8” or 1/2” gusset plate with tee sections or wide flange
  • Wood trusses: web members between double top and bottom chords or with all members in same plane connected with gusset plate
  • With light loads, bars or rods can be used for tension members
• **Rigid Frames**
  - Vertical & horizontal members work as a single structural unit
  - Efficient because three members resist vertical and lateral loads together
  - Beam are restrained by columns and becomes more rigid to vertical bending forces
  - Columns resist lateral forces as they are tied together by beam
  - With single concentrated load, cable assumes shape of two straight lines (not counting the intermediate sag due to the weight of cable)
  - Since rigid frames only resist loads in tension, instability due to wind must be stabilized or stiffened with heavy infill material (eg: cables attached to ground)

• **Air Supported Structures**
  - Simplest form, single membrane anchored continuously at ground level, inflated, and stabilized with cables over the top of the membrane.
  - Only resist loads in tension and are held in place with constant air pressure that is greater than the outside air pressure
  - The double skin inflatable structure is created by inflation of a series of voids

**Concepts/Goals:**
  - **Selecting a Structural System**
    - Primary consideration is resistance to loads
    - Anticipated loads are calculated given the known weights of materials, equipment, other dead loads, and requirements of international and local building code (the most stringent of which applies)
    - Unanticipated loads like changes in use, snow, ponding of water, degradation of the structure must also be considered
    - Building use and function is a major consideration
      - What's the occupancy type (wouldn't use the same system for a parking garage and a school)
      - Client's programmatic needs (hospital surgery needs major mechanical systems above ceiling and below ICU on floor above)

**Processes:**

<table>
<thead>
<tr>
<th>Selecting a Structural System Based on Economy, Span, and/or Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>If the building has...</strong></td>
</tr>
<tr>
<td>Irregular Form</td>
</tr>
<tr>
<td>Irregular Colum Grid</td>
</tr>
<tr>
<td>Exposed Structure</td>
</tr>
<tr>
<td>Minimum Floor Thickness or Minimum Total Building Height</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Minimum area occupied by columns and/or bearing walls</td>
</tr>
<tr>
<td>Changes in use over time</td>
</tr>
<tr>
<td>Exposure to Adverse Weather</td>
</tr>
<tr>
<td>Minimal off-site fabrication time</td>
</tr>
<tr>
<td>Minimal on-site erection time</td>
</tr>
<tr>
<td>1-2 stories with minimal construction time</td>
</tr>
<tr>
<td>4-20 stories with minimal construction time</td>
</tr>
<tr>
<td>30+ stories with minimal construction time</td>
</tr>
<tr>
<td>Minimal diagonal bracing or shear walls</td>
</tr>
<tr>
<td>Minimal dead load on foundation</td>
</tr>
</tbody>
</table>
Minimal structural distress due to unstable foundation

Frame without rigid joints

Steel frame with bolted connections
Heavy timber frame
Precast concrete system
Platform framing

Concealed Spaces for MEP

Not add height to building

Truss
Open web joists
Light Gauge Steel Framing
Platform Framing

General

Minimize Separate Trades/Contractors

Masonry
Precast, Loadbearing Wall Panels

**Implications of Design Decisions**

**Facts/Rules:**
- A steel building weighs less than a concrete/masonry building of the same parameter
  - Timber = 7-10 lbs/sf typical construction weight/floor
  - Steel = 15-20 lbs/sf typical construction weight/floor
  - Concrete/Masonry = 150-200 lbs/sf typical construction weight/floor
  - Light loads/Pneumatic = lightest system, but must deal with wind

**Concepts/Goals:**
- When selecting a system, it often comes down to **Time and Money** when choosing will be appropriate. The owner’s budget and schedule must be considered as well as the seismic design requirements and conditions
- Getting a contractor on board early to help in the selection process will help.
- Cost Implications vary depending on the type of building, location, and economy.
  - Precast Concrete: cast offsite and trucked in and installed with a crane
    - Subject to wide price swings depending on how it’s used
    - Can be an expensive solution
    - Prices are competitive with other systems when there are numerous pieces of the same size/shape
    - Formwork is one of the most expensive components
    - Can save time as it is prefab and can be erected quickly
    - Don’t have to worry about fire proofing
  - Cast in Place Concrete: poured into forms, on decking, or ground at location
    - Probably the most expensive and slowest structural system
    - Good for irregular shapes and fireproofing/durability needs
    - Slip Forming (forming that slides up each floor as it’s poured) helps save cost
  - Steel: beams, columns, floors and roof decks (concrete poured over decking as a structural part of the floor system)
• More economical framing system than concrete
• Takes less time than concrete to fabricate and erect
• More economical when spanning open spaces
• Durable
• Must be fireproofed

• Pre-Engineered Metal: standardized metal components are engineered to maximize use of the material’s structural properties and includes structure, metal roof, and metal wall panels (or tilt-up concrete panels)
  • Use without modifying standard design
  • It’s actually pretty difficult to modify as structure is designed close to max limit
  • Light Gauge system with 20 – 30 year life span
  • The least expensive way to quickly enclose a large area

• Wood: wood columns, beams, and framing floors, roofs and walls
  • Smaller commercial or residential
  • Economical up to 3 stories
  • Inexpensive for non-fire resistive construction

• Historic Preservation efforts include upgrades to building structure to protect the building from seismic and wind forces
  • Historic buildings are especially vulnerable to seismic/wind forces as they have not been designed and constructed to absorb swaying ground motions…can have major structural damage, or outright collapse
  • More and more communities are beginning to adopt stringent requirements for seismic retrofit of existing buildings.
  • Although historic and other older buildings can be retrofitted to survive earthquakes, many retrofit practices damage or destroy the very features that make such buildings significant.
  • Life-safety issues are foremost and there are various approaches which can save historic buildings both from the devastation caused by earthquakes and from the damage inflicted by well-intentioned but insensitive retrofit procedures.

• Three important preservation principles should be kept in mind when undertaking seismic retrofit projects:
  • Historic materials should be preserved and retained to the greatest extent possible and not replaced wholesale in the process of seismic strengthening
  • New seismic retrofit systems, whether hidden or exposed, should respect the character and integrity of the historic building and be visually compatible with it in design
  • Seismic work should be "reversible" to the greatest extent possible to allow removal for future use of improved systems and traditional repair of remaining historic materials.

Space Planning + Facility Planning/Management

Vocabulary:
• Indigenous/Vernacular Architecture: Specific to a time or place
• Anthropomorphic: relating to human characteristics
• Fathom: measure of the spread of arms
• Room Data Sheets: list all of the relationship requirements in a given room (eg: different rooms of a diagnostic imaging department have different needs, so each would have a
sheet) and include layout, equipment, activity zones, lighting, temperature, and comfort requirements.

- **Assignable area:** the amount of area needed for uses in square feet used for gross area calculations

**Facts/Rules:**
- Gross Area = Net Area (commonly used areas) + circulation (structure/mechanical/service)
  - Include covered which is enclosed by 2+ sides whether attached or detached to the main dwelling unit.
  - Include any covered area on/below the first or main floor when the average height of the 4 corners is more than 6'-0" above natural grade at the exterior
  - Include decks, patios, other usable open areas that are enclosed on 3+ sides (includes 2 walls and a solid roof)
  - Double the sf of any interior space with a ceiling height at 15'-0" or more. Exclude stairwells with no habitable space above/below, and a max of 60 sf of additional space (e.g. entry, atrium, study loft)
  - Include any attic of at least 150 sf and with a ceiling height of at least 7'-6"
- Building Efficiency = Net Area/Gross Area
- Floor Area Ratio (FAR) = Gross Area/Site Area
- Net Area = measured from inside walls
- Gross Area = measured from exterior face of walls
- Penthouses, fan rooms, and skylights are sometimes allowed to exceed height restrictions.

**Concepts/Goals:**
- **Space/Site Planning Hierarchy**
  - **Total Building Group:** all of the buildings in a complex, group or masterplan
  - **Component Building:** an individual building in the group
  - **Activity Center:** spaces related to each other by function
  - **Space Unit:** each individual space within a center
    - Ex: Medical Campus > Acute Care Hospital > Surgery Department > Pre-Op Suite
- **Space/Site Planning Considerations**
  - Relationship between site/structure
  - Response to site conditions (sun/vegetation/wind/sound)
  - Be visible but maintain human scale
  - Express and serve its purpose economically and thoughtfully
  - Utilize technologies and materials appropriately (honest tectonic expression)
  - Use local materials and building techniques
  - Create a hierarchy of parts that is interesting to look at
  - Create a relationship between the interior and exterior
  - Express human spirit and encourage human interaction

**Processes:**
- **Estimate Needs:**
  - Determine total area by calculating the amount of space and time required for each use. (e.g.: how many people need offices and how many hours do they need them, how often is a conference room used and can it be shared with anything else?)
• **Create Planning Diagrams**
  - **Matrix Chart**: numerical values of required relationships (1 = adjacent, 2 = no relationship, 3 = separate) are assigned to each program space with regard to the others.
  - **Bubble Diagram**: before space planning create a loose drawing of circles that indicates required adjacencies, priorities or relationships, and relative sizes.
  - **Block Diagram**: more accurate (but still preliminary) layout of spatial organization based on bubble diagram, but with accurate sizes used.

• **Create Blocking & Stacking Diagrams**
  - **Blocking**: assigning departments to a defined area on a floor based on its desired adjacency and support requirements.
  - **Stacking**: assigning floors/areas of floors to departments based on its desired adjacency and support requirements.

**Fixture, Furniture, Equipment, + Finishes**

**Vocabulary:**
- **Furniture, Furnishings, and Equipment**: Refers to a wide assortment of products that are prefabricated or custom:
  - System furniture
  - Loose furniture
  - Artwork
  - Accessories
  - Millwork
  - Speciality Equipment
  - Custom Lighting
  - Signage
  - Planters
  - Window Coverings
  - Custom Furniture
  - Awnings
  - Audiovisual Equipment

- **Ergonomics**: applied science concerned with designing equipment/furniture to maximize productivity by reducing fatigue and discomfort.
- **Freestanding Furniture**: individual tables, chairs, case goods, that aren’t built in
- **Systems Furniture**: components that can be assembled, configured, and reconfigured to create workstations/workspaces. Includes panels, work surfaces, shelving, storage, and power/data support for computers/communication systems, and other equipment.

**Facts/Rules:**
- Services are applicable to project of all sizes
- The budget for FF&E is about 3-4x Interior design fees.
- Specialized knowledge is required with respect to construction, fabric types, available lines, specification of furniture and fabrics, installation procedures, building codes, regulations in commercial projects.
- Understand client’s budget, and evaluate needs and constraints, to determine starting point for programming.

**Concepts/Goals:**
- Appropriate furniture reinforces the design concept of a building.
- Enhances the overall functionality of the building and influences the way that people use and interact with the space.
- Architects/design firms can offer additional services for FF&E selection/acquisition management.
• Vendors who help owners might not make selections that follow the design concept, choosing instead for low-cost, easily attainable products, that they represent or have hire quota they’re looking to move.

• **Reasons for FF&E Services**
  - To furnish a new space: using new or reconfiguring old for a space.
  - To replace or upgrade existing FF&E: accommodate new/replace outdated technologies
  - To refurbish existing furniture: restore antiques, refinish furniture instead of buying new
  - To expedite FF&E procurement: get things in time for a fast track project
  - To simplify FF&E procurement: assembles FF&E from multiple sources in one coherent package/one single point of sale.

**Processes:**

• **Evaluate Client Needs (FF&E Programming Process)**
  - Identify and document needs for all functional spaces including:
    - Function and types of spaces (personal, common, support)
    - Number of assigned staff
    - Numbers of visitors
    - Types and quantities of items to be stored
    - Signage requirements
    - Desired artwork and interior plantings
    - Quantity, condition, and types of existing furniture to be reused

• **Prepare a Cost Estimate**
  - Line Item breakout of all FF&E to establish budget.
  - Based on current prices of items comparable to those requested
  - Client should approve budget before proceeding so architect has a benchmark for considering products.

• **Select Furniture**
  - Decisions are based on:
    - **Function**: what the client needs
    - **Durability**: how long it should last
    - **Aesthetics**: what will enhance the design
    - **Budget**: how much the client can afford
    - **Style**: what scale/size/proportion is appropriate for the space

• **Prepare Specifications**
  - Include an instruction to bidders with requirements for delivery, installation, warranties, and punch list procedures, and reference/include a furniture plan.
  - 3 types of specifications to choose from:
    - **Proprietary (Closed) Spec**: does not allow for substitution, and typically used to control aesthetics, function, and quality.
      - Identify name, model number, finish type, and submittal requirement.
    - **Descriptive (Open) Spec**: used in competitive bidding, and does not give level of control in closed spec.
      - Describe characteristics, materials, finishes, workmanship, and fabrication of products and give list of comparable manufactures.
    - **Performance Spec**: used with vendors who propose products they think will meet requirements
      - Describe only the desired/required results. Give no characteristics or manufactures.
• **Assemble Bid Package/Solicitation of Bids**
  - Typically a two week process for mid size projects (approx. 20,000 sf.)
  - Allow three weeks for large projects (100+ workstations)
  - Include site factors, elevator access, building access, dumpster/recycling use.
  - Award bid to a single dealer, or divvy up to different furniture, equipment, fixture providers

• **Administer Contract**
  - Owner/Supplier enter into their own contract (much like Owner/Contractor agreement)
  - Supplier sends shop drawings/submittals to architect for review and approval
  - Purchase orders are sent directly to the owner for payment, architect is copied on all correspondence and notified of any issues (long lead time, discontinued items, etc)
  - Architect helps establish installation schedule and arranges for punch list.

• **Oversee Ordering Phase (furniture acquisition process task)**
  - Review supplier’s bid compared to furniture plan/spec to verify consistency
  - Review detailed furniture systems list
  - Review invoices and recommend payment (much like pay app process)
  - Review submittals for finish/fabric selections

• **Oversee Tracking/Scheduling Phase (furniture acquisition process task)**
  - Check acknowledgment for accuracy and complements
  - Record estimated delivery dates
  - Recommend substitutions/change for products with long lead time that might affect move-in date.
  - Coordinate delivery/installation schedule to ensure installation into the completed space or to arrange storage in secure (and bonded) temporary warehouse or storage area.

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**Adaptive Reuse of Buildings and/or Materials**

**Vocabulary:**

- **Embodied Energy**: the sum of all energy required to extract, process, deliver, and install materials needed to construct a building.
- **Mothballing**: term used in historic preservation when you designate certain areas to be repaired or restored at a later date, under a later contract.
- **Adaptive Reuse**: process of adapting old structures for purposes other than those initially intended while retaining their historic features.
- **Preservation**: the act or process of applying measures necessary to sustain the existing form, integrity and materials of an historic property.

**Facts/Rules:**

- Secretary of Interior’s Standards for Rehabilitation:
  - Allow for new additions/alterations to be different from the older structure, but must be complementary in massing, size, scale, and architectural features
  - Criteria must be met if Federal Tax Credits will be used
  - Takes precedence over state/local regulations
  - Clients may discover historical significance during site analysis. Archaeological activity and proper handling of structures/artifacts must take place.
Concepts/Goals:
- Embodied energy in existing buildings
- Benefits of reusing historic/existing buildings are considered based on economic, cultural, design, and embodied energy merits.
- Previously hasn't been addressed much in preservation
- Almost all US embodied energy applications are based on *Energy Use for Building Construction* report written in 1967.
  - Must be careful when using this information when comparing historic building to a new ones, because construction systems for building types has changed.
  - Ceiling heights in historic building are often higher than mid-century, schools in 1967 were one story and made of CMU, brick, concrete slabs while older schools were multi-story with load bearing masonry, wood roof framing, tile floor.
  - Processes for material manufacturing have become more efficient, e.g.: concrete, steel, masonry.
  - Equipment installed in the last 25 years is more efficient in physical make-up and in operation.
- Embodied energy allocation in a building:
  - Manufacture of basic materials and components = 50%
  - Mechanical/Plumbing/Electrical and misc materials = 20%
  - Direct fuel purchases = 15%
  - Administration (retail trade/misc business services) = 11%
  - Transportation of materials = 2.5%
  - Furnishing = 1%
  - Construction machinery/equipment = 0.5%
- Three different methodologies for measuring the embodied energy in historic buildings were developed in *Assessing the Energy Conservation Benefits of Historic Preservation*.
  - Concept Model: a planning approach where various building types are given embodied energy values based on the square footage. Gives a rough estimate.
  - Inventory Model: uses an accurate accounting of the material used in construction. Is more accurate than the concept model.
  - Survey Model: assumes that most of the embodied energy in a building is contained in the bulk of the architectural materials.
- Evaluating the benefits of renovation over new construction also raises the question of calculating how much energy is in building demolition.
- Dismantling a building for salvage recaptures embodied energy.
- Relative value of embodied energy vs operating energy should be more fully investigated for historic structures.
- History building are more likely to be at higher end of the ratio between total embodied energy to annual operating energy because of their use of durable, bulky materials and large volumes.

Processes:
- Define factors affecting the scope of historic preservation including the nature of the effort (will it be preservation, rehab, restoration, or reconstruction?), the applicable regulations, significance of the property, and condition of the structure.
- Team with structural/MEP engineers who have specialized historic preservation experience.
• Complete Preliminary Analysis/Predesign and Research:
  • Documenting existing conditions, programing the intended function/use of the building and site, doing research to investigate historic nature of project/area, determining which parts of the buildings are original and sequence of construction
  • Complete preliminary cost estimate of work to be done, and prepare applications for federal grants.

• Complete Design Phase:
  • Coordinate with standard steps of the building design process
  • Coordinate preservation with architecture/engineering development
  • Coordinate with specification/front end

• Complete Document Phase:
  • Coordinate with drawings, specs, final cost estimate
  • Coordinate with bidding/negotiation phase
  • Coordinate with construction administration, observation, and documentation
  • Reports for maintenance, determination of historic eligibility for review boards may be required

**Architectural History + Theory**

**Concepts/Goals:**

**• Heavy Timber Construction**
  • Wood beams have been used to span roofs and floors of buildings since the beginning of civilization
  • First timber framed buildings were lean-tos, teepees, pit houses, etc
  • Roof and floor timbers were combined with masonry load-bearing walls to build houses and public buildings
  • In the Middle Ages braced wall frames of timber were built for the first time
  • Halftimbering: braced wall framing exposed on the face of the building where the space between the timbers was filled with brickwork or wattle and daub
  • 17th and 18th Century carpenters emigrating to North America brought knowledge of how to build braced frames...for two centuries new construction in North America was hand-hewn wooden timbers joined by interlocking wood to wood connections
  • Nails were rare and expensive and were pretty much only used in door and window frame construction.
  • Until two centuries ago, logs were converted to boards and timbers by hand, a slow and laborious process
  • At the beginning of the 19th century water-powered sawmills began to make the milling process more efficient
  • Contractors switched to sawn timbers as soon as they became available

**• Wood Light Frame Construction**
  • First uniquely American building system
  • Developed in the first half of the 19th Century when builders recognized that the closed spaced vertical members used to infill walls of a heavy timber building where sufficiently strong enough and the heavy posts of the frame could be eliminated
  • Development was accelerated by two technological advances:
    • Water power sawmill
    • Machine made nails (less expensive than hand forged nails)
Masonry Construction
- Began spontaneously by stacking of stones or pieces of caked mud to create low walls
- Mortar was originally mud speared into joints to lend stability and weathertightness
- Stone was originally preferred to brick, when it was unavailable, brick was made from local clays and silts
- By fourth millennium BC people of Mesopotamia were building palaces/temples of stone and sun-dried brick
- Third millennium, Egyptians built first of stone temples and pyramids
- Greeks perfected temples of limestone and marble
- Romans made first large scale use of masonry arches and roof vaults
- Medieval Islamic craftsmen built with masonry and faced with brightly glazed tiles
- Industrial Revolution led to machines, Portland cement mortar coming into use, and greater strength and durable buildings
- 19th century urban buildings became more iron and steel framed
- 19th century invention of hollow concrete block helped stop extinction of masonry
- Brick cavity wall also helped save it which produced warmer, more watertight walls

Steel Construction
- Before the 19th Century metals had little structural role in buildings except as connection devices
- First all metal structure was a cast iron bridge in the late 18th century in England.
- Cast iron and wrought iron were use for framing industrial buildings in Europe and North American in the first half the 19th century, but limited because of the brittleness of cast iron and the high cost of wrought iron
- Steel was rare and expensive until the 1850s
- By 1889 when the Eiffel Tower was built of wrought iron, several steel frame skyscrapers had been erected in the USA

Concrete Construction
- Ancient Romans accidentally discovered a mineral that when mixed with limestone and burned produced a cement
- When mixed with water and sand, it produced a mortar that could harden underwater as well as in the air, and was so much harder, stronger, and cured more quickly than than ordinary lime mortar
- It became the preferred mortar for all their projects and began to alter the character of Roman construction
- Masonry was only the surface layer of piers, walls, vaults and the interiors were filled with this mortar.
- Eventually came to be known as modern portland cement
- Knowledge of concrete construction was lost with the fall of the Roman empire and was not regained until the later part of the 18th Century
- Joseph Aspdin patented portland cement in 1824 after Portland limestone whose durability as a building stone was legendary
- Reinforced concrete was developed in the 1850s by many people, and didn’t become widely used until the end of the 19th century
- Early experiments in prestressing had also begun
CONTENT AREA: ENVIRONMENTAL ISSUES

Hazardous Conditions + Materials

Vocabulary:

- **Asbestos**: Naturally occurring mineral found throughout the world
- **Asbestos Containing Materials (ACM)**: regulated by EPA/OSHA/State/Local Agencies
- **Permissible Exposure Limit (PEL)**: standard that sets the number of asbestos fibers a worker can be exposed to.
- **National Emission Standards for Hazardous Air Pollutants (NESHAP)**: an EPA regulation that dictates requirement of ACM removal before remodel/demo in order to prevent significant asbestos release into the air.
- **Asbestos Hazards Emergency Response Act (AHERA)**: an EPA regulation that handles asbestos found in K-12 schools, and requires that all facilities be inspected to determine the presence and amount of asbestos
- **OSHA**: designed to protect workers who handle ACM and other hazardous materials
- **Lead**: toxic material once used in paint and other household products, found in air from industrial sources, and in drinking water from plumbing materials.

Facts/Rules:

- **Types of Fires**:
  - Type A = Wood, Paper, Plastic, Cloth
  - Type B = Flammable Liquids, Grease, Gas
  - Type C = Electrical
  - Type D = Combustable Metal

- **Types of Fire Extinguishers**:
  - Water Extinguisher = Class A Fires
  - CO² Extinguisher = Class B Fires
  - ABC Extinguisher = Class A, B, or C Fires
  - K Extinguisher = Class B Fires (cooking oil)

- **Asbestos**
  - The three most common types of asbestos found in buildings are:
    - **Chrysotile**: white asbestos, accounts for about 95% of asbestos found
    - **Amosite**: brown asbestos
    - **Crocidolite**: blue asbestos
  - Asbestos was originally used for spray fireproofing, sound proofing, pipe insulation, floor/ceiling tiles, mastic, etc.
  - EPA banned spray application of asbestos containing fireproofing materials in 1973
  - Laboratory analysis is the only way to positively identify asbestos
  - Owner is responsible for cost to identify and remove asbestos.
  - Removal is less of a concern if no children will be living in the building
  - Health Hazards known to exist from exposure:
    - **Asbestosis**: non cancerous chronic respiratory disease caused by accumulation of asbestos fibers in the lungs
    - **Cancer of Lung, Stomach, and/or Colon**
    - **Mesothelioma**: rare cancer in the thin membrane lining the chest and abdomen

- **Lead**
  - Typically lead based paint that is in good condition is not a hazard
Children under 6 are at the greatest risk for lead poisoning
Most common sources for lead poisoning are by breathing or swallowing the following:
  • Deteriorating lead based paint
  • Lead contaminated dust
  • Lead contaminated residential soil

Processes:
  • Methods to minimize/contain asbestos fibers during removal:
    • Wet methods
    • HEPA vacuuming
    • Area isolation
    • Use of Personal Protective Equipment
    • Avoid sawing, sanding and drilling
  • Methods to minimize/contain lead during removal:
    • If disturbing more than 6 sf of lead paint in homes, child care facilities, or a school built before 1978, the work must be done by contractors certified by the EPA to follow procedures for safe removal
    • Contain work area
    • Minimize dust
    • Clean up thoroughly

Indoor Air Quality

Vocabulary:
  • **Indoor Air Quality (IAQ)**: the air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants

Facts/Rules:
  • Most people in western culture spend about 90% of their time indoors
  • Indoor pollutants can be categorized as particulate or gaseous, and include:
    • cooking smokes
    • environmental tobacco smoke
    • oil, gas, kerosene, coal, wood
    • natural dusts
    • molds/allergens (eg: dust mite wastes, pollen, spores, bacteria, viruses)
    • building materials and furnishings
    • asbestos containing insulation
    • wet/damp carpet
    • cabinets/furniture made of certain pressed wood products
    • HVAC and humidification devices
    • radon
    • outdoor air pollution
    • carbon monoxide
    • volatile organic compounds (VOCs)
  • Design strategies:
    • Pollutant source control, user-awareness, local air quality controls and health & safety legislation are important strategies in controlling IAQ
    • Particle removal can be achieved through mechanical air filtration (eg: HEPA, high efficiency particulate air filters) or by means of electronic air cleaners (eg: electrostatic precipitators).
Electronic air cleaners operate differently by applying high voltages to statically charge dust which is then attracted to oppositely charged plates on the cleaner.

Demand controlled ventilation: carbon dioxide sensors are used to control the rate of air changes dynamically, based on the emissions of actual building occupants.

Commercial buildings are often kept under slightly positive air pressure relative to the outdoors to reduce infiltration and help with moisture management and humidity control.

minimize the sources of harmful substances where possible

Geological mapping has been widely used to identify “at risk” areas for radon.

Pathogen destruction can be achieved using UV lamps.

Dilution of indoor pollutants with outdoor air is effective to the extent that outdoor air is free of harmful pollutants.

Ozone in outdoor air occurs indoors at reduced concentrations because ozone is highly reactive with many chemicals found indoors.

Concepts/Goals:
- Traditionally effective infiltration and natural ventilation has been used worldwide to effect a controlled exchange of indoor air to abate IAQ problems.
- Conflicting energy efficiency considerations have resulted in an increase in building “tightness” which adversely impacts infiltration mechanisms and discourages extensive use of natural ventilation.
- Indoor pollution sources that release gases or particles into the air are the primary cause of indoor air quality problems in homes.
- Inadequate ventilation can increase indoor pollutant levels by not bringing enough outdoor air to dilute emissions from indoor sources.
- High temperature and humidity levels can also increase concentrations of some pollutants.
- Generally, outdoor country air is better than indoor city air.
- The worst local air quality problems tend to be around hospitals, shopping areas or public transport hubs where large numbers of vehicles move slowly or idle.

Processes:
- Determination of IAQ involves the collection of air samples, monitoring human exposure to pollutants, collection of samples on building surfaces and computer modeling of air flow inside buildings.

Sustainable Design

Vocabulary:
- **Sustainability**: meeting the needs of the present generation without compromising the ability of future generations to meet their needs.
- **Biophilia**: the connections that humans subconsciously seek with the rest of life.
- **Building Commissioning**: process of ensuring that system are designed, installed, and functionally tested for effective operation/maintenance for an owner’s operational needs.
- **Retrocommissioning**: systematic investigation process applied to existing buildings to improve an optimize operating/maintenance.
- **Life Cycle Costing**: provides a tool for determining long-term costs for the total building.
- **Organic feedstock**: something organic (wood fiber, paper, cotton, etc.) that mold can use as an energy source. Mold cannot eat inorganic materials like concrete, brick, or gypsum (but it loves the paper on drywall!)
• **U-Factor:** measure of heat transmission where a Low U-value has a slow heat loss or gain (brick wall) and a High U-value has a rapid heat loss or gain (window)

• **R-Value:** measure of thermal resistance in a component. \((U-\text{Value} = 1/R-\text{Value})\) and typically the opposite of an U-Value. Used to define level of insulation.

• **Thermal Inertia:** ability of a material to store heat (concrete/masonry walls store heat in an arid climate and release it slowly at night)

• **Design Temperature:** the average temperature that a mechanical system is designed for, either for heating (how cold it gets) or cooling (how warm it gets)

**Facts/Rules:**

• Construction and occupation of structures takes up lost of earth's resources and generates a significant portion of environmental pollution.

• Buildings consume at least 40% of energy used in the world each year and produce 1/3 of the carbon dioxide, and 2/5 of the acid=rain causing compounds.

• Sustainability must be addressed on a life-cycle basis, from the origins of the material through the manufacture/installation, their useful lifetime in the building, and eventual disposal

• **The Natural Step:** an environmental approach that defines conditions for the sustainability of human activities on Earth.
  • Avoid digging stuff from the earth at a rate faster than it naturally replenishes
  • Avoid making stuff at a rate faster than it naturally breaks down into environment
  • Avoid destruction to the planet at rate faster than it takes to re-grow
  • Society moving toward more of well being, happiness, and meeting human needs

• **Leadership in Energy and Environmental Design (LEED):** a rating system for the design, construction, and operation of high performance green buildings, homes, and neighborhoods.
  • Credits are given based on the potential environmental impacts on hum an beginners of each credit. Categories Include:
    • Sustainable Sites
    • Water Efficiency
    • Energy and Atmosphere
    • Materials and Resources
    • Indoor Environmental Quality
    • Innovation in Design (for performance above the requirements set by LEED)

**Concepts/Goals:**

• Principles of Sustainable Design
  • The world has a finite amount of resources
  • Energy cannot be created or destroyed, only recycled
  • All seeks equilibrium and disperses as necessary

**Processes:**

• Minimize use of nonrenewable energy sources and maximize use of renewable energy

• Design in context:
  • Use infill/brownfield sites: reduce development on pristine habitat or farmland
  • Locate projects near public transpiration, and in developed areas
  • Retain/restore waterways on or near the site
  • Use native or adapted plants that don't require maintenance and restore biodiversity
  • Plant trees to reduce heat island effect/offset carbon dioxide from building emissions
• Use vegetated roofs to reduce amount of stormwater runoff, impervious surface area, and heat island effect. Also has a longer lifespan than a conventional membrane roofing system and lower overall maintenance cost
• Use swales/storage basins to reduce storm water runoff
• Avoid petroleum based fertilizers
• Respect natural habitat/local species (be wary of noise, light pollution)
• Design in correct Climate Zone:
  • **Hot & Dry**: minimize sun exposure and effects of wind. Use small windows. Optimize thermal mass for large temperature swing during the day, and closely cluster buildings for the shade they offer each other.
  • **Hot & Humid**: minimize sun exposure, maximize natural ventilation. Use lightweight construction to minimize radiation of heat and space buildings far apart for breezes
  • **Temperate**: maximize solar gain in the winter, minimize in the summer. Maximize breezes in the summer, minimize in the winter. Take advantage of daylighting opportunities
  • **Cold**: orient buildings/openings for maximum protection from cold winds and use small windows/compact shapes to minimize heat loss. Use south facing windows to maximize solar gains.
• **Create Healthy Indoor Environments**
  • Ample daylight and proper ventilation lead to greater satisfaction, more comfort, and increased productivity.
  • Supply fresh outdoor air, use passive ventilation or “Mixed-mode” systems in larger buildings that supply a mix of fresh/mechanical air.
  • Offer natural light and views to the outdoors with windows, skylights, light shelves, and the use of light colors
  • Control temperature and humidity with passive and mechanical technologies that are individually controlled by occupants.
  • Prevent moisture build up.
• **Conserve Water**
  • Reduce potable water use in irrigation and fixtures by using drip-irrigation or low-flow/graywater appliances
  • Use local vegetation that requires minimal or no irrigation
  • Compost
  • Catch rainwater for flushing fixtures, irrigation
  • Treat backwater through an on site living machine so it can be reused
  • Use few impermeable surfaces
• **Use environmentally preferable building materials**
  • Build to the size that is needed and no larger
  • Use materials/systems engineered for maximum efficiency
  • Use durable materials that last longer and with fewer maintenance resources
  • Avoid irreplaceable/engaged resources
  • Use renewable/well managed resources
  • Use recycled/recyclable resources and avoid anything that’s toxic
  • Avoid materials that general pollution during manufacturing, building, use, or disposal
  • Use materials with low embodied energy (how much fossil fuel was used to make it?)
  • Use materials the help conserve energy (thermal mass for energy, light reflective surfaces, radiant barriers, insulation)
• **Plan for the long term**
  • Maximize ecological, social, and economic value over time.
- Build buildings to last (duh!)
- Design for adaptability to accommodate future changes in program and use
- Design for versatility to accommodate future changes in technology
- Design for durability by using materials, construction methods and structural systems that will withstand weather, long term use, and catastrophic events.

**Make changes based on wisdom and user feedback**
- Postoccupancy surveys
- Install equipment to monitor building performance
- Design smaller/simpler buildings with accessible systems and short feedback loops
- Develop a common language of building metrics understood by designers and users (e.g. This building gets xx miles per gallon)
- Develop and share case studies. Don’t hog work, ideas, and findings!!

**Natural + Artificial Lighting**

**Vocabulary:**
- **Lighting:** the deliberate use of light for a desired aesthetic effect, and includes both artificial light sources (lamps and light fixtures) and natural daylight
- **Solar Gain:** the increase in temperature in a space, object, or structure that results from solar radiation.
- **Footcandle:** a unit of illuminance or light intensity. Measured as the illuminance cast on a surface by one-candela source one foot away
- **Lumen:** a measurement of how much light gets to what you want to light

**Facts/Rules:**
- Daylighting is often used as the main source of light during a day to save energy
- Daylight contains both visible and invisible radiation in about equal proportion and both contribute to the heating effect.
- Solar gain increase with the strength of the sun and with the ability of an intervening material to transmit or resist radiation
- Solar controls should be considered for all glazed openings exposed to direct sunlight.
- Solar control is particularly important on south to west-facing facades, since the solar gains will coincide with the hottest part of the day.
- North facing glazing, receives direct radiation in summer
- Solar control devices reduce the total amount of radiation entering a room by reflection and absorption and they improve the distribution of the light in the room
- **Types of Shading:**
  - **Retractable:** moveable devices that can adjust the total transmission of light (eg: shutters, roller blinds, and louvers)
  - **Fixed Redistribution Devices:** fixed devices that obscures part of the sky through which the sun passes (eg: overhangs, lighshelves)
  - **Fixed reduced transmission Devices:** glazed openings are made to have permanently reduced transmission (eg: fixed grids, perforated sheets, tinted/reflective/fritted glass)
  - **Selective High Performance Glazing:** glass that has a lower transmission for the invisible part of the spectrum than the visible, best used with Retractable or Fixed Redistribution Devices
- Location of shading devices can be internal, external or mid-pane
- External devices are the most efficient thermally because solar energy is intercepted before it enters the room
• Internal shading is typically much cheaper to install and easier for users to control, but less efficient and vulnerable to damage.
• Mid-Pane devices are installed in sealed, gas-filled double glazing units.

Passive Solar Building Design
• Windows, walls, and floors are designed to collect, store, and distribute solar energy in the winter and reject it in the summer.
• Doesn’t involve mechanical devices or system.
• Used for space and/or water heating.
• Energy is collected through properly oriented south facing windows.
• Storage of energy is in "thermal mass," building materials with high heat capacity such as concrete slabs, brick walls, or tile floors.

Artificial lighting consumes a significant part of all electrical energy.
• 20 -50% of energy used in residential/business is due to lighting.
• For some buildings over 90% of lighting is unnecessary expense due to overlighting.
• Replacing all incandescent lamps with energy efficient compact fluorescent globally would save 2.5% global energy consumption.
• Building automation and lighting control helps reduce overillumination by creating a centralized system that adjusts levels based on occupancy and use, using sensors, timers, etc.

Concepts/Goals:
• Daylight/sunlight are a single source of natural energy that we need to get into buildings.
• It’s harnessed as daylight for visual tasks and sometime for energy for desired heat gains.
• Energy has to be controlled to prevent overheating and glare.
• Most of the time it’s an on/off situation. If the sun is too bright, the blinds are pulled and the lights turn on, there’s no middle ground.
• So the goal is to modulate it, and possibly to re-distribute it spatially to provide a glare-free working illuminance for a minimum heat gain.
• Lighting energy forms a large proportion of energy consumption in buildings, so it is vital to use daylight whenever it is available.
• Solar gains are a common cause of overheating, and creates a large cooling energy demand.

Processes:
• In warmer countries, where the penetration of direct sunlight is almost always unwanted, traditional architecture often demonstrates elegant solutions – deep reveals overhangs, fins and louvres, and the correct use of them is often part of the unconscious culture.
• Designing lighting systems to minimize energy use can be done by:
  • Designing illumination specific for each room/area rather than an overall scheme.
  • Design space and finishes with lighting in mind.
  • Select fixtures that offer the best energy consumption strategies.
  • Maintain systems to prevent waste.
  • Use natural light whenever possible.
• Load shedding or rolling blackout can help reduce power requested by people to a main power supply. Often done regionally, but can also be done in an individual building.

Alternative Energy Systems + New Material Technologies

Vocabulary:
• **Renewable Energy:** energy that comes from natural resources like sun, wind, rain, geothermal heat and are naturally replenished.
Facts/Rules:

- **Renewable Energy Systems**
  - **Solar:** energy from the sun through the form of solar radiation
    - relies on photovoltaics and heat engines to collect and transmit
    - Can be used in large urban applications or small personal devices
    - Passive Solar: building orientation, materials with thermal mass, passive cooling/ventilation systems
    - Active Solar: photovoltaics, solar thermal collectors
  - **Wind:** airflow is used to run wind turbines
    - As wind speed increases so does the power output (to a max output based on the turbine).
    - Locations with strong and consistent winds are the best, typically offshore and high altitude
    - The Columbia River Gorge past The Dalles is a great spot for it.
    - Long term potential is greater than current systems
  - **Hydro:** energy found in water flow.
    - Running water spins generators, typically in dams, that is converted into power
    - Can be large like the Grand Coulee dam, or small systems in rivers for local power
  - **Biomass:** energy from plant materials.
    - Photosynthesis captures sun's energy and is released when the plant is burned
  - **Geothermal:** energy generated and stored in the earth.
    - Collected with a system of pipes that run underground and routed to a building.
    - Can be used in large commercial buildings or in residential applications

- **Innovative Building Products (just a few cool ones...there are countless.)**
  - Insulating Concrete forms are permanent formwork that have expanded polystyrene in interlocking CMU-like blocks. After the concrete cures it stays in place to bump up the insulating properties/r-value of the wall
  - External wall paints that are self cleaning and repel dirt, reduces maintenance costs and chemical runoff of cleaning products
  - Concrete adhesive repair material can be embedded in similarity brittle hollow fibers in the concrete. When a crack occurs, the adhesive is released and penetrates the fissures creating a new bond. It’s basically an infusion of structural integrity
  - White roofing material repels heat better than traditional black material

Concepts/Goals:

- Climate change, peak oil, and cost of conventional energy systems is driving factor behind finding new energy options and making them affordable
- Innovative and smart materials can reduce a building’s energy conception by maintaining stable temperatures without the need for air conditioning
CONTENT AREA: CODES + REGULATIONS

Government + Regulatory Requirements + Permit Processes

Vocabulary:

- **Prescriptive Code:** Building code that specifies techniques, materials and methods to be used. Cut and dry and simple to administer by the official
- **Performance Code:** Building code that describes functional requirements, but leave method to achieve decisions up to the designer.
- **Fire resistance:** values for how long a separation can resist the passage of fire. Stated in terms of hours and can be increased with the use of sprinklers. (eg: walls, doors, windows, floors, etc.)
- **Flame Spread Rating/Smoke Developed Ratings:** measures the amount of flame and smoke a material generates. (e.g. Carpet, fabrics, etc)
- **Area of Refuge:** a location designed to hold occupants when evacuation is not safe or possible. Has a steady supply of outside air, passive fire protection, electrical integrity/ emergency lighting, two way communication/call box to 24 hr manned, or outside line
- **Fire walls:** walls that divide a single building into two or more “buildings”, if either side collapses the wall will not for the duration of its rating
- **Fire barriers:** make up rated assemblies/enclosures (e.g.: shafts, exit enclosures, exit passageways, horizontal exits, atriums, mixed use occupancy separation)
- **Shaft enclosures:** openings through floors/ceilings connecting adjacent floors. 1 hour rated when connecting less than 4 stories, or 2 hour if passing through a 2 hour floor assembly or if connecting 4 or more stories
- **Fire Partitions:** demising walls separating tenants, residential units, corridor walls,
- **Smoke Barrier:** used as required to prevent the movement of smoke, have a 1 hour fire resistance rating
- **Smoke Partition:** like a smoke barrier, but does not have to resist fire
- **Horizontal Assemblies:** fire resistance rating (1 or 2 hours) applied to floor and roof construction
- **Incombustible:** consisting of or made of material that will not burn if exposed to fire

Facts/Rules:

- Legal restrictions on building begin with local zoning ordinances which govern the types of activities that ay take place on a given piece of land.
  - E.g.: setbacks, number of parking spaces, floor area ratio, fire zone
- Each local government regulates building code to protect the health and safety of public primarily from fire.
- Most building codes in north america are based on the model building code (National Building Code in Canada or International Building Code in US)
- **International Building Code (IBC)**
  - Begins by defining occupancy groups, the purpose of which is to distinguish various degrees/qualities of need for safety in a building.
<table>
<thead>
<tr>
<th>Group</th>
<th>Name</th>
<th>Includes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1 - A-5</td>
<td>Assembly Occupancy</td>
<td>Theaters, auditoriums, lecture halls, night clubs, restaurants, houses of worship, libraries, museums, sports arenas, etc.</td>
</tr>
<tr>
<td>B</td>
<td>Business Occupancy</td>
<td>Banks, admin offices, higher-education facilitates, police/fire stations, post offices, etc.</td>
</tr>
<tr>
<td>E</td>
<td>Educational Occupancy</td>
<td>K - 12 schools and day care facilities</td>
</tr>
<tr>
<td>F</td>
<td>Industrial Occupancy</td>
<td>Industrial Buildings</td>
</tr>
<tr>
<td>H1 - H5</td>
<td>High Hazard Occupancy</td>
<td>Toxic, combustible, or explosive materials present</td>
</tr>
<tr>
<td>I-1 - I-4</td>
<td>Institutional Occupancy</td>
<td>Healthcare, geriatric, or other spaces where occupants would not be able to save themselves during a fire/emergency</td>
</tr>
<tr>
<td>M</td>
<td>Mercantile Occupancy</td>
<td>Stores, markets, service stations, sales rooms</td>
</tr>
<tr>
<td>R-1 - R4</td>
<td>Residential Occupancy</td>
<td>Apartment buildings, dorms, frats/sororities, hotels, 1 or 2 family dwellings, assisted living facilities</td>
</tr>
<tr>
<td>S1</td>
<td>Storage Occupancy</td>
<td>Storage of hazardous materials</td>
</tr>
<tr>
<td>S2</td>
<td>Storage Occupancy</td>
<td>Storage of low-hazardous materials</td>
</tr>
<tr>
<td>U</td>
<td>Utility/Miscellaneous Occupancy</td>
<td>Agriculture buildings, carports, greenhouses, sheds, stables, fences, tanks, towers, other secondary buildings</td>
</tr>
</tbody>
</table>

- Buildings are classified by different Construction Types, which prescribe the fire resistance rating of the elements and the exterior wall.
- A building (or a portion of it) doesn’t have to meet a construction type height than the minimum requirements based on the occupancy, even if features of the building actually conform to a higher type of construction:

<table>
<thead>
<tr>
<th>Type</th>
<th>Includes</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>Building elements are of noncombustible materials</td>
<td>IA = 3 hour fire rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IIB = No fire rating</td>
</tr>
<tr>
<td>Type II</td>
<td>Building Elements are of noncombustible materials</td>
<td>IIA = 1 hour min. Fire rating</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IIB = No fire rating</td>
</tr>
<tr>
<td>Type</td>
<td>Includes</td>
<td>Rating</td>
</tr>
<tr>
<td>------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>Type III</td>
<td>Exterior walls are of noncombustible materials, interior elements are of</td>
<td>IIA = 1 hour min rating w/2 hr exterior</td>
</tr>
<tr>
<td></td>
<td>any material allowed by code</td>
<td>bearing walls</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IIIB = Unrated interior w/2 hr exterior</td>
</tr>
<tr>
<td></td>
<td></td>
<td>bearing walls</td>
</tr>
<tr>
<td>Type IV</td>
<td>Heavy Timber. Exterior walls are of noncombustible materials, interior</td>
<td></td>
</tr>
<tr>
<td></td>
<td>elements are of solid or laminated wood without concealed spaces</td>
<td></td>
</tr>
<tr>
<td>Type V</td>
<td>Structural elements, exterior, and interior walls are of any materials</td>
<td>VA = 1 hr exterior bearing walls</td>
</tr>
<tr>
<td></td>
<td>allowed by code</td>
<td>VB = No fire rating</td>
</tr>
<tr>
<td>A</td>
<td>Protected / Fire Resistance Rated Construction: All structural members</td>
<td></td>
</tr>
<tr>
<td></td>
<td>have additional fire rated coating/cover such as sheetrock, or spray on</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fireproofing. Extends the fire resistance rating of structure members by</td>
<td></td>
</tr>
<tr>
<td></td>
<td>at least an hour.</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Unprotected / Non-Fire Resistance Rated Construction: All structural</td>
<td></td>
</tr>
<tr>
<td></td>
<td>members have no added coating/cover. Exposed members are only fire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>resistant according to their natural ability or characteristic.</td>
<td></td>
</tr>
</tbody>
</table>

- For example, a building would be defined as Type IIA, Type VB, etc.
- Type IV Heavy Timber is just that...there’s no A or B protection.
- Type IA has the highest fire resistance rating, while VB has the lowest.
- Sprinklered buildings are fully protected by a complete fire sprinklers system in accordance with the NFPA.
- Unsprinklered buildings are not protected by a fire sprinkler system (duh.)
- If a building is protected throughout with an approve sprinkler system the IBC allows the tabulated area of a single story building to be quadrupled, and of multi story buildings to be tripled.
- If more than 1/4 of a building's perimeter walls face public way/opens space an increase in area is granted per a formula.
- If building is divided by fire walls and meets required fire resistance ratings each portion of the building that is separated from the reminder of the building by fire walls can be considered a separate building for purposes of calculating allowable area.
Basically a building can be a LOT bigger than the IBC table would normally be allowed.

- **Allowable building area and limitations** are Based on the Occupancy Type, if multiple uses are separated, and the construction type
- IBC also establishes standards for natural light, ventilation, means of egress, structural design, floor/wall/ceiling/roof construction, chimney construction, fire protection systems, accessibility, energy efficiency, etc…

**Building Egress**

- Egress is comprised of three parts:
  - **Exit Access:** the portion of a means of egress system that leads from any occupied portion of the building to an exit.
  - **Exit:** the portion of a means of egress system that is separated from other occupied spaces by fire-rated construction, and extends between the exist access and the exist discharge. Horizontal exist are ok.
  - **Exit Discharge:** the portion of a means of egress system between the exit and a public right of way

- **Horizontal Exits:** a path of egress travel from one part of a building to another part of a building on the same level, which affords safety from fire and smoke
- **Exit Passageway:** similar to an exit, but horizontal, and leads to the exit discharge
- Egress is regulated by the number of occupants and is based on the function of the space
- Aisles, stairs, and doors are sized by multiplying the occupant load by the Egress Width per Occupant table from the IBC (it’s usually 0.2’/person for stairs in a sprinklered building)
- Number of exits required from a space and a building is prescribed in the code. Generally at least 2 means of egress are required...unless there are more than 500 occupants, then more are required.
- For typical commercial uses, the threshold for needing more than one exist is 50 occupants
- Number of exits may be influenced by Travel Distance to an exist, or the length of the common path of travel to an exit
- When two or more exits are required, they must be separated by 1/2 the diagonal dimension of the building (1/3 for sprinklered buildings)
- Fire ratings for corridors are regulated by the IBC. Typically, commercial buildings with a sprinkler system don’t require a corridor rating.
- Residential buildings require a 30 minute corridor
- At least one accessible means of egress is required, which involves an elevator, stair, ramps and areas of refuge
  - An **Area of Refuge** is required for each 200 occupants and must be 30” x 48” in an area protected from fire and smoke

**Life-Safety Code (NFPA 101) Guidelines**

- Not a legal code, but written like one to facilitate adoption into law by cities
- Addresses construction, protection, and occupancy features necessary to minimize danger to life from fire including smoke, fumes, or panic.
- Does not address general fire prevention or building construction features that are normally part of fire/building codes.
- Applies to existing and new structures
- Is a source for determination of liability in accidents
• Groups flame spread ratings (materials propensity to burn rapidly and spread flames) into 5 classes:
  - Class A flame spread rating = 0-25
  - Class B flame spread rating = 26-75
  - Class C flame spread rating = 76-200
  - Class D flame spread rating = 201-500
  - Class E flame spread rating = over 500

• A flame spread rating number is the relative rate at which flame will spread over the surface of a material, as compared with flame spread on asbestos-cement board (rated zero) and on red oak (rated 100).

• Flame spread rating number is not the rate at which the flame actually spreads along the surface and is not an indication of the fire resistance of the material.

• American Society for Testing and Materials ASTM
  • establishes standard specifications for commonly used materials of construction.
  • Generally referred to by number (eg: C150 = specification for portland cement)
  • numbers are frequently used in specifications for specific/precise shorthand designation for the quality of material that is required.

• American National Standards Institute (ANSI)
  • develops standards for many industrial products (eg: aluminum windows, mechanical components of buildings)

• MasterFormat/Construction Specifications Institute (CSI)
  • a standard for organizing information about construction materials and components.
  • MasterFormat is used as the outline for project specifications
  • In 2004 the system was updated from 16 divisions to 50 divisions

<table>
<thead>
<tr>
<th>Division</th>
<th>Includes</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>Procurement &amp; Contracting Requirements</td>
</tr>
<tr>
<td>01</td>
<td>General Conditions</td>
</tr>
<tr>
<td>02</td>
<td>Existing Conditions</td>
</tr>
<tr>
<td>03</td>
<td>Concrete</td>
</tr>
<tr>
<td>04</td>
<td>Masonry (Concrete Block/Brick)</td>
</tr>
<tr>
<td>05</td>
<td>Metal (Beams)</td>
</tr>
<tr>
<td>06</td>
<td>Wood, Plastics, and Composites (Framing)</td>
</tr>
<tr>
<td>07</td>
<td>Thermal and Moisture Protection (Insulation, Water/Vapor Barriers)</td>
</tr>
<tr>
<td>08</td>
<td>Openings (Doors, Frames, Windows, Louvers)</td>
</tr>
<tr>
<td>09</td>
<td>Finishes (Gyp Board, Flooring, Ceilings)</td>
</tr>
<tr>
<td>10</td>
<td>Specialties (Signage, Toilet Accessories, Fireplaces, Storage, etc.)</td>
</tr>
<tr>
<td>11</td>
<td>Equipment (HVAC, Security, Kitchen, Entrainment, Athletic, Healthcare, etc)</td>
</tr>
<tr>
<td>Division</td>
<td>Includes</td>
</tr>
<tr>
<td>----------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>12</td>
<td>Furnishings (Art, Blinds, Casework, Seating)</td>
</tr>
<tr>
<td>13</td>
<td>Special Construction (Pools, Fountains, Aquariums, Amusement Parks, Ice Rinks, etc.)</td>
</tr>
<tr>
<td>14</td>
<td>Conveying Equipment (Elevators, Escalators, etc)</td>
</tr>
<tr>
<td>15 - 20</td>
<td>Reserved for Future Use</td>
</tr>
<tr>
<td>21</td>
<td>Fire Suppression</td>
</tr>
<tr>
<td>22</td>
<td>Plumbing</td>
</tr>
<tr>
<td>23</td>
<td>Heating Ventilating, and Air Conditioning (HVAC)</td>
</tr>
<tr>
<td>24</td>
<td>Reserved for Future Use</td>
</tr>
<tr>
<td>25</td>
<td>Integrated Automation</td>
</tr>
<tr>
<td>26</td>
<td>Electrical</td>
</tr>
<tr>
<td>27</td>
<td>Communication (T1/DSL/Cable/Satellite Data and Voice Services and Equipment)</td>
</tr>
<tr>
<td>28</td>
<td>Electronic Safety and Security (Fire Detection, Video Surveillance)</td>
</tr>
<tr>
<td>29 - 30</td>
<td>Reserved for Future Use</td>
</tr>
<tr>
<td>31</td>
<td>Earthwork</td>
</tr>
<tr>
<td>32</td>
<td>Exterior Improvements</td>
</tr>
<tr>
<td>33</td>
<td>Utilities</td>
</tr>
<tr>
<td>34</td>
<td>Transportation</td>
</tr>
<tr>
<td>35</td>
<td>Waterway and Marine</td>
</tr>
<tr>
<td>36 - 39</td>
<td>Reserved for Future Use</td>
</tr>
<tr>
<td>40</td>
<td>Process Integration</td>
</tr>
<tr>
<td>41</td>
<td>Material Processing and Handling Equipment</td>
</tr>
<tr>
<td>42</td>
<td>Process Heating, Cooling and Drying Equipment</td>
</tr>
<tr>
<td>43</td>
<td>Process Gas and Liquid Handling, Purification and Storage Equipment</td>
</tr>
<tr>
<td>44</td>
<td>Pollution Control Equipment</td>
</tr>
<tr>
<td>45</td>
<td>Industry Specific Manufacturing Equipment</td>
</tr>
</tbody>
</table>
### Division

<table>
<thead>
<tr>
<th>Division</th>
<th>Includes</th>
</tr>
</thead>
<tbody>
<tr>
<td>46</td>
<td>Water and Waterwaste Equipment</td>
</tr>
<tr>
<td>47</td>
<td>Reserved for Future Use</td>
</tr>
<tr>
<td>48</td>
<td>Electrical Power Generation</td>
</tr>
<tr>
<td>49</td>
<td>Reserved for Future Use</td>
</tr>
</tbody>
</table>

### Concepts/Goals:
- The purpose of the code is to protect public health, safety, and welfare
- Accessibility services scope can vary depending on the size of the client, their organization, and the project.
- Name recognition matters...large, public, visible companies are more vulnerable to lawsuits so need to be prepared for issues.

### Specialty Codes + Regulations including Accessibility Laws, Codes, + Guidelines

#### Vocabulary:
- **Americans with Disabilities Act (ADA):** prohibits discrimination based on disability
- **Building Owners and Managers Association (BOMA):** professional organization that for commercial real estate professionals
- **Fair Housing Act:** law that prohibits housing discrimination on the basis of race, color, religion, sex, disability, familial status, and national origin.
- **HUD:** US Department of Housing and Urban Development

#### Facts/Rules:
- **Fair Housing Act Guidelines:**
  - Covers most housing (owner-occupied building with 4 or less units, single family houses sold/rented by owner, and housing run by clubs that limit occupancy to members are sometime exempt)
  - Requirements for New Buildings with 4 or more units and an elevator:
    - Public common area must be accessible
    - Doors and hallways mush be wide enough for a wheelchair (32”-36” min)
    - All units must have:
      - An accessible rough into and through the unit
      - Accessible light switches, electrical outlets, thermostats, etc
      - Reinforced bathroom walls to allow later installation of grab bars
      - Kitchens/bathrooms can be used by people in a wheelchair
    - These rules do not replace more stringent state/local codes
- **ADA Accessibility Guidelines:**
  - All new design or new construction areas must meet accessibility requirements
  - Includes all employee work area and temporary construction that is open to the public
  - Some areas are not require to be accessible:
    - Temporary construction facilities (e.g. Job shacks, scaffolding, trailers)
    - Raised areas used for security/life safety (e.g. Security or life guard towers)
• Non-occupiable service areas accessed infrequently for maintenance (e.g. Mechanical rooms, penthouses)
• Tollbooths
• Water slides
• Non-public animal containment areas
• Raised structures for officiating/announcing sports events

**Dimensional Standards:**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheelchair Passage Width</td>
<td>32” clr at a point/36” clr continuous</td>
</tr>
<tr>
<td>2 Wheelchair Passing Width</td>
<td>60” clr min</td>
</tr>
<tr>
<td>Headroom</td>
<td>80” min</td>
</tr>
<tr>
<td>Turning Space</td>
<td>5’-0” circle min</td>
</tr>
<tr>
<td>Clear floor space</td>
<td>2’-6” wide x 4’-0” long min</td>
</tr>
<tr>
<td>Changes in levels</td>
<td>1/4” max w/o edge treatment</td>
</tr>
<tr>
<td>Beveled Edge Ok</td>
<td>1/4” – 1/2” w/ 1:2 max slope</td>
</tr>
<tr>
<td>Requires Ramp</td>
<td>1/2” or more</td>
</tr>
<tr>
<td>Doors</td>
<td>32” clr min when open 90 deg</td>
</tr>
<tr>
<td>Door clearance</td>
<td>1’-6” clr on pull side of door</td>
</tr>
<tr>
<td>Accessible route cross slope</td>
<td>1:50 max</td>
</tr>
<tr>
<td>Ramps</td>
<td>1:20 min to 1:12 max</td>
</tr>
<tr>
<td>Slope</td>
<td>3’-0” wide</td>
</tr>
<tr>
<td>Width</td>
<td>30’-0” max</td>
</tr>
<tr>
<td>Length</td>
<td>5’-0” at each end (width of ramp)</td>
</tr>
<tr>
<td>Landings</td>
<td>If rise is +6” or run is +72”</td>
</tr>
<tr>
<td>2 Handrails</td>
<td>34” min - 38” max</td>
</tr>
<tr>
<td>Handrail Height</td>
<td>1-1/4” - 2” and 1-1/2” clr from wall</td>
</tr>
<tr>
<td>Handrail Cross Section</td>
<td>12” top and 12”+ 1 tread bottom</td>
</tr>
<tr>
<td>Handrail Extension</td>
<td>48” clr between hand rails min</td>
</tr>
<tr>
<td>Stairways</td>
<td>1:20 max (5%)</td>
</tr>
<tr>
<td>Walkways</td>
<td>3’-0” sides 1:10 max, front 1:12</td>
</tr>
<tr>
<td>Curb Cuts</td>
<td>9’-0” wide with 5’-0” wide aisle</td>
</tr>
<tr>
<td>Car Parking Space</td>
<td>11’-0” wide min w/5’-0” wide aisle</td>
</tr>
<tr>
<td>Van Parking Space</td>
<td>200’-0” max from building entrance</td>
</tr>
<tr>
<td>Parking Space Location</td>
<td>2 accessible spaces</td>
</tr>
<tr>
<td>7 - 50 car lot</td>
<td>3 accessible spaces</td>
</tr>
<tr>
<td>51 - 100 car lot</td>
<td>5 accessible spaces</td>
</tr>
<tr>
<td>101 - 150 car lot</td>
<td></td>
</tr>
</tbody>
</table>

**Concepts/Goals:**

- Accessibility services scope can vary depending on the size of the client, their organization, and the project.
- Name recognition matters...large, public, visible companies are more vulnerable to lawsuits so need to be prepared for issues.

**Processes:**

- Identify client’s potential accessibility problem areas and desired outcomes
- Identify strategies for correcting problems including a proposed implementation schedule and budget/cost analysis
- Develop prototype design details for implementation
- Prepare and administer surveys if required to assess population using building
- Prepare client training program manuals and facility monitoring documentation
Masonry

Vocabulary:
• **Brick**: Rectangular masonry unit molded from clays and shales, dried and fired in a kiln.
• **Veneer**: Exposed masonry attached, but not structurally bonded, to the backing.
• **Efflorescence**: White powdery deposit caused by soluble salts from water penetrations.
• **Corbel**: A projection of brick jutting out from a wall to support a structure above it.
• **Point**: Filling joints to the face with mortar and tooling them to the desired profile.
• **Needle Beam**: A temporary member thrust under a building or foundation used in underpinning.

Facts/Rules:
• **Mortar**
  • Made of portland cement, hydrated lime, an inert aggregate (sand), and water.
  • Sand must be clean and screened to get out particles that are too coarse or fine.
  • Portland cement is “harsh” meaning that it doesn’t flow well on a trowel or under a brick….lime is added to impart smoothness and workability.
  • Lime is made by burning limestone or seashells in a kiln to drive of CO$_2$ and leave quicklime, which is then allowed to absorb as much water as it will hold. This is called hydrated lime. It’s dried, ground, and bagged for shipping.
  • Makes up about 20% of the exposed surface of a brick wall.
  • Types M or S: For masonry that is load-bearing and/or exposed to the weather.
  • Types N and O: Lesser compressive strength required.
  • Serves to cushion the masonry units and allow them to bear fully against one another despite surface irregularity.
  • Seals between the units to keep water and wind from penetrating.
  • Adheres units to one another to bond them into a monolithic structural unit.
  • Portland cement mortar cures by hydration, not by drying. A set of chemical reactions take up water and combine it with the cement and lime to create a dense, strong crystalline structure that binds sand particles and masonry units together.
  • If mortar is mixed less than 90 minutes prior to its stiffening it has only dried and a mason can safely retemper it with water to make it workable again (note, this is not the case with concrete!).
  • Mortar older than 2 1/2 hours must be discarded because it has begun to hydrate and can’t be retempered without reducing its final strength.

• **Brick Masonry**
  • A product of fire…and therefore most resistant to fire.
  • A traditional brick is shaped and dimensioned to fit the human hand.
  • Produced by factories all over the place with local clay and shale. It’s expensive to ship long distances because it’s so heavy.
  • Molding methods:
    • Soft mud process: (oldest method) relatively moist clay is pressed into simple rectangular molds.
    • Dry-press process: use for clays that shrink excessively during drying, clay mixed with water is pressed into steel molds by a machine working at high pressure.
• Stiff mud process: high-production, most widely used, clay with water is extruded and sliced by wires to form brick
• After molding bricks are dried for 1-2 day sin a low temp dryer kiln and then fired
• Entire process of firing takes about 40 - 150 hours
• There's no truly standard brick size. The most common is 8” x 3 5/8” x 2 1/4”
• Use of larger bricks can lead to substantial economies in construction
• Brick shapes can be solid, cored, hollow, or frogged
  • Reducing the volume of a brick reduces fabrication, transportation costs
• ASTM testing procedures establish three grades of brick based on resistance to weathering and three types of facing bricks, bricks that will be exposed to view, based on the degree of uniformity in shape, dimension, texture, and color from one brick to the next
  • Grades for Building and Facing Bricks
    • Grade SW: Sever Weathering (Oregon, most of the Eastern half of US)
    • Grade MW: Moderate weathering (Midwest, most of Washington)
    • Grade NW: Negligible weathering (Along southern US border)
  • Types of Facing Bricks
    • Type FBX: High degree of perfection, narrow color range, slight size variation
    • Type FBS: Wide range of color and greater size variation per unit
    • Type FBA: Non uniformity in size, color, and texture per unit
• Laying Bricks
  • Wythe: simplest wall, a vertical layer of masonry units one unit thick
  • Course: a horizontal layer of bricks or other masonry units
  • stretcher: a brick laid with its face parallel to the wall and its long dimensions horizontal
  • Header: a brick laid to bond two wythes together
  • Solider: brick laid on its end with its face (long skinny side) parallel to the wall
  • Sailor: brick laid on its side with its end parallel to the wall
  • Rowlock: brick laid on its face with its end (short skinny side) visible in the wall. Often used for caps on walls and floor sloping sills under windows
• Structural bonds for brickwork
  • Running bond: entirely of stretchers
  • English Bond: alternates course of headers and stretchers
  • Common Bond: header course every sixth course, head joints are aligned between the header and stretcher courses
  • Flemish Bond: alternates headers and stretchers in each course
  • Expansion joints are required when structure is over 200' long or where wings occur
  • Speed is essential to the economy of masonry
  • Mortar joints can bray in thickness from 1/4" - 1/2"
  • Joints in brickwork are tooled 1 - 2 hours after laying as the mortar begins to harden, and must be appropriate for the weather condition the wall is located in.
  • Outdoor joints mush shed water away from the wall and resist freeze-thaw damage
  • Bricklaying should occur during temperatures between 40 and 90 F

Ok for Outside Applications
Weathered joint
Concave joint
Vee joint
Flush joint

Ok for Indoor Applications
Raked Joint
Stripped joint
Struck joint
Flush joint
• Brick should be wetted prior to setting to minimize absorption of water from the mortar for a better bond
• Should be set on a full bed of mortar
• There are three types of lintels for spanning openings in brick walls
  • Double angle steel: hardly visible in finished wall
  • Reinforced brick lintel: works like a reinforced concrete beam and is not visible
  • Precast reinforced concrete lintel: totally visible
• The brick arch is so widely used and structurally and symbolically powerful
• Types of arches:
  - Segmental
  - Jack
  - Tudor
  - Elliptical
  - Roman
  - Gothic
  - Parabolic
• Reinforced brick masonry consists of 2 wythes of brick separated by a 2" - 4" with vertical and horizontal rebar filled with grout in the middle
  • Grout is portland cement, aggregate, and water
  • Must be fluid enough to flow readily into narrow cavity and fill it completely

• Stone Masonry
• Building stone is obtained by taking rock from the earth and reducing it to the required shapes and sizes for construction
  • Igneous rock: rock that was deposited in a molten state (granite, basalt)
  • Sedimentary rock: deposited by the action of water and wind (limestone, sandstone, brownstone)
  • Metamorphic rock: formerly either igneous or sedimentary rock transformed by heat or pressure (marble, soapstone, slate)
• Stone is used in two fundamentally different ways in buildings:
  • Laid in portland cement mortar like bricks or concrete blocks. Avoid moisture penetration
  • Mechanically attached in large sheets to the structural frame and walls as thin facing (less common)
• Types of stone classification:
  • Rubble: unsquared pieces of stone
  • Ashlar: squared pieces of stone
  • Coursed: continuous horizontal joint lines
  • Uncoursed/Random: no horizontal lines
• Stone blocks are often used as exterior facing with a concrete masonry backup wall
• Stonework must stay clean, flashings must be plastic or nonstaining metal, work is kept covered as much as possible
• Stonework can only be cleaned with mild soap, water, and a soft brush
• Masonry accessories and anchors include:
  • Strap anchors: galvanized steel attachment
  • Dovetail anchors: splayed tenon that fits into the recess of a corresponding mortise
  • Cramp anchors: used under coping stones at vertical joints to tie 2 stones together
  • Pin anchor: anchor placed into a drilled hole and a pin is hammered in
  • Threaded dowel: used at vertical/horizontal joints between panels to align and maintain distance between panel and backup structure

• Concrete Masonry Units (CMU’s)
• Stiff concrete mixture is placed in steel molds, cured, and quickly dried.
• Includes concrete brick, concrete block, concrete tile, and cast stones
Typical concrete block size is 7 5/8” x 7 5/8” x 15 5/8”
Many colors and surfaces types are available
Hollow concrete block masonry is generally more economical per unit of wall area than brick or stone masonry.
- Blocks are cheaper on a per unit basis and made into a wall more quickly because of their size
- Widely used in masonry bearing wall construction due to strength and insertion of rebar and grout into cores
- Often used as a backup wythe behind brick or stone facing, or stucco, plaster, tile
- Single wythe exterior concrete masonry walls tend to leak in wind driven rains
- Exterior should be painted with masonry paint
- Walls subject to moderate stresses can be reinforced horizontally with steel joint referencing which is thin enough to fit into an ordinary bed joint of mortar
  - Vertical reinforcing is done with ordinary reinforcing bars grouted into the cores of the blocks
- Lintels for concrete block are comparable to those of brick masonry:
  - Steel lintel: wide flanged section welded to a plate
  - Reinforced block lintel: made of bond beam units filled with grout and rebar
  - Precast reinforced concrete block lintel: totally visible
- Decorative CMUs
  - Easily made in a variety of surface patterns, textures, colors, interior/exterior applications
  - Include scored face, ribbed face, fluted face, angular face, etc.

**Other Types of Masonry Units**
- Glass blocks: solid or hollow and based on a 4” module.
  - Not structural, and limited in area, height, and length
- Gypsum Block/Tile: made from gypsum plaster and available in 2” - 6” thick panels
  - Interior, non load bearing partitions and fireproofing protection
- Structural Clay Tile: hollow burned clay masonry units, architectural terra cotta is clay tile in various colors
  - Ceramic veneer is terra cotta in large face dimensions, thin sections and glazed finishes

**Loadbearing Masonry Wall Construction**
- Three different wall types
  - Either reinforced or unreinforced
  - Either 1 type of masonry or a composite of 2+ types of blocks
  - Either a solid masonry wall or a masonry cavity wall
- Reinforced Masonry Walls
  - Unreinforced walls can't carry such high stresses as reinforced walls and are unsuitable for high seismic areas
  - Top floor walls support only the load of the roof, below that the walls support the loads of the roof, the the top floor, and top floor walls...and so on down the building
  - That’s why mansard walls must be thicker at the bottom than the top (e.g.: the Monadnock building in Chicago)
  - With steel reinforcing, the thickening can be reduced or eliminated (saving labor and materials costs too!) and allowing a much taller building
  - When designing a composite masonry wall the designer should ensure that the differences in the thermal or moisture expansion characteristics of the two materials are not sufficient to cause warping or cracking of the material
Solid or composite walls are seldom used for exterior walls because they must be able to resist water penetration and heat transfer.

- Are usually built with internal cavities.
- Cavities are spanned by corrosion resistant metal ties that hold the wythes together.
- When water passes through an outer wythe and into a cavity, it has nowhere to go but down... it falls and is caught by an impervious membrane called **flashing** and drains out a **weep hole** at the bottom of the wall.
  - Weep holes are located at 24” apart in brick and 32” apart in concrete masonry.
  - Weep holes are about 1/4” diameter minimum.
- Cavity must be kept free of construction debris, brick chips, and/or mortar droppings so water can drain properly.

**Flashings**

- **External Flashings**: prevent moisture from penetrating into the masonry wall where the wall intersects the roof.
  - At the intersection of a flat roof and wall parapet, it’s constructed in two overlapping parts, a base flashing and a counterflashing or cap flashing.
  - Allows for some movement between the wall and roof components.
  - Base flashing should be turned up for at least 8” tall.

- **Internal (Concealed) Flashings**: catch water that has penetrated a masonry wall and drain it through weep holes to the outdoors.
  - Required at every location where the cavity is interrupted (e.g.: window heads, door heads, window sills, shelf angles, spandrel beams).
  - Installed by masons that construct the wall.
  - Should be turned up 6” - 9” at the interior face of the wall.
  - Should penetrate at least 2” into the interior wythe.

- Can be made of sheet metal, plastic, elastomeric compounds, or composite material.
  - Sheet metal is the most durable and most expensive.
  - Copper and stainless steel is best.
  - Galvanized steel eventually rusts and disintegrates.
  - Aluminum and lead are unsuitable because they react chemically with mortar.
  - Plastics are the least expensive, some are good, some are bad.

**Thermal Insulation of Masonry Walls**

- Solid masonry wall is a good conductor of heat...it’s a poor insulator.
- In hot, dry climates, the capacity of an uninsulated masonry wall to store heat and retard its passage is effective in keeping the inside of the building cool during the day and warm at night.
- In cold climates, thermal resistance must be improved. Introducing an empty cavity into a wall helps, but not enough.
- Three general ways of insulating masonry walls.
  - On the outside face: using an Exterior Insulating and Finish System (**EIFS**).
    - Consists of panels of plastic foam that are adhered to the masonry and covered with a thin continuous layer of polymeric stucco reinforced with glass fiber mesh. It looks like stucco (it doesn’t work in the Northwest, lots of moisture means they are prone to failure).
  - Within the wall: if the cavity is wide enough, slabs of plastic foam insulation can be inserted against the inside wythe of masonry.
    - The airspace should be adjusted to still be 2” clear minimum.
Hollow cores of a CMU wall can be filled with granular insulation (Vermiculite), or with special molded to fit liners of foam plastic.
- Most effective when coupled with an unbroken layer of insulation in the cavity or on one face of the wall.
- On the inside face: attaching wood/metal furring strips to to the inside wall with masonry nails and house the necessary thickness of fibrous or foam insulation.

**Spanning System for Masonry Bearing Wall Construction**
- Ordinary construction is essentially balloon framing.
- Floors and roof are framed with wood joists and rafters and supported on the perimeter on masonry walls.
- Listed as Type IIIA and IIIB construction per the IBC.
- Heavy Timber or Mill Construction:
  - Listed as Type IV in the IBC combos masonry exterior walls with a wood frame interior.
  - Uses heavy timbers rather than light joists/rafters/studs and thick timber decking.

**Steel and Concrete Decks with Masonry Bearing Walls**
- Spanning systems of structural steel, sitecast concrete, and precast concrete are frequently used in combination with masonry bearing walls.
- Depending on the degree of fire resistance of spanning these construction may be Type I or Type II Construction.

**Expansion and Contraction**
- Walls expand and contract due to changes in temperature and moisture content.
- Thermal movement is easy to calculate, moisture...not so much.
- New concrete masonry units usually shrink as they give off excess water following manufacturing.
- Expansion/contraction of masonry is small compared to moisture movement in wood or thermal movement in plastics/aluminum.
- **Surface divider joints** must be provide to avoid excessive buildup of forces that could crack or spall the masonry.
- **Expansion Joints**: intentionally created slots that can open to accommodate shrinkage in surfaces made of concrete masonry.
- **Control Joints**: intentionally created cracks that can open to accommodate shrinkage in surfaces made of concrete masonry.
- **Abutment/Construction/Isolation Joints**: placed at junctions between masonry and other materials, or between old and new masonry, to accommodate differences in movement.

**Efflorescence**
- Sometimes appears on the surface of a wall of brick, stone, or concrete masonry.
- Consist of one or more water soluble salts that were originally present in the masonry unit or in the mortar.
- Brought to the surface and deposited there by water that seeped into the masonry, dissolved the salts, then migrated to the surface and evaporated.
- Can be avoided by choosing masonry units that are lab tested and don't contain water soluble salts.
- Will eventually diminish and disappear with time as the salt is gradually leached out of the wall.

**Mortar Joint Deterioration**
- Mortar joints are the weakest link (...goodbye!) in masonry walls.
• Water tends to accumulate here, and rounds of freezing and thawing gradually **spalls** or splits off flakes of the mortar
• Joints must be well filled and tightly compacted with a concave or vee tooling at the time it’s laid

**Moisture Resistance**
• Most masonry materials are porous and can transmit water from the outside of the wall to the inside
• Can also enter through the cracks between the masonry units and mortar and through defects in the mortar joints
• To prevent, appropriate types of masonry units, mortar, and joint tooling should be specified
• Masonry walls should be protected against excessive wetting of the exterior surface of the wall as best possible
• Below grade, masonry should be **parged** or plastered on the outside with two coats of Type M mortar to seal cracks and pores

**Cold/Hot Water Construction**
• Mortar can’t be allowed to freeze before it’s cured, it might damage the strength and watertightness
• In cold conditions masonry units and sand are kept dry, protecting from freezing temps prior to use, warming the mixing water (and maybe sand) to produce mortar at an optimum temperature, using a Type III cement to accelerate the curing of the mortar, and mixing the mortar in smaller quantities so that it’s not cool by the time it’s ready to be used.
• Workstations should be protected from wind and heated
• Finished masonry must be protected against freezing for 2 - 3 days
• Tops of walls should be protected from rain or snow
• In hot weather mortar might dry too quickly before it cures, it’s helpful to keep everything in the shade.

**Concepts/Goals:**
• Masonry if often chosen for its association in people’s minds with beautiful buildings and architectural styles, as well as for the qualities of permanence
• Chosen for uniqueness of color, texture, patter, and for its fire resistance
• It’s economical, labor intensive but creates a high performing, long lasting building
• Carried out with small tools and machines, doesn’t require big shops but does need long construction schedule times and special precautions
• Walls constructed of brick, stone, concrete masonry, or combos can be used to support roof and floor structures of wood light framing, heavy timber framing, steel, site cast concrete, precast concrete, or masonry vaulting
• Bearing walls do double duty by serving as exterior walls and interior partitions too
• Often a very economical system of construction compared to wood/steel/concrete
• Masonry walls must be designed to handle loads as well as resist water penetration and heat transfer

**Metals**

**Vocabulary:**
• **Alloy:** a combination of pure metals to give greater strength or resistance to corrosion
• **Ferrous Alloy:** alloys that contain a lot of iron (e.g.: stainless steel, galvanized iron)
Non Ferrous Alloys: doesn’t contain much iron (e.g.: aluminum, copper, zinc)

Iron: The most abundant metal

Cast Iron: hard brittle alloy of iron and 2.1 - 4% carbon that can be readily cast in a mold, use for pipes, plumbing fixtures, hardware, castings, etc. (Crystal Place made of it)

Wrought Iron: iron that has been purified by beating it repeatedly with a hammer, used for ornamental work, grilles, pipes, and outdoor furniture (Eiffel Tower made of it)

Steel: any range of alloys of iron and carbon that contain less than 2% carbon, the most widely used structural metal in construction, used for framing, concrete, rebar, lathing, conduit, pipes, fixtures, connectors like nails, bolts, and pins.

Aluminum: Light weight metal with good thermal/electrical conductivity and resistance to corrosion, used for lightweight framing, railings, grills, siding, curtain walls, doors/windows, flashings, roofing, hardware, etc

Copper: Metal that resists corrosion, electrical and thermal activity, used for electrical work, water pipes, roofing/flashings, and mesh

Brass: metal that resists corrosion, used for finish hardware, plumbing, HVAC components and fittings

Lead: Metal that resists corrosion and is workable, but also toxic, heavy, soft, and weak, used for foundations, rough hardware, roofing and flashing

Zinc: Metal used for roof coverings, flashings, and protective coatings for steel

Monel: Metal used for roofing, flashing, countertops, sinks

Bessemer Process: steelmaking procedure where carbon, silicon, and other impurities are removed from iron to make steel.

Basic Oxygen Process: steelmaking procedure where a hollow, water-cooled lance is lowered into a container of molten iron/recycled steel scrap and a stream of pure oxygen is blown in at high pressure from the lance to burn off the excess carbon/impurities.

Light Gauge Steel: steel that is cold rolled and lighter than .018”

Bulb Tees: a steel reinforcing member used when constructing pre-stressed, poured gypsum deck. When the gypsum is poured, it surrounds the Bulb-Tee.

Facts/Rules:

- Metal is know for its luster, opaqueness, hardness and ability to conduct heat and electricity
- Galvanic Action or electrolysis occurs when different metals are in contact and moisture is present.
  - One metal corrodes as its ions are deposited onto the other metal
  - When two metals are close to each other on the galvanic scale (right) they have a lessor tendency to corrode.
  - Cathodes are stable metals not prone to corrosion
  - Anodes are less stable and more likely to corrode
  - So keep Cathodes and Anodes away from each other!! They don’t place nice.
- Extracted metal is made into shapes in different ways:
  - Cast: Molten metal is poured into a mold
  - Wrought: Metal is forcibly shaped as required
  - Metals are finished for protection
  - Anodizing: process of coating aluminum with a protective oxide layer by an electrolytic process
Galvanizing: coating iron or steel with a protective layer of zinc by immersing it in a molten bath.

**Purpose of Galvanizing:** When metal is going to be used in an environment where corrosion is likely, it is often galvanized so that it will be able to withstand the conditions.

**Galvanic Corrosion:** an electrochemical process where one metal corrodes preferentially to another when they both are in electrical contact and immersed in an electrolyte (which is a liquid or gel that contains ions and can be decomposed by electrolysis)

**Steel Frame Construction**
- Steel alone has useful tensile strength compared to masonry and concrete
- Mild structural steel is known as ASTM A36 and used to be the primary type of steel used for structural purposes.
- Now less expensive steels used with scraps/recycled content (e.g.: ASTM A572, ASTM A992) have replaced A36 as most used.
- High strength, low alloy steels have increased tensile strength and are good for use as tension members or columns with minimized cross sectional requirements
  - The elastic modulus is not increased so using the member as abeam can only be done if the deflection of the beam isn’t the critical factor
- When exposed to the atmosphere, a coating of tenacious oxide forms to protect them from further corrosion and can be left exposed to the weather without painting

**Structural shapes**
- Formed by rolling metal blanks through a series of rollers that squeeze the metal into rough versions of the desired shapes
  - Lengths are cut into shorter segments and cooled in a cooling bed
  - Crooked edges are cleaned up and the pieces are shipped to fabricators

<table>
<thead>
<tr>
<th>Shape</th>
<th>Sample Designation</th>
<th>Read as</th>
<th>Range of Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide Flange</td>
<td>W12x36</td>
<td>W(nominal depth in inches) x (weight per foot of length in lbs)</td>
<td>Nominal Depth:  4” - 18” @ 2” increments and 18 - 40” at 3” increments</td>
</tr>
<tr>
<td>American Standard</td>
<td>S18x70</td>
<td>S(nominal depth in inches) x (weight per foot length in lbs)</td>
<td>Nominal Depths: 3” - 8”, 10”, 12”, 15”, 18”, 20”, 24”</td>
</tr>
</tbody>
</table>
| Angle                          | L4x3x3/8           | L(nominal depth of leg one in inches) x (nominal depth of leg 2 in inches) x thickness of legs in inches | Leg depths: 2”, 2.5”, 3”, 3.5”, 4”, 5”, 6”, 7”, 8”, 9”  
Leg thickness: 1/8” - 1 1/8” | |
| Channel                        | C9x13.4            | C(nominal depth in inches) x (weight per foot in lbs)                   | Nominal Depth: 3”, 4”, 5”  
6”, 7”, 8”, 9”, 10”, 12” 15” |
| Structural Tee (a split Wide flange) | WT13.5x47         | WT(nominal depth in inches) x (weight per foot in lbs)                   | Nominal Depths: 2” - 9” in 1” increments, 10.5” - 18” in 1 1/2” increments  |
• **Wide Flanges**: used for beams and columns (took the place of American Standard (aka I Beam) shapes)
  - Larger/heavier wide flanges can also be produced by welding together a flange and web plates rather than rolling
  - Manufactured either tall and narrow for beams or square-ish for columns
• **Angles**: versatile, used for short beams supporting small loads (e.g.: as lintels spanning doors and windows in masonry construction)
  - Primarily used in steel construction connect wide flange beams, girders, and columns
  - Used as diagonal bracing and as members of trusses when paired back to back with flat gusset plates at the joints of the truss
• **Channels**: used with truss members and bracing as well as for short beams/lintels
• **Most common structural steel shape is a Open Web Steel Joist**
  - A lightweight steel truss used to provide direct support for roof or floor decks and to transfer the load imposed on the deck to the structural frame (column or beam)
  - Selected based on the span between bearing points, joist span, slope, live/dead loads, collateral loads, wind up lift, deflection criterial, and max depth allowed
  - Spacing is commonly ranges from 2’ - 10’ on center
• **Joist Girders** are beefier versions designed to carry heavier loads...usually bays of the open web steel joists. These bear on columns and structure.
  - Remember: columns hold up joists, which hold up beams, which hold up decking
• **Steel Member Connections**: 
  - **Rivets**: steel fasteners consisting of a cylindrical body and formed head that is brought to a a high heat inserted through holes matched in members to be joined and then worked with a special hammer to make another head on the other side.
    - As it cools is shrinks and clamps the jointed pieces together
    - Was originally the most used technique, but is very labor intensive compared to bolting and welding
  - **Common bolts**: easy to find in hardware stores, and installed for less than high-strength bolts. Used in joints where lower strength is sufficient enough to carry the load
    - Act primarily in bearing and shear
  - **High Strength Bolts**: heat treated during manufacture to develop necessary strength
    - Can get connecting ability from sheer resistance or from being tightened to the point hat the members they join are kept from slipping by the friction between them (know as slip critical connections)
    - Inserted into holes slightly larger than the diameter of the bolt
    - Washers may or may not be required, depending on if load needs to be bread over a larger area
    - Tightened with an electric wrench to 70% of its ultimate tensile strength if used to connection by friction
    - Hard to verify if necessary tension has been met
• **Welding**: joints the members of a steel frame as if they were a monolithic whole, and connections are stronger than members they join in shear and moment force resistance.
  - Welding and bolting can be combined in the same connection to take advantage of the unique qualities of each
• Arc welding: an electrode is held close to a seam between steel members and an electric arch generates heat to melt both and form a single puddle which then cools and solidifies
• A complex science in the field, air must be kept away to prevent quick oxidation
• Required thickness/length of weld is determined by designer

- **Steel Frame Connections**
  • Created with angles, plates, or tees as transitional elements between members being connected
  • Angles are usually bolted to a web of a beam in the shop and then bolted to a column after the beam is in place in the field
  • Used to transmit shear forces from a beam to a column
  • Does not transfer bending moment stresses because the flanges aren’t connected
    • To do that, you have to weld the beams to the columns. If the columns aren’t strong enough to take the forces, then stiffing plates must be installed inside the column flanges.
  • Other shear and moment connections for lateral forces are:
    • Diagonal Bracing: braces act like pins or hinges and diagonally connect beam/column connections between floors, creating triangle shapes that are much stronger than rectangles
    • Eccentric Bracing: like diagonal bracing, but braces terminate in the beams
    • Shear Panels: stiff walls made of steel or concrete don’t require moment connections, and must be stacked on top of each other from foundation to roof
    • Moment Connections: stabilizes a frame without diagonal bracing or shear panels, many beam/column connections must be welded in the building

- **Fireproofing Steel Framing**
  • Building fires are usually not hot enough to melt steel, but can weaken it enough to cause structural failure
  • Exposed steel framing is usually limited to buildings up to three stories
  • Fireproofing was orientally done by encasing steel beams and columns in brick masonry or poured concrete, which were effective but the additional weight was hard for the frame to bear.
  • Metal lath and plaster wrapped around the steel members is lighter option
  • Plaster based on lightweight aggregates like vermiculite instead of sand makes it even lighter
  • Beam or column enclosure with gypsum board or other fire restive materials and can also often serve as the finished surface
  • Spray on materials are the most prevalent type, which consist of a fiber and binder or a cementitious mixture and are sprayed over the steel to the required thickness
  • Intumescent mastics and paints are thin coatings that allow steel elements to remain exposed to view in the situations of low/moderate fire risk.
    • Expand when exposed to fire to form a thick, stable char that insulates the steel from the heat
    • Most intumescent paints come in different colors, or can be painted over with a desired ordinary paint.
  • Steel box or tube columns exposed on the exterior of a building can be filled with water and antifreeze. Heat dissipates throughout the column by convection in the liquid filling. This is a pretty specialized technique.
• **Long Spans in Steel**
  - Standard wide flange beams are suitable for most office, schools, hospitals, residential, retail, uses.
  - Building types that require more open space (e.g.: theaters, aircraft hangers, religious assembly buildings) use wide flange beams with longer spans
  - **Castellated beam**: beam produced by cutting the web of wide flange along a zigzag, then reassembling the beam by welding its two half point to point, increasing its depth without increasing the length
  - Plate girders are custom designed and fabricated for long span beams
    - Steel plates and angles are assembled by bolting or welding in such a way as to put the steel where it is needed for the required loads. Higher bending forces have thicker flanges in the middle of the span, and more web stiffeners are provided where the web stresses are high
  - Rigid frames are made by welding together steel wide flange sections or plate girders
    - Must be braced laterally by purlins, girts, decking, or diagonal bracing to prevent them from buckling.
  - Steel trusses are generally deeper and lighter than improved beams
    - They can usually span longer distances and can be designed to carry light or heavy loads
    - Custom made roof trusses for light loads are made up of steel tee or paired angle top and bottom chords with paired angle internal members, spaced just far enough apart to leave space between for the steel gusset plate connectors that join them to he other members of the truss
  - Steel space truss is a 3D truss that carries its bending load in both axes...kind of like a two way concrete slab.
    - It must be supported by columns spaced almost equally in both directions
  - Steel arches are produced by bending standard wide flanges or by joining plates/angles
  - Tensile structures are made of high tensile strength wires of cold drawn steel made into cables

• **Composite Columns**
  - Columns the combine strength of structural steel and sitecast concrete are common
  - Steel wide flange column is surrounded by sitecast reinforced concrete
  - A steel pipe is filled with concrete
  - A wide flange is inserted within the pipe and then concrete is poured in
    - Commonly used in high rise buildings to carry major portions of lateral and vertical loads

• **Steel and the Building Code**
  - Steel frame construction as either IA, IB, IIA, IIB, IIIA, or IIIB
  - Exact classification depends on the amount of fireproofing treatment applied to members
  - With a lot of fireproofing unlimited building heights and areas are permitted for most occupancy groups

• **Light Gauge Steel Frame Construction**
  - Sheet steel is fed from continuous coils through machines that fold it into long members at room temperature whose shapes make them stiff and strong
  - Often referred to as cold-formed steel components
• The non combustible equivalent of wood light frame construction
• Members correspond closely to the dimensional standard of 2” wood framing members
• May be sheathed, insulated, wired, and finished the same way light frame wood is
• Strength and stiffness of a member depends on the shape and depth of the section and the gauge, or thickness, of the sheet that it’s made from
• Webs are are punched at the factory to provide holes at 2’ intervals to allow wiring, piping, and bracing to pass through the studs
• Usually joined with self drilling, self tapping screws which drill their own holes and for threads in the holes as they are driven
  • Plated with zinc to resist corrosion
• Welding is offend used to assemble panels of framing that are assembled in a shop
• Designed to nest together to form a tubular configuration when used for a ridge board or header
• Much more prone to twisting or buckling than wood members under load, more attention to bracing and bridging must be given
  • Typically braced at 4’ intervals
  • Wall baring consists of diagonal steel scraps screwed into studs
  • Permanent resistance to buckling, twisting, and lateral seismic and wind loads is imparted largely by subfloorings, sheathing, and interior finish materials
• Used to construct many components of fire resistant building with a structural steel, masonry, or concrete structure.
  • Interior wall and partitions
  • Suspended ceilings
  • Fascia, parapets, backup walls for exterior cladding
• Where noncombustibility is not an issue metal and wood light framing can be used in the same building for the most economical use of materials
• Thermal conductivity is much higher than that of wood
  • Cold climates must have thermal breaks detailed into framing members
    • Foam plastic sheathing or insulating edge spaces between studs and sheathing conduct heat rapidly enough to reduce the thermal performance of wall or roof
    • Prevents excessive energy loss and/or moisture condensation on interior surfaces
• Won’t burn, but will lose structural strength when exposed to fire
• Must be protected from fire with gypsum sheathing and/or gypsum wallboard or plaster
• Can be classified as high as Type IIB construction
• Any exited finishes used in light frame wood construction can be used
• Wood trim components are applied with special finish screws that have small heads

Concepts/Goals:

• Steel
  • strong and stiff, as well as precise and predictable
  • Well suited to rapid construction, repetitive building frames, and architectural detailing
  • Uniquely plentiful and inexpensive
  • Has a tendency to corrode in certain environments and loose strength during fires
  • A relatively small amount of steel can do a structural job that would take much greater amount of material.
It's dense, but produces the lightest structures and those that span the greatest distances.

Frames go together quickly with relatively few tools.

Unlike masonry/concrete it doesn’t lend itself easily to forming a total building enclosure...except for a few industrial cases.

**Light Gauge Steel Framing**

- Shares most of the advantage of wood light framing: versatile, flexible, excepts a wide range of finish material, etc.
- Can be used in buildings where noncombustible construction is required by code, allowing it to be used in larger buildings.
- Significantly lighter than equivalent wood members.
- Can be spaced at 24” o.c. Rather than the 16” o.c. Of wood.
- Can span slightly longer than equivalent wood members of same depth.
- More dimensionally stable and unaffected by changing humidity.
- May corrode if exposed to moisture over time (e.g.: oceanfront locations) can’t fall victim to termites/decay.
- Prices are relatively stable, unlike wood which fluctuates as an agricultural commodity.
- Lighter and easier to insulate, and accept electrical wiring and plumbing/heating pipes compared to equivalent masonry walls.
- A dry process that can be carried out in wet/dry conditions.

Processes:

**Steel Frame Construction Process**

**Fabrication:**

- Fabricator creates detailed shop drawings that show how each piece will be made, including dimensions.
- Designs connections to transmit loads per engineering design drawings.
- Fabricator can design as economically as possible, so long as it meets engineers requirements.
- Also prepares drawings to show where/how foundation anchor bolts for connection to columns will take place.
- Shop drawings are reviewed and approved by the architect, typically with the help of the engineer who designed the system.
- Fabricator orders necessary steel members from the mill and makes full sized templates from the approved shop drawings.
- Plates, angles, tees for connections are cut to size and shape and bolt hole locations are marked and punched or drilled.
- Beams, girders, columns are marked with a code that says where they exactly go in the building.
- Members are cut to length and ends that must bear on base plates or other members are squared and made flat.
- Beams and girders are **cambered** (curved slightly upward) so they will deflect in a straight line once loads are applied on site.
- Stiffening Plates are arc welded to each pieces as required and connecting angles/plates/tees are welded or bolted to beam webs as required.
- Plate girders, built up columns, trusses, are assembled in the shop, they can be any size, but must be able to be transported to the job site.

**Erection:**

- Assembly starts with the first two-story tier of framing.
• Cranes lift members into place
• Typically columns are furnished in sections that are two stories high and lowered over anchor bolts and onto the foundation where they are bolted down
• Foundation details vary based on the design
• Beams and girders for the first two stories are bolted in place, components are put in place and bolted just enough so that it holds together
• Bolters follow behind inserting the rest of the bolts and partially tightened,
• The first two stories are squared up, making sure everything is plumb and and connections are tightened
• Diagonal bracing is rigidly attached as required
• Erection of additional tiers continues, and columns are connected by splice plates to the first tier columns
• Placing of the last beam on top of a building is traditionally a ceremonious occasion… ever see a small evergreen tree and a flag on top? That’s why.

• Floor and Roof Decking
  • Temporary plank decks are replaced with permanent floor and roof decks of incombustible materials
  • Metal decking is a thin sheet of corrugated steel which is puddle welded to the joists, beams and girders
  • Longitudinal edges of the deck panels are connected at frequent intervals when acting as a diaphragm
  • Composite metal decking is designed to work together with concrete floor topping to make a stiff, lightweight, economical deck
    • Metal decking serves as tensile reinforcing for the concrete which it bonds by means of special rib patterns in the sheet metal
  • Concrete floor/roof slabs are often used instead of metal decking and concrete fill
    • Poured into plywood forms or erected as precast slabs lifted into place
    • Relatively light and quick to erect
    • Typically require an additional thin concrete topping poured to smooth the slab
  • Many different types of decks are available for low steel frame buildings
    • Corrugated metal with or without concrete fill
    • Rigid insulation boards capable of spanning corrugations to make a flats surfaces
    • Corrugated decks finished with a weather resistant coating that allows them to become water-resistive surface for the roof
    • Heavy timber decking or wood joists are also used over steel framing where code allows combustible materials

• Light Gauge Steel Framing
  • Essentially the same as that used for nominal 2” wood members
  • Constructed in the platform fashion:
    • Ground floor is framed with steel joists
    • Mastic adhesive is applied to the upper edges and wood panel subflooring is laid sown and fastened with screws
    • Steel studs are laid flat on the subfloor and jointed to make wall frames
    • Frames are sheathed with wood panels or gypsum sheathing panels (for noncombustible construction...similar to gypsum wallboard, but has a water resistant paper face. It’s that yellow Georgia Pacific DensGlass Sheathing you always seen on construction projects)
    • Frames are tipped up and screwed down to the floor frame
Temporary braces support the walls at each level until the next floor platform has been completed.
Upper floor platform is framed, then upper floor walls, and so on.
Ceiling and roof are framed like wood frame.
- Prefab trusses of light gauge steel are screwed or welded together are often used.
- Corrugated steel decking with a concrete topping is sometime substituted for wood panel subflooring to get a higher construction type rating.
- Openings in floors and walls are frame the same as light frame wood, with doubled members around each opening and strong headers over doors and windows.

Wood

Vocabulary:
- **Wood**: hard fibrous substance beneath the bark of trees
- **Lumber**: wood that has been sawn into construction members
- **Timber**: lumber that is +5" in its smallest dimension
- **Softwood**: evergreen trees (pine, fir, spruce) used for framing, sheathing, etc.
- **Hardwood**: deciduous trees (maple, oak) used for flooring, paneling, trim, furniture
- **Lamella**: a thin finished top layer of an engineered wooden floor

Facts/Rules:

**Wood**
- Wood is readily available as a building material
- Lower cost than concrete, masonry, and steel structures
- Stronger in compression than tension
- For improved tension and compression apply load parallel to the grain
- For improved shear strength, apply load perpendicular to the grain
- Heavy Timber resists fire better than unprotected steel

**Sawing**:
- Most lumber intended for use in building framing is **plainsawed**, which produces the maximum yield of lumber from a log.
- Some pieces have the rings running perpendicular to the faces of the piece, some have rings on various diagonals, and some have rings running parallel to the faces.
- Varying grain orientation cause pieces to distorted differently during seasoning, or drying, vary differently in their appearance, and erode at different rates when used as flooring, siding, etc.
- Wood that will be seen in finish applications (e.g.: flooring, interior trim, furniture, hardwoods, casework) are **quartersawn** to produce lumber that have annual rings running nearly perpendicular to the face of the piece.
- Boards tend to remain flat, regardless of the change in moisture content
- Visible grain is considered more aesthetic
- Waring quality is improved because there are not broad ares of soft springwood exposed in the face.
Seasoning

- Water content in a piece of wood can vary between 30% - 300% of the oven-dry weight of the wood. This unseasoned wood is called **greenwood**.
- Seasoned lumber is stronger and stiffer than unseasoned, more dimensionally stable, and lighter in weight.
- When a tree is cut, the water slowly begins to evaporate in the following order:
  - **Free Water**: water held in the cavities of the cells. Reduces water content to 26% - 32% moisture
  - **Bound Water**: water held in within the cellulose of the cell walls, wood starts to shrink at this point and the strength and stiffness of the wood begins to increase.
- Wood can be dried to any moisture content.
- Framing lumber is considered **seasoned** when the moisture content is 19% or less.

Drying methods:

- **Air drying** takes several months and results in 10% - 20% moisture content
- **Kiln drying** takes a few days and results in 10% moisture content
- Kiln drying is generally preferred because it’s faster and has a more uniform quality.

Wood doesn’t shrink uniformly when moisture content changes.

- **Longitudinal shrinkage**: shrinkage along length of the long is negligible
- **Radial shrinkage**: shrinkage in the radial direction is very large by comparison
- **Tangential shrinkage**: shrinkage around the circumference of the log is about half again greater than the railed shrinkage.

Surfacing

- Surfacing makes lumber smooth and more dimensionally precise
- Usually takes place after seasoning process.
- Easier to work with than rough lumber because it’s more square and uniform in dimension
- Done by planing the surface of each piece of wood / slightly rounding each side.
- Almost all lumber has one or more discontinuity or defects, caused by growth or natural characteristics or manufacturing characteristics.
  
<table>
<thead>
<tr>
<th>Natural</th>
<th>Manufacturing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knots and Knotholes</td>
<td>Splits and Checks</td>
</tr>
<tr>
<td>Insect Damage</td>
<td>Wane</td>
</tr>
<tr>
<td>Decay</td>
<td>Crooks, Cups, Bows, Twists</td>
</tr>
</tbody>
</table>

- Depending on the amount of defect, the lumber can either still be used as intended, or partially used as blocking.

Grading

- Each piece of lumber is graded for appearance or structural strength and stiffness at the mill.
- Appearance grading is done visually by trained inspectors.
- Structural grading is done either visually or by machine.
• Lumber is sold by species and grade .... Higher grade = more $$$ Grade stamps are applied to each piece of lumber.
• Grade name, number or abbreviation indicates the grade of the lumber according to the national standard.

 2” - 4” thick, 2” - 4” wide = structural light framing  
  (SEL STR No. 1, 2, & 3,  
  CONST, STAND, or UTIL)

 2” - 4” thick, 2” + wide = studs  
  (STUD)

 2” - 4” thick, 5”+ wide = structural joists & planks  
  (SEL STR No. 1, 2, & 3)

• Structural Strength of Wood
  • Structural strength of wood depends on its species, grade, and the direction in which the loading acts with respect to the direction of the grain
  • Wood is several times stronger parallel to grain than perpendicular to grain.
  • Even with typical defects it is stronger in compression than in tension.
  • Allowable strengths vary with species and grade
  • Allowable compressive strength parallel to grain for commercially averrable grades and species of framing lumber varies from 325 psi - 1,700 psi
  • Architects/Engineers determine the max stress that are likely to occur in each of the members and selects an appropriate species and grade of lumber
  • In different locations a limited number of species and grades may be available
  • It’s common practice to use a stronger but more expensive species like Doug Fir for highly stressed major members and to use a weaker and cheaper species like Eastern Hemlock for the remainder of the structure.

• Lumber Dimensions
  • Sizes are given as nominal dimensions or whole dimensions, but in actuality, are smaller due to seasoning and surfacing

<table>
<thead>
<tr>
<th>Nominal Dimension</th>
<th>Actual Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>1”</td>
<td>3/4”</td>
</tr>
<tr>
<td>2”</td>
<td>1 1/2”</td>
</tr>
<tr>
<td>3”</td>
<td>2 1/2”</td>
</tr>
<tr>
<td>4”</td>
<td>3 1/2”</td>
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<tr>
<td>5”</td>
<td>4 1/2”</td>
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<tr>
<td>6”</td>
<td>5 1/2”</td>
</tr>
<tr>
<td>8”</td>
<td>7 1/4”</td>
</tr>
<tr>
<td>10”</td>
<td>9 1/4”</td>
</tr>
<tr>
<td>12”</td>
<td>11 1/4”</td>
</tr>
<tr>
<td>Over 12”</td>
<td>less 3/4”</td>
</tr>
</tbody>
</table>

• Dimension lumber is usually supplied in 2 foot increments of length. The most common of which are 8’, 10’, 12’, 14’, and 16’
• Lumber is priced and sold by board foot measurement
  Board feet = [ cross section area / 12 ] x length
  For example…. A 10 foot long 2x4 = [ 2 x 4 / 12 ] x 10 = 6.67 board ft

• Wood Product Types
  • To make up for fewer and/or more expensive solid wood structural members, various composite, laminated, and panel products have been created.
  • Laminated Wood/Glu-Lam are produced by joining many small strips of wood together with glue.
• Any desired size can be laminated up to the capacity of the machinery and transportation means available to the site
• Can be laminated into shapes that can’t be found in nature (e.g. Curves, angles)
• Seasoning is carried out before wood is laminated
• Strongest and best quality wood can be placed in the parts of the member subject to the most amount of stresses
• Individual laminations are about 1 1/2” thick in straight members and 3/4” thick in curve members
• Adhesives are chosen according to the moisture conditions under which the member will serve.
• Standard depth of member is about 3” to 6’-0”
• Standard widths of members range from 2 1/8” to 14 1/4”

**Structural Composite Lumber**
• Made up of ordinary plywood veneers or of long strands of wood fiber
• All grains of all the veneers or strands are oriented in the longitudinal direction of the piece of lumber to achieve max bending strength.
• **LVL** (or laminated veneer lumber) uses the veneers in sheets and looks like thick plywood with no crossbands
• It’s stronger, straighter, and more uniform than conventional lumber and less likely to warp, twist, bow, or shrink

**Wood Panel Products**
• Panel dimensions are usually 4’ x 8’
• Require less labor for installation because fewer pieces have to be handled
• Minimize many of the problems of boards and dimensional lumber…
  • Panels are more equal in strength in their two directions
  • Shrinking, swelling, checking, and splitting are greatly reduced
• More efficient use of forest resources than solid wood products
• Structural wood panel products fall into three categories:
  • **Plywood**
    • Manufactured wood panel made from thin sheets of wood veneer permanently bonded together
    • Grain of each ply is perpendicular to the adjacent and each sheet has an odd number of plies
    • Used as wall and roof sheathing, subflooring, underlayment, and formwork.
  • **Composite Panels**
    • Have two parallel faces of veneer bonded to a core of reconstituted wood fibers
  • **Non Veneered Panels** which include:
    • **OSB (Oriented Strand Board)** made of long shreds/strands of wood compressed and glued in 3 - 5 layers
      • Strands are oriented in the same manner in each layer as the grain of the veneer layers in plywood
      • Typically stronger than other types of non veneered panels
      • More economical than plywood because it can be produced from small tree/branches
      • Most commonly used for sheathing and sub flooring of light frame wood buildings
    • **Waferboard** large wafer like flakes of wood compressed and bonded into panels…largely replaced by OSB
• **Particleboard** smaller wood particles compressed and bonded into panels and used as a base material for cabinets or underlayment for resilient flooring

• **Fiberboard** very fine grained board amide of wood fibers and synthetic resin binders used in cabinets, furniture, moldings, etc.

• Most common form is **MDF** (or medium density fiberboard)

• **Structural Panel Specification**
  • For uses like sulfuring and sheathing wood panels may be specified by thickness or by **span rating** which is determined by lab load testing and shown on the gradestamp

• Span rating system permits the uses of many different species of woods and types of panel to achieve the same structural objectives

• For example...a panel with a span rating of 32/16 may be used as roof sheathing over rafters spaced 32" apart or as sub flooring over joists spaced 16" apart

• Long dimension of the sheet must placed perpendicular to the length of the support member

• **Exposure durability classification**
  • **Exterior**: suitable for use as siding or other permanently exposed applications
  • **Exposure 1**: have fully waterproof glue by don’t have veneers of as high a quality as Exterior. Can be used for structural sheathing and subflooring
  • **Exposure 2**: suitable for panels that will be fully protected from weather and will be subjected to a minimum of wetting during construction

• About 95% of structural panel products are Exposure 1

• **Wood Preservation**
  • **Insects**: in warm/humid climates termites eat wood from within. Avoid by allowing proper drainage, good ventilation, and impervious concrete foundations.
  • **Decay**: caused by fungi in mild temperatures, moisture and air. Treated with preservatives, and by keeping it well ventilated and dry

• **Chemical Treatment**:
  • Creosote is an oily derivative of coal that is widely used in engineering structures, but rarely in building construction due to odor and toxicity.
  • Pentachlorophenol is also an oil solution and wood tartered with it can’t be painted
  • Most widely used is water born salts, where preservatives are used and the wood can still be painted or stained

• **Fire Protection**: prevention by impregnating a chemical solution or by
• **Wood Fasteners**
  • The weak link in wood construction, it’s usually impossible to insert enough nails, screws, or bolts in a connection to develop the full strength of the member being joined.
  • Adhesives and toothed plates are often capable of achieving this strength, but are usually limited to factory installation.
  • **Nails** are sharpened metal pins driven into wood with a hammer/nail gun
    • Common and finish are the two most common types
    • Common nails have flat heads and used for structural connections
    • Finish nails are almost headless have used to fasten finish woodwork
    • Size of a nail is measured in pennies
    • Typically made of plain unloaded steel
    • Nails exposed to weather should be of a corrosion resistance type, (e.g.: hot-dip galvanized, aluminum, stainless steel)
  • Fastening types:

  ![Face Nail](image1) ![End Nail](image2) ![Toe Nail](image3)

  • Face nailing is the strongest method, end nailing is the weakest and used for holding members in alignment while gravity forces and sheathing does all the work to make a stronger connection
  • Toe nailing is used when access to end nailing isn’t available and hold about 5/6 as much load as face nails of the same size
  • Nails are the favored means of fastening wood because they require no pre drilling and are extremely fast to install
  • **Nails for Western Red Cedar:** hot dipped galvanized, aluminum, and stainless steel (the best option). All others (including copper) can rust and disintegrate and react with the oils present in the cedar.

• **Wood Screws and Lag Screws** are inserted into drilled holes and turned into place with a screwdriver or wrench
  • Cost more and take longer to install than nails
  • Often used in casework, furniture, and for mounting hardware
  • Form tighter, stronger connections than nails
  • Large screws are called Lag Screws and have square of hexagonal heads
  • Drywall screws are made for use in attaching gypsum board to wood farming and are almost as easy to install as nails

• **Bolts** are used for major structural connections in heavy timber framing
  • Washers are inserted under the heads of nuts and bolts to distribute the compressive force from the bolt across a greater are of wood
  • **Carriage Bolts:** round headed bolt used for timber, threaded along the shank and inserted into holes already drilled.
• **Lag Bolts**: heavy woodscrew with a square of hexagonal head that is driven in with a wrench

• **Split Ring Connector** are high capacity connectors used in heavily loaded joints of timber frames and trusses.
  - Is used in conjunction with a bolt and is inserted in matching circular grooves in the mating pieces of wood.
  - It spreads the load across a much greater area of wood than can be done with a bolt alone

• **Toothed Plates** are used in factory produced lightweight roof and floor trusses, inserted with hydraulic presses or mechanical rollers, and act as metal splice plates each with a very large number of built-in nails.

• **Joist Hanger** are used to make strong connection in floor framing wherever wood joist bear on one another at right angles
  - Simpson brand hangers are really popular!
  - They are attached with special short nails driven through the holes punched in the hangers
  - Post bases serve double duty by preventing water from entering the end of the post and anchoring the post to the foundation

• **Wood Manufactured Building Components**
  - **Trusses**
    - Most trusses are based on 2x4 and 2x6 joined with toothed plate connectors
    - Designers just have to specify the span, roof pitch, and desired overhang detail, the manufacture will figure the rest
    - Roof trusses use less wood than a comparable frame of conventional rafters and ceiling joists
    - Like floor trusses, they span the entire width of the building, freeing the floor plan from columns and allowing for more freedom for interior partition locations
    - Make attic space unusable and restrict designer to spatial monotony of a flat ceiling throughout the building
  - **Wood I-Joists**
    - Useful for framing both roofs and floors
    - Flanges of members may be made from solid lumber, laminated veneer lumber, or laminated strand lumber
    - Webs consist of plywood or OSB
    - Use wood more efficiently than traditional rafters, and are lighter too.
    - Available in lengths to 40 feet

• **Panel Components**
  - Framed Panel: a section of framing about 4’ wide, sheathed with a sheet of plywood, OSB, or waferboard.
  - Stressed Skin Panel: facings are bonded with adhesive to thin wood spaces to form a structural unit
  - Sandwich Panel: functions the same as a stressed skin panel but are bonded to a core of foam insulation instead of wood spacers.

• **Heavy Timber Construction**
  - Large timbers have a greater capacity to absorb heat and are much slower to catch fire and burn than smaller lumber
  - Heavy timber beams will be deeply charred by gradual burning but will continue to support its load long after an unprotected steel beam would have collapsed.
• If fire doesn’t last long, the timber can be sandblasted to remove surface char and can continue in service.
• Heavy Timber construction that meets certain code requirements is considered to have fire resistive properties
• Either sawn or laminated timbers are permitted by the IBC
• Perimeter of the floors and roof of a heavy timber building must be supported on concrete or masonry and the interior can be supported by heavy wood columns.
• Buildings must be detailed to minimize the effects of shrinkage by eliminating cross grain wood from the interior lines of support.
• Anchoring Timber Beams and Masonry Walls
  • Beam must be protected from decay that might come from moisture seeping through the wall by leaving ventilated airspace between the wall and all sides of the beam except the bottom (unless the beam is chemically treated to resist decay)
  • Beam must be securely anchored to the walls to that it won’t pull away under normal service
  • Beam must be able to rotate freely so that it doesn’t pry the wall apart if it burns through during a fire. By firecutting the end of the beam it can fall away
• Building code requires heavy timber buildings have floors and roofs of solid wood construction without interval cavities
• Heavy timber building with an exterior masonry or concrete bearing wall is typically braced against wind and seismic forces by shear resistance of its walls working with the diaphragm action of its roof and floor decks
• In high seismic areas, walls must be reinforce vertically and horizontally and decks may have to be specially nailed or overlaid with plywood to increase shear resistance
• In buildings with framed exterior walls, diagonal bracing or shear panels must be provided
• Heavy timber is often used with smaller wood framing and doesn’t meet the requirements for the heavy timber classification...these are considered Type V or

Wood Light Frame Construction
  • Brings the appearance and structural performance of bam and deck framing to small free standing buildings
  • No restrictions on minimum size of timber, thickness of decking, or exterior wall materials
  • Use of heavy timber exposed beams and decking normally made of light frame construction presents some problems that don’t usually come up:
    • Thermal insulation can’t be inserted between ceiling joists, but must be placed on top of the roof deck
    • Electrical wiring for lighting fixtures that are mounded on the underside of the deck have to be run through exposed metal conduits below the deck or through the insulation above the deck
• If walls and partitions are made of masonry or stressed skin panels instead of light framing, special electrical, plumbing and heating accommodations must be made as well.

• Buildings that require spans over 20’ (about as long as sawn timbers can span typically) there are a few options:
  • Large beams: glu-lams rather than large old-growth timber are used now
  • Rigid frames: glu-lam to shape and find wide use in long span buildings, many standard options or custom designed, exert a horizontal thrust so must be tied at the base with steel tension rods
  • Trusses: heavy timber joints are made with steel bolts and welded steel plate connectors or split-ring connectors
  • Arches/Domes: long curved timbers are easily fabricated in glu-lam, they exert lateral thrust that must be countered by tie rods or appropriately designed foundations

• **Wood Light Frame Construction**
  • Earliest version of framing was **balloon framing**: framed solely with slender, close spaced wood members:
    • **Joists**: for the floors
    • **Studs**: for the walls
    • **Rafters**: for the sloping roofs
    • Balloon frame used full-length studs that ran continuously for two stories from foundation to roof...but this method was too inefficient as the studs were too long.
    • Also, all the spaces between the studs acted like a chimney in a fire unless they were blocked by firestops.

• **Platform Frame** is now the universal standard for light frame construction
  • A floor platform is built and load bearing walls are erected upon it
  • A second floor platform is built upon these walls
  • The attic and roof are then built upon the second set of walls
  • It uses short, easily handled lengths of lumber for the wall framing
  • Vertical hollow spaces are automatically fire stopped at the floor
  • Platforms are convenient working surfaces for frame builders
  • **Sheathing**: facing layer of boards or panels that join and stabilize the studs
  • **Floor Joists**: parallel pieces in a floor structure
  • **Headers/Rim Joists/Band Joists**: crosspieces at the ends of joists
  • **Subfloor**: sheathing on the floor
  • **Studs**: parallel pieces in a wall
  • **Sole Plate**: cross piece at the bottom of the wall
  • **Top Plate**: crosspiece at the top of a wall (doubled for strength)
  • **Ridge Board**: peak where rafters are headed off
  • **Headers and Trimmers**: frame openings for doors, windows (doubled for support)
  • **Sill**: head off the bottom of openings

• Foundations for light framing was originally made of stone or brick, but is now typically site cast concrete
• Concrete and masonry foundations are highly conductive of head and must be insulated to meet energy code
• Basement needs to be dampproofed and drained to avoid flooding with ground water and to prevent build up of water pressure in surrounding soil
• Subflooring should be glued to joists to prevent squeaking and increase floor stiffness
• Plywood and OSB panels must be laid with grain of thief face layers perpendicular to the direction of joists as it is stiffer.
• Sheathing provides permanent bracing to walls and acts as a **shear wall** when properly sheathed. It can resist lateral forces.
• Shear walls must be provided in both North/South and East/West directions and distributed almost symmetrically in the floor plan.
• Diagonal bracing is let into the face of a frame if a building will not have rigid sheathing.
• Most common roof shapes are:
  - Flat Roof
  - Shed/Single Pitch
  - Gable Roof
  - Hip Roof
  - Gambrel Roof
  - Mansard Roof
• Rafters in gable and hip roofs must be securely tied together the top of supporting walls by well nailed ceiling joists for structural stability.
• **Pitch** or slope of roof is specified as a ratio of rise to run.
• In areas subject to hurricane, local code sometime requires that rafters be attached to supporting walls with sheet metal anchors.
• Roof trusses get a lot of use in platform framing because of their speed of erection, economy of material usage, and long spans.
  - Are typically about 1 1/2” thick with a 24’ - 32’ span.
  - Have a tendency to buckle sideways until they are braced with sheathing and interior finishes.
• IBC Allows building of every occupancy group to be constructed with wood platform framing...or **Type V Construction**
  - Relatively sever restriction on height and floor area.
  - Some occupancy types have higher fire resistance ratings are require for some components of the building.
  - Example: A nursing home would be Occupancy Group I-2, and Type VB construction is not allowed, while Type VA is for a single story up to 9,500 square feet.
• Zoning ordinances in most cities identify certain densely build areas where wood platform framing is not allowed.
• Platform framing is probably regulated more closely by codes than any other construction type.
• Automatic fires alarm systems including smoke detectors are almost universally required.
• **Roofing**
  - Before a roof can be shingled the **eaves** or horizontal roof edges and **rakes** or sloping roof edges must be completed.
  - Siding should easily join to them.
  - Edges of the roof shingles should be positioned and sported so water will drip free of the trim.
  - Gutters and downspouts are installed on the eaves to remove rainwater without wetting the walls.
  - **Splash Blocks** spread water away from the building at the ground.
  - Minimum overhang for gutterless buildings are 1’-0” on one story buildings and 2’-0” for two story buildings.
• **Housewraps, Windows and Doors**
Before windows and doors are installed, the wall sheathing is covered with a membrane called **tarpaper** that acts as an air barrier and backup waterproofing layer.
- Allows water vapor to pass freely so that it doesn’t accumulate on the wall.
- Housewraps (e.g., Tyvek) are airtight, vapor permeable papers made of synthetic fibers are stapled to sheathing in as large of sheets as possible to minimize seams.
- Seams are sealed with self-sticking tape.
- Edges around windows and doors must be carefully flashed for the resistance of leakage of water and air.

**Wood Siding**
- Exterior cladding material applied to the walls of a wood light frame building.
- Can be wood boards, plywood, wood shingles, metal or plastic siding, fiber-cement siding, brick or stone, and stucco.
- Horizontally applied board sidings are nailed so that the nails pass through the sheathing and into the studs.
  - Allows for installation over insulating sheathing materials without requiring a nail based sheathing.
  - In the US, boards are nailed tightly over the wall sheathing and housewrap.
  - In Europe, siding is nailed to vertical wood spacers (1x3’s) that are aligned over the studs...called a **rainscreen** and creates a pressure equalization chamber behind the siding that acts to prevent water penetration in a wind drive rain.
- Vertically applied siding is nailed at the top and bottom plates and at one or more intermediate horizontal blocking lines installed between the studs.
- Heartwood redwood, cypress, and cedar siding may be left unfinished to weather.
- Plywood siding is often chosen for economy...it’s less than other materials and labor rates are lower.
  - Often time sheathing can be eliminated leading to further cost savings.
  - **Z flashing** of aluminum is used to detail the horizontal end joints between sheets...it’s visible!
- Shingle siding require a nailbase sheathing material like OSB or Plywood.
  - Corrosion resistant nails or air driven staples may be used.
  - Application is labor intensive, especially at openings and corners because there’s a lot of cutting.
- Metal and Plastic Siding is usually designed to imitate wood siding and are generally guaranteed against need repainting for long periods...about 20 years or so.
  - Have a poor resistance to denting (metal) and cracking (plastic) and occasionally shatter on impact.
- Stucco is a portland cement plaster that is strong, durable, economical, fire resistant material.
- A single wythe of masonry or stone veneer can be used to face a building.
- Most siding materials require vertical corner boards as well as trim board around windows and doors.
- Roof boards require trim boards including fascias, soffits, frieze boards and moldings.
- Most common trim is Pine.

**Interior Finishes for Wood Light Frame Construction**
- Thermal Insulation and Vapor Retarder
  - **Thermal Insulation** keeps a building cooler in the summer and warmer in the winter by retarding the passage of heat through the exterior surface of a building.
<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
<th>Installation</th>
<th>Advantage/ Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batt or Blanket</td>
<td>Glass wool/ rock wool</td>
<td>Between framing members and held in place by friction or facing stapled to framing</td>
<td>Low in clots, faith high R value, easy to install</td>
</tr>
<tr>
<td>Loose fill</td>
<td>Glass wool/ rock wool</td>
<td>Fill is blown onto attic floors and into wall cavities through holes drilled in siding</td>
<td>Good for retrofit insulation in older building, may settle in walls</td>
</tr>
<tr>
<td>Foamed in place</td>
<td>Polyurethane</td>
<td>Foam is mixed from two components and sprayed or injected into place where it adheres</td>
<td>High R value, high cost, good for structures that are hard to conventionally insulate</td>
</tr>
<tr>
<td>Rigid Board</td>
<td>Polystyrene Foam</td>
<td>Boards are applied over wall framing members either as sheathing on the exterior or as a layer beneath the interior finish material</td>
<td>High R value, can be used in contact with the earth, moderate cost</td>
</tr>
</tbody>
</table>

- **Radiant Barriers** are increasingly used in roofs and walls to reduce the flow of solar heat into a building
  - Thin sheets of panels faced with a bright metal foil that reflects infrared radiation
- **Vapor retarder** is a membrane of metal foil, plastic, or treated paper placed on the warm side of thermal insulation to prevent water vapor from entering the insulation and condensing into liquid
  - Many batt insulation materials are furnished with a vapor retarder layer of treated paper or aluminum already attached

**Concepts/Goals:**
- Wood is the only major building material that is organic in origin, which accounts for much of its uniqueness as a structural material
- Most of the work of manufacturing wood is done for us by the process of life and growth within the tree
- Unlike steel or concrete we can’t do much to adjust or refine wood’s properties to suit our needs, we must accept its natural limitations and strengths
A tree itself is a structure made from wood, it’s a tower erected for the purpose of displaying leaves to the sun, and subjected to many of the same forces as the buildings we erect. It supports itself against the pull of gravity, the forces of wind, and the accumulation of snow and ice. It resists the stresses of the environment including temperature, attack by other organisms, and physical abuse.

Heavy timber can’t span as far or with the delicacy of steel but many people respond more favorably to it.
- May stem from the color, grain, figure, and warmer feel of wood
- Probably due to the nostalgia people have for old timber buildings

Timber is no longer an automatic choice for building due to diminishing forests, reduction in quality, and increase in shipping costs.

2x4 stud walls have been the standard since light framing was invented.
- More requirements for heating fuel conservation have led to code requirements for more thermal insulation than can be reasonably inserted in a 2x4 stud wall
- 2x6 framing has become more common (at 24” o.c.) to insulate

Wood light framing is popular because it’s flexible and economical.
- There’s ease to create complex buildings from simple tools
- Complete and open system of construction...incorporates structure, enclosure, thermal insulation, mechanical installation, and finishes into a single constructional concept

Processes:

- Plywood production:
  - Veneers for structural panels are rotary sliced; logs are soaked in hot water to soften and then rotated in a large lathe against a stationary knife that peels off a continuous strip of veneer
  - Strips are dried and moisture content is reduced to 5%
  - Sheets are assembled into larger sheets, repaired with patches, and graded and sorted according into quality
  - Glue is spread on top of veneer as they are stacked in the correct sequence and orientation
  - Loaded into presses that apply pressure and temperature to create dense, flat panels
  - Trimmed to size, sanded as required, and gradestamped

- Preliminary Design of Heavy Timber Structure
  - Estimate the depth of wood roof decking at 1/40 the span
  - Estimate the depth of wood floor decking at 1/30 the span
  - Estimate the depth of sold wood beams at 1/15 the span and add the depth of glu-lam beams at 1/20 the span. Add a nominal 6” to these depths for girders
  - Estimate the depth of timber triangular roof trusses at 1/2 to 1/5 the span
  - Estimate the size of a wood column by adding the total roof and floor area supported by the column. Wood columns are usually square

- Erection of a Platform Frame
  - A platform is built on top of the foundation
  - Walls are assembled horizontally on the platform and tilted up
  - Another platform or roof is built on top of the walls
Concrete

Vocabulary:

- **Concrete**: a rocklike material produced by mixing coarse and fine aggregates, portland cement, and water, and allowing the mixture to harden
- **Coarse aggregate**: gravel or crushed rock
- **Fine aggregates**: sand
- **Hydration**: chemical reaction between water and cement which creates heat
- **Cement**: a product of lime, iron, silica, and alumina, crushed, ground, proportioned and blended, then sent through a kiln, cooled and pulverized to a powder
- **Vermiculite**: a mineral that expands upon being heated, used in the expanded state for heat/sound insulation and fireproofing
- **Perlite**: form of obsidian formed by cracking of cooling volcanic glass, used as insulation
- **Slurry**: freshly mixed concrete, unstable mixture of solids and liquids
- **Construction joints**: horizontal or vertical joints between two successive concrete pours
- **Expansion Joints**: joints that allow free movement of adjacent parts due to expansion or contraction of concrete. Typically waterproof, watertight, filled with an elastic filler. Required at buildings over 200’ long, at joints of building wings, and additions
- **Control Joints**: joints that allow for shrinkage of large areas, and controls and induces cracking to occur along the joint
- **Isolation Joints**: joints located at slab on grade, columns, or walls to allow for independent movement
- **Acid etching**: process of cutting into a surface (concrete, glass, etc) by applying acidic, caustic, or abrasive substances
- **Abrasive Blasting (Sandblasting)**: process of forcibly propelling a stream of abrasive material against a surface under high pressure to smooth, etch, clean it
- **Bush Hammering**: process of creating a rough, pockmarked texture on concrete or stone that resembles naturally weathered rock
- **Honing**: process of sanding/polishing for a matte or slightly reflective surface

Facts/Rules:

- Concrete cures/hardens due to hydration, where considerable heat is given off as the cement combines with water to form strong crystals that bind the aggregates together
- **Concrete Strength**
  - Commonly designed on the basis of the strength that is reaches after 28 days
  - Typical strength ranges from 3,000 psi - 10,000 psi
  - Early strength concrete can reach normal 28 day strength in 7-14 days
  - 7 day strength should be about 75% of the designed 28 day strength
  - Nominal weight is 150 lbs per cubic foot
- Concrete shrinks lightly during the process
- Majority of the volume consist of coarse and fine aggregates, proportioned and graded so that fine particles complete fill the spaces between the coarse ones
- Each particle is completely coated with cement/water paste that joins it to the surrounding particles
- The quality of cement is established by the ASTM:
  
<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>Normal (used for most construction)</td>
</tr>
<tr>
<td>Type IA</td>
<td>Normal, air entraining</td>
</tr>
<tr>
<td>Type</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Type II</td>
<td>Moderate resistance to sulfate attack (used when in contact with water with a high concentration of sulfates)</td>
</tr>
<tr>
<td>Type IIA</td>
<td>Moderate resistance, air entraining</td>
</tr>
<tr>
<td>Type III</td>
<td>High early strength (hardens more quickly, used when reduced curing time is required)</td>
</tr>
<tr>
<td>Type IIIA</td>
<td>High early strength, air entraining</td>
</tr>
<tr>
<td>Type IV</td>
<td>Low heat of hydration (used in massive structures like dams, where heat emitted might raise the temperature of the concrete to damaging levels)</td>
</tr>
<tr>
<td>Type V</td>
<td>High resistance to sulfate attack (used when in contact with water with a high concentration of sulfates)</td>
</tr>
</tbody>
</table>

**Air Entrained Cements** contain ingredients that cause microscopic air bubbles to form in the concrete during mixing which give improved workability during placement, and greatly increases the resistance of the cured concrete to damage caused by repeated cycles of freezing and thawing.

- Commonly used for pavings and exposed architectural concrete in cold climates
- Can reach the same structural strength a regular concrete

**Aggregates** take up about 3/4 of the volume of concrete

- Structural strength is heavily dependent on the quality of its aggregates
- Must be stone, clean, resistant to freeze-thaw deterioration, chemically stable, and properly graded for size distribution
- A range of sizes must be included and properly proportioned to achieve close packing of the particles
- The largest particle in a concrete mix must be small enough to easily pass between the most closely spaced reinforcing bars and to fit easily into the formwork
- Maximum aggregate size should not be more than 3/4 of the clear spacing between bars or 1/3 the depth of the slab
- 3/4” or 1 1/2” maximum is common for most slab and structural work
- Can be up to 6” for dams and other massive structures
- Structural lightweight aggregates are made from minerals like shale and reduce the density of concrete by about 20%
- Vermiculite or perlite used in non structural lightweight concrete (used for insulating roof toppings) are less dense than expanded shale

**Mixing water** for concrete must be free of harmful substances, clay, salts, etc. If it’s good enough to drink, it’s good enough to be in concrete.

**Admixtures** are ingredients other than cement, aggregates, and water that are added to the mix to alter it in various ways

- **Air entraining admixtures:** increase the workability of wet concrete, reduce freeze/thaw damage, and (when a lot is used) create very lightweight non structural concretes with thermal insulating properties
- **Water reducing admixtures:** allow a reduction in the amount of mixing water while retaining the same workability, results in a higher strength concrete
- **High range water reducing admixtures (Superplasticizers):** organic compounds that transform a stiff concrete mix into one that flows freely into forms, used to help place concrete in challenging circumstances, or to reduce the water content in a mix in order to increase its strength
- **Accelerating admixtures:** cause concrete to cure more rapidly
• **Retarding admixture:** slow curing to allow more time for working with wet concrete
• **Fly ash:** a fine power that's a waste product from coal-fired power plants, which increases concrete strength, decreases permeability, increase sulfate resistance, reduces temperature rise during curing, reduces mixing water, and improves workability
• **Silica fume (microsilica):** a powder 100x finer than portland cement, a byproduct of electronic semiconductor chip manufacturing that when added produces extremely high strength and low permeability
• **Blast furnace slag:** byproduct of iron manufacture that improves workability, increases strength, reduce permeability, reduce temperature rise during curing, and improve sulfate resistance
• **Pozzolans:** varicose natural/artificial material that react with calcium hydroxide in wet concrete to form cementing compounds
• **Workability agents:** improve the plasticity of wet concrete to make it easier to place in forms and finishes
• **Corrosion inhibitors:** used to reduce rusting of rebar in structures that are exposed to road deicing salts or other corrosion causing chemicals
• **Fibrous admixtures:** short fibers of glass or steal added to a concrete mix to act as microreinforcing
• **Freeze protection admixtures:** allow concrete to cure at temperatures as lot as 20 degrees F
• **Extend set control admixtures:** used to delay the curing reaction in concrete for up to 7 days.
• **Coloring agents:** dyes and pigments used to alter the color of concrete
• Design of a concrete mixture is a science.
• No need to spend money to make concrete better than it needs to be for a given application
• Strength of concrete is primarily dependent on the amount of cement in the mix and the water-cement ratio.
  • Water is required as a reactant in the curing, and much more must be added than is needed for hydration in order to give the wet concrete the necessary fluidity and plasticity for placing and finishing
  • Extra water eventually evaporates leaving microscopic voids that impair the strength and surface qualities
  • Absolute water cement ratio should be kept below 0.60 for most applications (the weight of water should't be more than 60% of the weight of the portland cement)
  • Higher water cement ratios make concrete that's easier to place in forms, but likely to be lower strength
  • Low water cement ratios make concrete that is dense and strong, but without admixtures will not flow easily and have large voids
  • Should be formulated with the right quantity of water for each situation
• **Slump Test** may be performed at the time of pouring to determine if the desired degree of workably has been met without the concrete being too wet.
  • A hollow metal cone is filled with concrete and tapped with a rod, the cone is lifted off and the concrete slumps under its own weight, the amount of slump is measured
• **Test cylinders** are poured for structural concrete from each load.
  • Within 48 hours of pouring the cylinders are taken to a lab, cured as required, and tested for compressive strength
• If lab results are not up to the required standard, test cores are drilled from the actual members made from the questionable batch, if they’re also deficient the defective back has to be cut out and replaced

• If concrete slurry is vibrated excessively, dropped from a height, or moved too far horizontally in formwork its likely to segregate
  • Aggregate works its way to the bottom of the form and water/cement to the top
  • Result is non uniform and unsatisfactory, and typically has to be redone
  • Segregation is prevented by depositing fresh from the mixer as close as possible to the final position
  • Should not be dropped more than 3’ - 4’
  • If it must be moved to an inaccessible location, it should be pumped through hoses or conveyed in buckets

• Must be consolidated in the forms to eliminate trapped air and the fill complete around rebar and all the corners of the formwork

• Concrete must be kept moist until its required drying strength is achieved
  • If it’s allowed to dry before that point the straight will be reduced
  • Premature drying is a big danger when slabs are poured in hot/windy weather
  • Can cause cracking before it even begins to cure
  • If concrete reaches subfreezing temperatures while curing, the reaction stops completely until it rises above the freezing mark again

• Formwork shapes and supports concrete until it cures enough to support itself
  • Formwork for a beam or slab is also a temporary working surface during construction
  • Must be strong enough to support weight concrete without deflection
  • Usually repeatedly used and must be protected
  • Coated with a form release compound that prevents adhesion of concrete to the form
  • Formwork is basically an entire temporary building that has to erected and demolished to construct the actual building. It’s a major cost of the project.

• Reinforcing is required because concrete has no useful tensile strength
  • Steel rebar is placed where there are tensile forces in a structural member, and concrete resist the compressive forces
  • Rebar is hot rolled like structural shapes, round in cross section with ribs for better bonding to concrete
  • Bars are numbered based on the number of eights of an inch the bar’s diameter is
    • Ex: number 6 rebar is 6/8” (or 3/4”) in diameter, number 8 rebar is 8/8” or 1”

• Reading Rebar:
  • Top letter or symbol = Producing mill
  • Second marking = Bar size (given in eights of an inch)
  • Third marking = Manufacturing material ( "S" for carbon-steel or "W" for low-alloy steel)
  • Bottom marking = Grade marking

• Structural engineer knows how to calculate the amount of rebar required for a given cross section and can be achieve with a few big bars or many small bars
• Rebar in structures exposed to salts like seawater are prone to rust

Grade 520
• Galvanized or epoxy coated rebar is used in the case
• Rebar for slabs is produced in sheets of welded wire fabric, a grid of wires spaced 2” - 12” apart
• After fabrication and shipment to the project site, bars are temporarily wired together in forms to await pouring of concrete
  • Any transfer of load from one bar to another is done by the concrete
  • **Rebar Splicing**: The process of overlapping of joining rebar ends. Splicing can be done with either lap splices or butt splices. Butt splices are either welded or with mechanical couplings
  • When two bars have to be spliced, they are overlapped by about 30 bar diameters, either mechanically with a wedge connection, a welded connector, grouted sleeve, threaded sleeve, clamping sleeve, or flanged coupler
• In a simply supported beam under a uniform load, the maximum compressive stress is located in the top of the beam at midspan and the maximum tension stress is located at the bottom of the beam at midspan
  • Bottom rebars and stirrups are placed horizontally near the bottom of the beam, leaving a specified amount below and to the sides for cover (which protects them from fire and corrosion) by sitting on **chairs** made of heavy steel wire or plastic, which remain in the beam after the concrete is poured
  • Bars are most heavily stressed at the midpoint of the beam
  • Stirrups are used to resist lesser diagonal orientation near the ends of the beams
  • When concrete is to come in direct contact with the soil concrete bricks are used to support the bars to prevent rust from forming under the feet of the chairs
• In columns, inward buckling is prevented by the concrete core of the column and outward buckling is prevented by ties
  • **Column ties**: bands are wired at required spacing and used for square, circular, or rectangular columns. Generally more affordable than column spirals
  • **Column spirals**: shipped to the construction sight as tight coils of road that are expanded accordion style to the required pacing and wired to the vertical bars. Used for square or circular arrangements

**Prestressing**
• When steel elongates under tension forces the concrete around it cracks from the deg of the beam to the horizontal plane
• If initial tension or prestress in the steel bars where of sufficient magnitude, the concrete poured around them would never be subjected to tension and no cracking would occur
• The beam is also capable of carrying a greater load with the same amount of concrete and steel, making them less expensive as conventional reinforced beams
• Ordinary rebar is not strong enough and high strength steel strands must be used
• Steel strands are stressed tightly between abutments in a plant and concrete is cast around the steel
• After the concrete has cured to a minimum compressive strength, the strands are cut off at either end, and the beam recoils which squeezes all the concrete of the member into compression

**Posttensioning**
• Done in place on the building site, high strength strands, called tendons, are covered with a steel or plastic tube to prevent them from bonding to the concrete and are not tensioned until the concrete has cured.
• Each tendon is anchored to a steel plate embedded in one end of the beam/slab
• A hydraulic jack applies tensile force to the other end while compressing the concrete with an equal and opposite forces applied through the plate.
• The tendon is anchored to the plate and the jack is removed
• Efficiency is almost identical to that of prestressing system

**Sitecast Concrete Framing Systems**

• **Slab on Grade** is a levels surface of concrete that lies directly on the ground and used for roads, sidewalks, patios, airport runways, and ground floors of buildings
  - Usually experiences little structural stress
  - There’s no such thing as perfectly flat floor, everything undulates a little, and most of the time isn’t noticed

• **Concrete walls** at ground level usually rest on a poured concrete strip footing, which is poured much like a concrete slab on grade
  - Cross sectional dimension are rebar are determined by a structural engineer
  - A key groove that will form a mechanical connection to the wall is formed in the top of the footing
  - Vertically projecting dowels of steel reinforcing bars are installed in the footing before pouring and will later be overlapped with vertical bars in the walls
  - Footings are left to cure at least a day before walls are formed and erected
  - Wall forms may be custom built for each job, but prefab panels are typical
  - Insulating concrete forms can be used to both form the wall, and stay in place permanently to serve as insulation

• **Concrete Columns** is cast and formed like a wall with a few exceptions:
  - The footing is usually an isolated column footing, pile cap, or caisson rather than a strip footing
  - Dowels are sized and spaced to match the vertical bars in the column
  - Cage of column rebar is assembled with wire ties and hoisted into place over the dowels, and the bars may be spliced end to end with welds or mechanical connections mentioned above.
  - Can be formed from a box of plywood, cylindrical steel or plastic tube bolted together for easy removal later, or a waxed cardboard tube that peeled away later (like one of those Pillsbury biscuit tubes that you unwrap)

• **One Way Floor and Roof Framing**
  - Spans across parallel lines of support form walls or beams
  - Forms for the girders, beams, and slab are poured simultaneously as a single piece
  - Edges are beveled so shape edges of concrete don’t break off during form stripping
  - Rebar is placed and concrete is poured
  - Slabs are usually 4" - 10" deep depending on the span/loading
  - Top of slab is finished like a slab on grade and covered for damp curing
  - When slab/beans have enough strength to support themselves, formwork is removed and then reshored with vertical poops to relieve them of loads until they have reached full strength. Formwork is moved up to the next level after cleaning
  - As one way concrete slabs spans increase a thicker slab is required
    • Eventually the slab becomes too thick and the weight alone is too much for it to handle unless unnecessary concrete is removed … called a **Concrete one way Joist System**
• Bottom steel is concentrated in spaced ribs or joists and the thin slabs that span it are only reinforce by shrinkage temperature bars. The only concrete in the system is working...everything unnecessary is stripped away
• Joists are formed with metal pans spaced as required for joist thickness
• The bottom of each joist is formed by the wood deck the pans sit on
• Beam and joist rebar is placed and concrete is poured and finished

**Two Way Floor and Roof Framing**
• Generally more economical than one way systems where the columns can be spaced in bays that are nearly square
• Two way solid slab is rarely seen, most are made without beams
• The slab is reinforced in such a way that varying stresses in the different zones of the liable are accommodated with a uniform thickness of concrete
• A **two way flat slab** is used for heavily loaded buildings, and the slab is flat expect for a thickening of the concrete to resist shear forces around the top of each column, either by a drop panel, or a mushroom capital
• Typical depths are about 6” - 12” deep
• Rebar is laid in both directions to resist bending forces
• In lightly loaded buildings like hotels, dorms, or apartments, thickening at the column may not be necessary and the slab can be totally flat
• Complete flat ceilings allow room partitions to be placed anywhere and floor to floor heights can be kept to a minimum

**Two Way Waffle Slab**
• Tow way equivalent of the one way concrete joist system
• Metal/plastic pans are used as formwork to eliminate nonworking concrete from the slab, allowing longer spans feasible than a flat plate system
• Standard forms are 6” wide on 36” centers and a variety of depths up to 20” deep
• Solid heads are created around the columns, which serve the same function as the drop panels in the two way flat slab

**Lift Slab Construction** used with two way flat plate structures eliminates formwork, the slabs are stacked on the ground and hydraulic jacks are used to lift the slabs up the column to their final elevations

**Slip Forming** is useful for tall walled structures such as elevator shafts, stairwells, and storage silos, a ring of formwork is pulled by jacks supported on rebar while concrete is added

**Tilt Up Construction** is when a floor slab is cast on the ground, and reinforced concrete wall panels are poured over in a horizontal position. When cured, they’re hoisted into position and grouted together

**Shotcrete** is concrete sprayed into place pneumatically, and used primarily for repairing damaged concrete on the faces of beams/columns

**Architectural Concrete** is left exposed as finished interior/exterior surfaces, after partial curing additional texture modifications can be made, including rubbing with abrasive stones, grinding smooth, and hammering with a number types of hammers

**Longer Spans in Site Cast Concrete** are possible, including post tensioned beams and girdlers...like steel plate girders and rigid frames
• Space frames and trusses aren’t common in concrete
• Barred shells and folded plates made of thin concrete plate increase rigidity without adding material
• Cost of a concrete frame can be broke down into cost of the concrete, rebar, and formwork
• Formwork generally accounts for over 1/2 the cost of sitecast concrete construction
• Concrete is usually the least significant
• Standardization of forms is key to cost savings

• Sitecast concrete and the building code
  • Inherently fire resistant...when fire attacks the water of hydration is gradually driven out and the concrete loses strength, but it’s a sloooow process.
  • With adequate cover over rebar and adequate slab thickness, concrete structures are considered Type I buildings
  • Sitecast concrete has rigid joints, and in many cases needs no additional structural elements to achieve necessary resistance to wind/seismic

• Precast Concrete Framing Systems
  • Cast at cured in factories, transported to the jobsite and then erected as rigid components
  • Many advantages over sitecast concrete: done under shelter, at ground level, can be highly mechanized, greater control of workmanship, forms can be used many times, prestressed steel have greater structural efficiency, and have superior strength
  • For the fastest curing it’s made with Type III portland cement
  • Prestressing plant can produce fully cured structural elements in a 24 hours systole
  • Erection process is similar to structural steel and is much faster than sitecast concrete because there’s no formwork and and little or no waiting for curing
  • Heavy and bulky to transport to the jobsite and hoist into place
  • Most standardized elements are those used for floor and roof slabs
    • Supported by bearing walls of concrete, steel, masonry
      • Solid Flat Spans: used for short spans and minimum slab depths- 3 1/2” - 8” deep
      • Hollow Core Slabs: precast elements suitable for intermediate spans where longitudinal voids replace much of the nonworking concrete, 8”-12” deep
      • Double Tees and Single Tees: longest spans with deepest elements and more nonworking concrete eliminated, single tees: 36”-48” deep, double: 12”-32” deep
    • Manufactured with a rough top and 2” topping slab is poured on top to unify finish and help elements act together as a unified system
    • Underfloor electrical conduits can be embedded in the topping
  • Precast Concrete Beams, Girders, and Columns are made in several shapes
    • Rectangular, L Shaped, Inverted Tee, AASHTO Beam
    • Ledges provide support for precast slab elements
  • Precast Concrete Wall Panels made of precast solid slabs in low and high rise applications
    • Prestressing strands to strengthen the wall against buckling and to eliminate camber
  • Supporting Precast Concrete Slabs
    • On a precast concrete skeleton
    • On precast loadbearing wall panels
    • On a combination of the two
    • Simplest joints in precast concrete rely on gravity by placing one element on top of another (e.g.: a slab resting on a bearing wall). Bearing pads prevent grinding between the two
    • Post tensioning can be done to combine precast elements into even larger ones on the site
  • Construction Process is parallel to that for steel framing
• Shop drawings are submitted to the designer for review, and any special models are made. Finished elements are made and marked for their location. Then transported to the site and assembled.

• Fire resistance of precast concrete building frames is dependent on if they are made of lightweight concrete or normal concrete. Typically it is considered Type I or II construction.

• Slab elements are usually amiable in 1 and 2 hours fire resistance ratings, and beam/columns from 1-4 hours.

**Types of Heavy Duty Concrete Connections/Fasteners** used to anchor building components and machinery

- Anchor bolt
- Steel plate welded to a bent rod
- Steel angle with a traded stud welded to it
- Adjustable insert of malleable iron nailed to formwork
- Threaded inserts cast into concrete
- Sheet steel dovetail slot used with anchor straps to tie masonry to concrete

**Concepts/Goals:**

- Concrete is the universal material of construction
- Raw ingredients are available pretty much everywhere in the world
- Can be made into buildings with primitive tools or fancy high tech equipment
- Relatively low in cost
- Can’t burn or rot
- Can be used for every building type
- Has no useful tensile strength or form of its own...must be combined with steel
- Concrete that is cast into forms on site leaves tons of possibilities for the designer, any shape that can be formed can be cast.
- It’s the most potent of architectural materials
- In many cases where sitecast concrete could be replaced with precast, sitecast remains the method of choice because of its more massive, monolithic architectural character
- Sitecast concrete tends to be heavier than other types of structures, and are relatively slow to construction because each level must be formed, poured, cured, and stripped for formwork before continuing on
- Precast, prestressed concrete elements are crisp, slender, precise, and repetitive
  - They combine all weather erection of structural steel framing with the self fireproofing of sitecast concrete framing to offer economical options
  - It’s architectural aesthetic is just coming to maturity…no longer just for industrial buildings and parking lots!

**Processes:**

**Slab on Grade Construction**

- Unusable topsoil is scraped away and 3/4” diameter crushed stone is compacted at least 4” deep over the subsoil as a drainage layer to keep water way from the underside of the slab
- Simple edgeform of wood/metal is fastened to the takes driven into the ground and coated with form release compound
- Top edge of the form is leveled, and the thickness of the slab can range from 3” for residential to 6”-8” for industrial
• If the slab is to be the floor of a building, a moisture barrier is laid over the crushed stone to prevent any water from rising through the slab
• A reinforced mesh of welded wire fabric is cut to size just smaller than the dimensions of the slab and laid over the moisture barrier.
  • Residential applications have a 6” wire spacing
  • Grid is used to help protect the slab from cracking that might be caused by concrete shrinkage, temperature stresses, concentrated loads, frost heaving, or ground settlement.
• Control joints are provided by inserting a fibrous strip into the form before it is poured, or be made by running a special trowel along a straightedge to form a groove
• Pouring of the slab starts by placing the concrete in the formwork, either by chute from the transitmix truck, buckets, wheelbarrows, or a concrete pump and hoses
• Concrete is spread by workers with shovels or rakes until the form is full and then air pockets are eliminated by agitating slightly with the same tools
• The welded wire is raised to the middle height of the slab with metal hooks to resist tensile forces
• Strike off or straightedge the concrete by drawing a stiff plank of wood/metal across the top edge of the formwork to achieve a level, but rough surface.
• If a concrete topping will be poured later, or if a stone/brick/terrazzo will be applied the slab might be left rough to cure
• If not, after the watery sheen has evaporated from the surface the slab smoothed with a flat tool called a float
• Shake on hardeners are sometime applied to react with the concrete to form a very hard, durable surface for heavy wear applications like warehouses and factories
• Troweling is done after floating when the slab is firm for a smooth surface
• Slab should be cured under damp conditions for at least a week, otherwise it could crack
  • Accomplished by covering the slab with an absorbent material like sawdust/sand/earth and maintaining the material in a damp condition,
  • Or an impervious sheet of plastic/waterproof paper can be placed over the slab to prevent the escape of moisture
  • Or spraying the concrete with one or more applications of a liquid curing compound with forms an invisible moisture barrier membrane over the slab

• **Cast in Place Walls**
  • Wall forms are placed and form ties are inserted, and reinforcing is placed
  • Concrete is brought to the site, test cylinders are made, and slump test is performed
  • Concrete is transported to the top the wall by a pump or bucket, and concrete is deposited in the forms, consolidating with a vibrator to eliminate air pockets
  • Hand floats are used to smooth and level the top, and the top of the form is covered with plastic sheet or canvas and left to cure
  • After a few days, the bracing is taken down and formwork is stripped from the wall
  • Form tie ends are twisted off and covered with grout
  • Defects in the wall are repaired

• **Selecting a Sitecast concrete framing system**
  • Decide if bays of the building are square, if so, a two way system will probably be more economical than a one way system
  • Calculate the spans. If they are less than 25’, a two way flat plate system might be more economical due to the simplicity of the formwork. Longer spans work better with a waffle slab or one-way joist system
• Calculate the weight of the loads. Heavy loading does better with a thicker slab and larger beam
• Decide if there will be a finish ceiling beneath the slab. If not, a flat plate/one way slab construction have smooth, paintable undersides that can serve as ceilings (and are really desired right now)
• Decide of the lateral stability of the building against wind/seismic loads have to be provided by the concrete frame. If so, a one way system with deeper beam-to-column connections will work better

**Manufacturing Precast Concrete Structural Elements**
• Elements are produced in permeant forms called casting beds which average in length from 400' to 800' or more in some plants
• Cycle beings in the morning, high strength steel reinforcing strands are are strung between abutments, then pretensioned with jacks.
  • Mild steel rebar and welded wire fabrics are placed and weld plates and other embedments are installed
  • Concrete is placed in the bed, vibrated to eliminate voids and struck off level
  • Live steam or radiant heat is applied to accelerate curing
  • 10 - 12 hours after pouring the concrete has reached a compressive strength of 2,500 - 4,000 psi and has bonded to strands
• The next morning, the exposed strands are cut, hoisted off the bed and stock piled for shipment

**Other Materials**

**Facts/Rules:**

**Soil**
• Soil is formed by the chemical decomposition of rock; water, air, and temperature action on rock; and the decay of vegetable and animal matter. Types include:
  • **Gravel:** well drained and able to bear loads (+2 mm)
  • **Sand:** well drained and can serve as foundation when graded (0.5 - 2 mm)
  • **Silt:** stable when dry, swells when frozen, do not use when wet (.002 - .05 mm)
  • **Clay:** must be removed, too stiff when dry and too plastic when wet (< .002 mm)
• **Levels of Soil:**
  A Level = Topsoil (organic/mineral material)
  B Level = Minerals
  C Level = Partially weathered/fractured rock
  D Level = Bedrock
• **Alluvium:** soil, sand or mud deposited by flowing water
• **Humus:** soft dark soil containing decomposed organic matter, poor bearing capacity
• **Loam:** rich soil containing equal parts of sand, silt, and clay
• **Complete Soil Testing**
  • **Bearing Capacity:** max pressure a foundation soil can take with harmful settlement
    Bedrock = 10,000 psf
    Well graded gravel/sand = 3,000 - 12,000 psf
    Compacted sand/fill = 2,000 - 3,000 psf
    Silt/Clay = 1,000 - 4,000 psf
• **Borings:** locations depend on nature of the building and should be 20'-0" past firm strata
  - Open warehouses: one in each corner and one in the middle
  - Large structures: 50'-0" spacing
  - Uniform conditions: 100 - 500' spacing
• **Wash boring:** the drilling of a test hold to locate bedrock beneath very compact soil. A pipe is driven into the soil while water forces the material to the surface. It can penetrate all materials other than rock.
• **Auger boring:** soil testing that uses an auger drill big fastened to a rod to bring the soil to the surface. Most efficient in sand and clay because the bit is easily obstructed. It has limited depth
• **Core boring:** an intact cylindrical sample is extracted by drilling through all types of soil including bedrock. Very reliable and expensive
• **Test pit:** an excavation of an open pit that allows for a visual examination of the existing conditions as well as the ability to take intact samples for further testing. Can determine the depth of the water table.
• **Prevent Future Problems**
  - Connect new on-site drainage to natural drainage
  - Design surface water runoff based on worst case storm scenario
  - Prevent erosion by using channels, gutters, swales, and xeriscaping
• **Foundations**
  - **Spread Footing:** Most economical…$ method.
    - Delivers load directly to soil over a large area
    - Area of the footing = load/safe bearing capacity.
  - **Wall Footings:** Most common method
    - Under a continuous foundation wall that supports a bearing wall
  - **Column Footing:** one footing supports one column
  - **Combined Footing:** when 2+ columns are too close to each other or a property line for separate footings, one footing is poured for them all
  - **Strap/Cantilever Footing:** like a combined footing, but columns are far apart
  - **Mat Foundations:** Very expensive…$$$ method.
    - Typically it’s only used when the strata is weak,
    - It acts as one continuous foundation.
  - **Pile Foundations:** used when soil is unsuitable for spread footings (e.g.: expansive soils or clay near surface) by transmitting loads through soil to a more secure bearing farther below
    - Located in groups or in alignment under a bearing wall
    - Load transferred from wall to pile caps.
    - Piles are either driven (timber, steel, precast conc) or drilled (caissons) Belled Caissons: holes are drilled to firm strata and concrete poured.
    - They’re basically really, really
deep spread footings

- **Friction Pile**: Driven into softer soil.
  - Friction transmits the load between pile and soil.
  - Bearing capacity is limited by whichever is weaker: strength of the pile or soil
- **Socketed Caissons**: like Belled Caissons, but the hole is drilled deep into the strata.
  - Bearing capacity comes from end baring and frictional forces.
- **End Bearing Piles**: 2-3x cost of spread footings.
  - Driven until tip meets firm resistance from strata

- **Retaining Wall Types**
  - **Cantilever wall**: (most common type) constructed of reinforced concrete
    - resists forces by the weight of the structure and weight of the soil on the heel of the base slab
    - A key projects form the bottom to increase the resistance to sliding
    - 20'-25' max height due to economics
  - **Counterfort walls**: like cantilever walls, with a counterforts spaced at distances approximately half the wall height
  - **Gravity walls**: resist forces by own weight and made of non reinforced concrete
  - Retaining walls fail as a whole by overturning or sliding.
    - To prevent this, the friction between the footing and the surrounding soil/earth pressure in front of the toe must be 1.5 the pressure that typically causes the wall to slide.

- **Roofs**
  - First line of defense against the weather
  - **Low sloped roof**, less than 3:12 or 25%
    - A highly interactive assembly made up of many components
      - **Deck**: structural surface that supports the roof
      - **Thermal Insulation**: installed to slow the passage of heat in and out of the building
      - **Vapor Retarder**: essential in colder climates to prevent moisture from accumulating within the insulation
      - **Roof Membrane**: impervious sheet of material that keeps water out
      - **Drainage**: components that remove water that runs off the membrane
      - **Flashings**: prevent water from penetrating membrane wherever it is penetrated by pies, joints, conduits, hatches, etc
    - Roof decks should be adequately stiff under loading and fully resistant to wind uplift forces
    - They must slope toward drainage points, even with deflections of structure
    - A slope of at least 1/4” per foot should be provided
    - Beams that support the deck are often sloped by shortening columns, or the deck can be level and slope created from tapered rigid insulation panels
    - If the slope is too shallow, water will pool and stand for extended periods of time in low spots leading to deterioration of roofing materials and further deterioration
    - If the deck is large, it should have enough movement for expansion and contraction
    - Roof membrane must be laid over a smooth surface,
      - Wood deck should have no large gaps or knotholes
      - Sitecast concrete deck should be troweled smooth
      - Precast concrete plank deck must be topped or grounded at junctions to fill cracks
• Corrugated steel decks must be covered with panels of rigid insulation, wood, or gypsum to bridge the flutes in the deck
• Deck should be dry at the time of roofing to avoid problems with water vapor trapped under the membrane
• Concrete decks and insulating fills must be fully cured and thoroughly air dried
• Thermal insulation can be installed
  • **Below the structural deck**: traditional location for it, in the form of low density rigid board or lightweight concrete in order to support the membrane.
    • It protects the deck from temperature extremes and is protected by the membrane.
    • If water or vapor accumulates in the insulation it’s trapped below the membrane and can lead to decay of the insulation and deck.
• **Between the deck and membrane**: in cold climates a vapor retarder should be installed below the insulation and the insulation should be ventilated to allow the escape of any moisture that may accumulate there.
• **Above the membrane**: relatively new concept, membrane is protected from extreme heat and cold and is on the warm side of the insulation where it is immune to vapor blistering problems.
  • Insulation is exposed to water when placed above the membrane, it must have a material that retains its insulating value when it gets wet...and it can’t decay or disintegrate either.
  • Extruded polystyrene panels are embedded in a coat of hot asphalt to adhere them to a membrane below, or are laid loose.
  • Held down and protected from sunlight by a layer of ballast, which consists of crushed stone, a thick concrete layer laminated to the upper surface of the board, or interlocking concrete blocks.
• Poured gypsum and concrete deck fill insulation are economical & applied directly to the corrugated steel decking and rough concrete decks, easily tapered during installation.
• Membrane in a protected membrane roof also serves as the vapor retarder.
  • Most common consists of two layers of asphalt saturated roof felting bonded together and adhered with hot asphalt.
  • The vapor retarder must be located so that it will always be warmer than the dew point of the interior air under every common condition of use. This means it goes on the warm side of the insulation (inside in cold climates, outside in warm climates).
• **Built up Roof Membranes**: assembled in place from multiple layers of asphalt impregnated felt bedded in bitumen, foam insulation, polymer fabric, and ballast.
• **Single Ply Roof Membranes**: diverse group of sheet materials that are applied to the roof in a single layer, and require less labor to install.
• **Fluid Applied Membranes**: used for domes, shells and other complex shapes, a waterproofing layer over sprayed on polyurethane foam insulation.
  • Traffic decks are installed over flat roof membranes for walks, terraces, etc.
• **Steep Roofs** have a pitch of 3:12 or greater.
• Coverings include:
  • **Thatch**: bundles of reeds, grasses, or leaves, and a highly labor intensive process rarely used today.
  • **Shingles**: can be wood, asphalt, slate, clay tiles, concrete tiles, applied overlapping layers with staggering joints.
Architectural Sheet Metal: sheets of lead and copper have been used since ancient times, now terne roofing is made of steel/stainless steel that’s alloy coated with lead or tin. Metal panel roofs are made of long sheets of aluminum, aluminized steel or galvanized steel

Most installation/vapor barriers are installed below the roof sheathing or deck

Have a tendency to form ice dams at the eaves under wintertime conditions

The same metals should sues for every component of a sheet metal roof, including the fasteners and flashings, if not possible, similar galvanic activity metals should be used, dissimilar should be separated by rubber gaskets

When strongly dissimilar metals touch, galvanic action causes rapid corrosion

Roofing material are grouped into four classes:

Class A: effective against fire exposure (slate, concrete tile, clay tiles, asphalt singles with glass felts) and may be used on any building in any type of constriction

Class B: effective against moderate fire exposure (built up and single ply roofs, sheet metal roofing, asphalt shingles on organic felts) and are the minimum class that may be used on Type IA, IB, IIB, IIIA, IV, and VA construction types

Class C: effective against light fire exposure (fire retardant treaded wood shingles and shakes) and the minimum class that may be used for Type IIB, IIIB, and VB construction types

Nonclassified roof coverings (untreated wood shingles) can be used on Type VB construction and some agriculture, accessory, and storage buildings

Glass and Glazing

Float glass has been produced in america since 1963 and now accounts for almost all domestic flat gals protection

Glazing: the installing of glass in an opening, or to the transparent material (typically glass) in a glazed opening

Glazier: a person who installs glass

Lights/Lites: individual pieces of glass

The major ingredient of glass is sand, which is mixed with soda ash, lime, and a small amount of alumina, potassium oxide, and various element to control color

When drawn into small fibers, glass is stronger than steel, though not as stiff

Glass that is placed in tension will crack form an imperfection near the point of maximum tension and the glass will shatter

Glass thickness ranges from 3/32” (single strength) - 1/8” (double strength) - 1” depending on the manufacture

Thick glass is required for buildings with larger windows, and for windows in tall buildings. Increased attention to the frame is also required

Window glass is annealed or cooled slowly under controlled conditions to avoid locked int thermal tresses that might cause unpredictable behavior

Tempered Glass: produced by cutting annealed glass to required size, reheating to 1200 degrees’ and cooling both its surfaces rapidly with blast of air while core cools more slowly

Glass is about 4 times as strong in bending and much more resistant to thermal stress and impact.

If it breaks, the sudden release of internal stresses causes it to break into small granules rather than long, sharp edged shards

Used in exterior doors, floor to ceiling sheet glass, doors that have no frames, squash/handball courts, hockey rink enclosures, basketball hoop backboards
• More expensive than annealed glass
• **Heat Strengthened Glass:** process is similar to tempering but the induced compressive stresses in the surfaces and edges are about 1/3 as high
  • About 2 times as strong in bending and more resistant to thermal stresses and impact compared to annealed
  • Breakage is more like annealed glass than tempered glass
• **Laminated Glass:** made by sandwiching a transparent polyvinyl layer between sheets of glass and bonding the three together under heat and pressure
  • Not quite as strong as annealed glass of the same thickness
  • When it breaks the interlayer holds the shards of glass in place
  • Used in skylights and overhead glazing
  • A better barrier to the transmission of sound than solid glass
  • Used to glaze windows of residences, classrooms, hospital rooms, etc., that must be kept quiet in otherwise noisy environments
• **Security Glass** used at drive up bank tellers and other secure locations is basically beefed up laminated glass and can stop any caliber of bullet
• **Fire Rated Glass:**
  • Glass in fire doors/separation walls must maintain its integrity as a barrier to the passage of smoke, heat, and flames even after exposure
  • Specially tempered glass is rated at 20 minutes of fire protection
• **Wired Glass** is produced by rolling a mesh of small wires into a sheet of hot glass
  • When wired glass breaks from thermal stresses, the wires hold the sheets of glass together to act as a fire barrier
  • Holds a fire resistance rating of 45 minutes
• **Patterned Glass:** hot glass is rolled into sheets with many types of surface patterns and textures to use when light transmission is desired but vision must be obscured for privacy
• **Fritted Glass:** surface of glass is imprinted with silk screened patterns of ceramic based paints, which are made of pigmented glass particles called frit
  • After it’s been printed, the glass is dried and fired, turning the frit into hard, permanent ceramic coatings in a variety of color
• **Spandrel Glass:** opaque glasses for covering spandrel areas (bands of wall around the edges of floors) in a glass curtain wall construction
  • Uniform coating of frit is applied to the inter surface of the glass
  • Usually tempered or heat strengthened to resist thermal stresses that are accumulated by solar heat behind the spandrel
• **Tinted and Reflective Coated Glass:**
  • Solar heat build up can be a problem in inhabited spaced, especially in the summer
  • Fixed sun shading devices are the best way to block unwanted sun, but some tinted/reflective glass is designed to reduce glare and cut down solar heat gain
• **Tinted Glass:** made by adding small amounts of selected chemical elements to molten glass mixture to produce a gray, bronze, blue, green, or gold hue
• **Reflective Coated Glass:** thin durable films of metal can be deposited on a surface of clear or tinted glass to make it reflective
• **Visible Transmittance:** measures the transparency of glass to light, and range downward from 0.9 for clear glass
• **Insulating Glass:** glass is an extremely poor thermal insulator
  • It conducts heat about 5x faster than polystyrene foam insulation
Double Glazing: a second sheet of glass applied to a window with an air gap between cuts heat loss in half
Practice of doubling (or tripling) layers has been used in cold climates
The thickness of an airspace is less critical to the insulating value than the mere presence of it
A standard overall thickness is 1” with 2, 1/4” glass sheets and a 1/2” air gap
Thermal performance can be improved by low-e coating on one or both of the sheets of glass. It’s a thin metallic coating that reflects selected wavelengths of light and heat radiation

Plastic Glazing Sheets: transparent materials often used instead of glass for special applications, and typically more expensive than glass.

Glazing
Process of placing glass in downs and making weathering joints between the glass and its frame using glazing compounds
Clearances must be allowed between glass and frame to be surrounded by a watertight seal, but but must also allow for thermal expansion and contraction
Small lights of glass aren’t subject to wind stresses or big thermal expansion and so can be glazed very simply
Large lights (over 6 square feet in area) require more careful glazing
Weight of glass must be supported not to subject it to intense stress patterns
Support against wind pressure and suction
Insulate glass from the effects of structural deflections in the frame
Allow for expansion and contraction of both glass and frame without damage to the other
Avoid contact of the glass with the farm of the window or with any other material that would abrade or stress the glass
Glass is a two-way pipeline for the flow of both conducted and radiated heat. It conducts heat quickly out of a building and holds on to solar heat inside a building
Per the IBC, large sheets of glass that might be mistaken for a clear opening, or located in or near doors/windows having more than 9 square feet of glazing area must be glazed with tempered, laminated, or plastic glazing materials

Cladding Systems
Primary function of cladding is to separate the indoor environments of a building from the outdoor in such a way that they indoor can be maintained at levels suitable to the buildings intended use
Keep Water Out
Rain, snow, ice, moisture, you name it...it should’t get in.
Can be tricky to do because water can be driven into the face of a building at high speeds and high air pressures, not just downward, but upward, sideways, and every direction you can name
Especially an issue on all buildings
Preventing Air Leakage
Prevent the unintended passage of air between indoors and outdoors
Small air leaks are bad because they waste conditioned air, cary water through the wall, allow moisture to condense inside and allow noise outside to get in
Sealants, gaskets, weatherstrips and air barrier membranes are used
• Control Light
  • Control the passage of sunlight, that is heat that may be unwelcome
  • Sunlight is visible light light, great for illumination, but bothersome if it causes glare within a building
  • UV wavelengths must be kept off human skin and away from interior materials that will fade/disintegrate
  • Sometime includes external shading devices

• Control the Radiation of Heat
  • Should present interior surfaces that are at temperatures that will not cause radiant discomfort
  • Cold interior spaces near walls is uncomfortable even if the rest of the building is warm. Same is true for warm interior spaces when the rest is cool

• Controlling the Conduction of Heat
  • Cladding must resist conduction of heat in and out of the building
  • Avoidance of thermal bridges where wall components that are highly conductive (e.g.: metal framing) are likely to cause localized condensation on interior surfaces
  • Thermal insulation, good glazing, thermal breaks are used to control heat

• Control Sound
  • Isolate the inside of the building from noises outside and vice versa
  • Best achieved by airtight walls that are massive and resilient
  • Secondary function of cladding is to resist wind and control water vapor, weather gracefully, and control fire

• Resist Wind Forces
  • Must be strong and stiff to sustain the pressure and suctions that will be placed upon it by wind
  • Easier to meet with lower buildings, taller buildings have faster winds and suction

• Control Water Vapor
  • Retard the passage of water vapor in both summer and winter
  • Must be constructed with adequate levels of thermal insulation, a suitable vapor retarder, and sealed sealants, cracks, and holes to prevent condensation of moisture

• Adjust to Movement
  • Tugging, pushing, twisting, and settling is always happening to the frame and the cladding.
  • These forces must be anticipated and allowed for in the design

• Allow Thermal Expansion and Contraction
  • Indoor/outdoor temperature difference can cause warping of cladding panels due to differential expansion and contraction of tier inside and outside faces

• Accommodate Moisture Expansion and Contraction
  • Caused by varying moisture content
  • Bricks/stones tend to expend slightly after installation
  • Concrete block/precast concrete shrinks slightly after installation and curing
  • Individual movements are small, but can accumulate to significant quantities in an overall system

• Structural Movement
  • Must adjust to changes in the structural frame
• Foundations might settle unevenly, gravity forces shorten columns, wind/earthquake forces push laterally

**Resist Fire**
• Code provisions help protect the building

**Weather Gracefully**
• Maintain the visual quality of the building
• Allow for periodic cleaning and replacement of glass/sealant/etc
• Resist oxidation and UV degradation

**Easy to Install**
• Should be secure places for installers to stand, easy to make adjustments of inaccuracies
• Dimensional clearances provided to allow installation without binding against other components
• Backup air barriers and drainage channels to protect the building if the primary method fails

**Watertightness In Cladding**
• In order for water to get into a building these three things must happen simultaneously:
  • There must be water present on the outer face of the wall
  • There must be an opening for the water to move through
  • There must be a force to move the water through the opening
• If one of these conditions is not met, the wall won’t leak. Oh but only if it was that easy...

**Barrier Wall Approach:** eliminate openings from a wall by carefully sealing every seam in the wall with membranes, sealants or gaskets and attempt to eliminate all the holes and cracks
• Hard to do because joints are unlikely to be perfect, either improperly installed, building movement tears its loose, fails due to weathering, etc…

**Internal Drainage/Secondary Defense Approach:** internal drainage channels within the cladding and backup sealant joints are installed
• An important part of every metal/glass curtain wall system
• Gravity is a factor that pulls water though a wall at an inclined plane
• Surface tension of water can allow water to be drawn into the building unless a drip is provided on the underside surface where water might adhere
• Capillary action is the surface tension effect that pulls water through any opening that can be bridged by a water drop
• Capillary breaks provided somewhere in the opening stops this

**Rainscreen Principle**
• Creation of an airtight plane, or air barrier, at the interior side of the cladding
• Air barrier is protected from direct expire of the outdoors by the reinsertion
• Between Th. Rain screen and the air barrier is space called a Pressure Equalization Chamber
• As wind pressures build up and fluctuate, currents of air pass back and forth through each unsealed joint and equalize the pressure in the chamber and outside

**Sealant Joints In Cladding**
• Most cladding systems require seams that are closed with rubberlike compounds
• The role of sealant is to fill the joints between cladding components, preventing the flow of air and/or water while still allowing dimensional tolerances
- Widths are usually 3/8" - 3/4"
- Often used to seal joint between panels of stone or precast concrete in a curtain wall, and to seal between dissimilar materials like metal/glass cladding meets a masonry wall
- Gunnable sealant materials are visually sticky liquids (mastics) injected into joints with a sealant gun
  - Cure within the joint and become rubberlike
- Gaskets are strips of various fully cured elastomeric (rubberlike) materials compressed into a joint to seal tightly against the surfaces on either side
- Preformed Cellular TpAe Sealant: polyurethane sponge strips impregnated with mastic sealant that expands when unwrapped and inserted into a joint
- Backer rods are cylindrical strip of highly compressible, flexible plastic foam material that limits the depth in which the sealant will penetrate

**Building Cladding Systems**
- Load bearing wall: high strength masonry and concrete with the addition of thermal insulation materials, cavities, flashings for water resistance, and steel reinforcing to allow walls to be thinner and lighter
  - Often attractive and economical for low and medium rise buildings
- Curtain Wall: exterior cladding system supported at each story by the frame, bears no vertical load, thin and light in weight, constructed of any non-combustible materials

**Cladding and Building Code**
- Major issues are in the area of structural strength, fire resistance, and energy efficiency

**Masonry Veneer Curtain Walls**
- Beanery wythe is erected brick by brick/stone by stone with conventional mortar, starting from a steel shelf angle that is attached to the structural frame
- Essentially the same as a single story masonry cavity wall system, except:
  - A soft joint under each shelf angle designed to absorb the maximum sum of column creep, brick expansion, spandrel beam deflection, and dimensional tolerances to allow construction inaccuracies
- Must be divided vertically by movement joints to allow the frame and masonry to expand and contract independently
- Backup wall of light gauge steel studs covered with water resistant sheathing panels of gypsum is interchangeable with a concrete masonry backup wall
- Prefabricated brick panel curtain walls are constructed in pieces and then fastened

**Stone Curtain Walls**
- Stone panels can be mounted on a steel subframe which is erected first
- Horizontal members are aluminum shapes that engage slots in each panel to connect to the building
- Backer rods and sealant fill these paces between the panels, allowing for considerable range of movement
- Depends on the integrity of the sealant joints

**Precast Concrete Curtain Walls**
- Concrete cladding panels are made in the factory and can include ceramic tile, thin brick, or thins stone attachments and thermal insulation incorporated

**Exterior Insulation and Finish System (EIFS)**
- A layer of plastic foam insulation that is adhered or fastened to:
  - A backup wall,
• A reinforcing mesh that is applied to the outer surface of the foam by embedment in the base coat of a stucco-like material.
• An exterior finish coat similar to stucco is troweled over the reinforced base coat.
• Constructed in place over a backup wall made of masonry or steel studs and water-resistant sheathing.
• Is also used over wood light framing in small commercial/residential buildings.
• Insulating foam can be up to 4” thick and there’s almost no thermal bridging.
• Finish layer can come in a range of colors and textures… virtually indistinguishable from stucco.
• Designed as a barrier system which means it has no internal drainage system.
  • If anything fails like sealants, the whole wall could be damaged.
  • Is easily dented or punctured.

**Aluminum Extrusions**
• Aluminum is the metal of choice for curtain walls.
  • It protects itself against corrosion.
  • It accepts and holds a variety of attractive surface finishes.
  • It can be fabricated economically into elaborate shapes by means of extrusion (basically like a metal version of that playdough extruder you had as a kid).

**Thermal Breaks**
• Aluminum conducts heat rapidly.
• In cold weather indoor surfaces aluminum members that pass from the outside of the building to the inside (e.g.: a window frame) would be so cold that moisture would condense on the them.
• The opposite is true in hot weather in an A/C building…outdoor surfaces might be cool enough to condense air.
• **Thermal breaks** are internal components of insulation material that isolates the aluminum on the interior side of the component, dramatically reducing the flow of heat through the member.

• Aluminum doesn’t corrode away in services because it protects itself with a tin, tenacious oxide film that discourages further oxidation.
• **Anodizing** is a process that produces an integral oxide coating on aluminum that is thicker and more durable than the natural oxide film.
  • Components are immersed in an acid bath and become the anode in an electrolytic process.
• **Powder coatings** are also widely used on aluminum cladding, composed of resins and pigments that are electrically charged and sprayed onto the aluminum.
• Wire brushing, wheel/belt polishing, buffing, grinding, burnish, sand blasting, abrasive blasting produce different surface textures.

**Models of Metal Cladding Assembly**
• Stick System: metal and glass curtain walls where components are metal mullions and rectangular panels of glass and spandrel materials that are assembled in place on the building.
• Unit System: Takes full advantage of factory assembly and minimizes on site labor.
• Panel System: made up of homogenous units that are formed from metal sheet.
• Column cover and Spandrel System: emphasizes structural module of the building rather than creating its own grid.
• Can be outside glazed (glass is installed by workers standing on scaffolding outside) or inside glazed (installed by workers standing inside the building).
• Expansion Joints in Metal and Glass Walls
  • Aluminum has a relatively high coefficient of thermal expansion, the coefficient for glass is half as much
  • Difference in thermal movement between glass and aluminum are generally accommodated by very small sliding and flexing motions that occur between the glass and gasket

• Types of Plastics
  • Polymer: a substance that has a molecular structure built from a lot of similar units bonded together. Often times is in reference to the family of plastics
  • Polyurethane: a synthetic resin in which polymer units are linked by urethane groups and used primarily in paints and varnishes
  • Polystyrene: a rigid clear thermoplastic polymer that can be molded into a foam and used for physical and electrical insulating as well as packing

Specialties (accessories, equipment, and fittings)

Facts/Rules:
• Mechanical and Electrical Services
  • Systems are installed after the building has been roofed and most of the cladding has been installed
    • Waste lines and water supply lines are installed, as are fire suppression system pipes
    • Most of the work for HVAC is completed (installing large equipment, pumps, fans, piping and ductwork)
    • Electrical, communication, and control wiring is are routed
    • Elevators and escalators are installed
  • Sometime specific floor are reserved for mechanical/electrical functions, typically in rooms or closets
  • Interior finishing operations follow a carefully ordered sequence that varies depending on the specific requirements of the project. Typically:
    • Hanger wires for suspended ceilings are hung
    • Full height partitions and enclosures for elevator/stair shafts, mechanical rooms
    • Firestopping is inserted around pipes, conduits, and ducts where they penetrate floors and fire rated walls
    • Major horizontal electrical conduit and air ducts installed
    • Grid for suspended ceiling is attached to the hanger wires
    • Lights and ventilating lovers are mounted
    • Framing for partitions that don’t penetrate the ceiling is installed
    • Electrical/communication wire brought down to serve outlets
    • Walls are finished and painted
    • Finish flooring materials installed

• Selecting Interior Finishes
  • Form and height of ceiling, changes in floor level, interpretations of space, and configurations of partitions are primary factors in determining the character of the interior space
  • Patterns/texture of materials bring the building down to a scale that can be appreciated by the human eye and hand
• Wear and tear on materials must be expected and designed for. Good decisions take into account the way the space would be used. There’s a reason why interior finishes for a community center are different than those of a corporate office.
• Maintenance procedures and costs should be considered. How often, and how well, will everything be cleaned, repaired, and kept up?
• Interior finishes strongly affect noise levels.
• DAM Pen the transmission of sound vibrations are necessary.
• Interior finish materials join the mechanical/electrical services of a building at the points of delivery (e.g.: outlets, switches, fixtures, toilets)
• If service lines are to be concealed, access points/doors/hatches must be provided
• Cost of interior finish systems can be measured by a few ways:
  • First Cost: the installed cost
  • Life Cycle Cost: a cost that accounts for first cost, maintenance cost, fuel costs, replacement costs, assumed rate of economic inflation, and time value of money
• Many synthetic/wood panel products emit formaldehyde fume off gassing, other materials affect the indoor air quality and must be carefully selected so to not cause harm to the building occupants

**Types of Paints/Coatings**
• **Coal Tar Enamel**: coating for anti corrosion, resistant to soil bacterial, marine organisms, and root growth. Used in subterranean pipelines for petroleum products
• **Alkyd**: a modern synthetic resin used to replace oil in varnishes, paints and adhesives.
• **Acrylic Paint**: fast drying, water resistant paint containing pigments suspended in acrylic polymer emulsion
• **Urethane Paint**: a catalyst paint known for exceptional durability...hard and long lasting
• **Oleoresinous Paint**: naturally occurring mixture of oil and a resin extracted from pine/fir trees and thinned with a solvent like turpentine.
• **Intumescent Paint**: coating used for fire protection. When heat is present it swells to protect the member it coats (exposed steel structure for instance)
• **Bituminous Paint**: a low cost coating that contains asphalt or coal tar, a thinner, and drying oils used to waterproof concrete and to protect piping where bleeding of the asphalt is acceptable

**Interior Walls and Partitions**
• Patrons that will be finished in plaster or gypsum board are typically framed with wood or metal studs
  • Wood is allowed based on combustibility requirements of the code
  • Fire retardant treated wood is allowed in partition framing for all types of construction
  • Metal framing is analogous to wood light framing and are typically light-gauge steel studs and runners
  • Plaster/gypsums surfaces applied to a masonry wall are space away with metal or wood **furring strips** which allow for installation of a flat wall finish over an irregular masonry surface
• **Plaster** is a generic term that refers to any of a number of cementitious substances that are applied to a surface in paste form and allowed to dry and harden
  • Applied to masonry surface directly, or to a plaster bases know as **lath**
    • Lath used to be thin strips of wood nailed to wood framing with small spaces left for keying of plater.
    • Most lath today is made from expanded metal or preformed gypsum boards
• Lathing trim accessories are used at edges to make a neat, durable edge or corner, and to control cracking
• Ancestor to plaster systems is **wattle and daub**, a mesh of woven sticks and vines stuck with mud
• Can be applied either by machine or hand
  • Plaster is applied over expanded metal lath in three coats:
    • **Scratch Coat**: troweled on roughly and scratched while still wet, using a notched rake to create rough surface for second layer to bond after it hardens
    • **Brown Coat**: build strength and thickness and to present a level of surface for the application final application
    • **Finish Coat**: produced by drawing a long straightedge across the surfaces of the grounds to strike off wet plaster
• **Stucco**
  • Applied over galvanized metal lath, using galvanized or plastic accessories to prevent rusting at damp areas
  • Shrinks and is prone to cracking during drying
  • Should be provided with control joints to channel shrinkage
  • Curing reaction in stucco is the same as concrete and is slow compared to plaster
  • Must be kept moist for at least a week before it’s allowed to dry in order to reach max strength through hydration
  • Usually applied in three coats
  • Pigments or dies can be added
• **Gypsum Board**
  • Prefabricated pastel sheet material manufactured in sizes 4’ x 8’ - 14’
  • Least expensive of all interior finishing materials for walls and ceilings
  • Retains fire resistive characteristics of gypsum plaster but installed with less labor
  • Can be installed over wood studs or light gauge steel studs using self drilling, self tapping screws
    • Wood studs can shrink when drying which can cause nails to loosen slightly and pop through finish surface of the board
    • Usually installed with the long edges horizontal
    • Metal trim accessories are required at exposed edges and external corners to protect the board and make a neat edge
  • Before painting, wall is sanded to remove any roughness or ridges
  • Spray on textures and textured paints can be applied to genitive a rougher surface
  • Gypsum Association Standardized levels of gypsum board finish allow designer to quickly specify the minimum level of finish acceptable on any portion of a project

<table>
<thead>
<tr>
<th>Finish Level</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>The minimum, consisting of just the boards without taping, finishing or accessories. Used in temporary construction or where finished is postponed until later</td>
</tr>
<tr>
<td>Level 1</td>
<td>Joints be covered with tape set in joint compound. Used in areas not viewable: above ceilings, attics, service corridors</td>
</tr>
<tr>
<td>Finish Level</td>
<td>Properties</td>
</tr>
<tr>
<td>--------------</td>
<td>------------</td>
</tr>
<tr>
<td>Level 2</td>
<td>Adds to Level 1 with a coat of joint compound over the accessories and fasteners. Used in garages, warehouses, storage areas, backer of ceramic tile</td>
</tr>
<tr>
<td>Level 3</td>
<td>Adds another coat of compound over the tape, accessories, and fasteners. Used for surfaces that will be textured or covered with heavy wall covering</td>
</tr>
<tr>
<td>Level 4</td>
<td>Adds another coat of compound. Designed for surfaces to be finished with flat paints, light textures or thin wall coverings</td>
</tr>
<tr>
<td>Level 5</td>
<td>Adds a very thin skim coat of joint compound over the entire surface to fill pores and low spots in the wall. Used for surfaces that will have gloss or semigloss paints</td>
</tr>
</tbody>
</table>

• **Finish Ceilings**
  • Ceiling surface is an important functional component of a room
  • Helps control the diffusion of light and sound around the room, and can help control the passage of sound between rooms
  • Often designed to resist the passage of fire
  • Includes distribution of air, light, and energy sources as well as sprinkler heads, loudspeakers, telemetry devices, etc.
  • Color, texture and pattern are prominent in the overall impression of the room

• **Exposed Structural and Mechanical Components**
  • Often offers advantages of economy and ease of access for maintenance if precision and attractive installation are not required
  • Many types of floor and roof structures are inherently attractive if left exposed
  • Extra time and money can go into making mechanical systems and ceilings look good

• **Tightly Attached Ceilings**
  • Ceiling are attached tightly to wood/steel joists, wood rafters, concrete slabs
  • Special finishing for ducts, pipes, sprinkler heads that drop below the ceiling must be completed

• **Suspended Ceilings**
  • Suspended on wires some distance below the floor or roof structure and can hang level and flat regardless of the structure above
  • Ducts, pipes, conduits can run freely in the plenum space between the ceiling and structure above
  • Can be made out of almost any material, the most widely used is gypsum board, plaster, or panels made of incombustible fibers
  • Supported on a small steel framing system and hung from wires

• **Acoustical Ceilings (Lay-In Ceilings)**
  • Made from fibrous materials in the form of lightweight tiles or panels that are highly absorptive of sound energy
  • Most economical is a system of lay-in panels supported by an exposed grid
• Panels can be lifted and removed for access to services in the plenum space
• Often less costly than plaster or gypsum ceilings
• Many are rated for fire resistance

• **Interstitial Ceilings**
  • Many hospitals and laboratory buildings have elaborate mechanical/electrical systems including the standard equipment, but also fume hood ducting, oxygen piping, vacuum piping, and chemical waste piping
  • All this stuff occupies a volume of space that almost equals a normal occupied area, and has to be accessed for maintenance frequently
  • Workers can travel freely in the plenum space, usually while walking upright

• **Finish Flooring**
  • Floors affect the acoustics of a room and interact with light
  • Can be a major functional component of a building, subject to wearing, water/grit/dust,
  • Require more cleaning than any other component of a building
  • Floor structures are frequently used for the distribution of electrical and communication wiring, especially in open areas with few partitions
  • Raceways can be cast into floor slabs to change out wiring as demand and technology advances
  • Raised access flooring is useful in building where wiring change are frequent and unpredictable such as in computer rooms and offices with machines
  • If an access floor is high enough, ductwork for air distribution can be run beneath it
  • Hard flooring materials (e.g.: concrete, stone, brick, tile, and terrazzo) are usually chosen for their resistance to wear and moisture
    • Not comfortable to stand on for long periods of time
    • Contribute to noisy acoustic environment
  • **Concrete:** good for finish floors for parking garages and industrial buildings
    • Color can be added with a admixture, stain, or coats of paint
    • Low initial cost and durability
  • **Stone:** simple installation but highly skilled procedure of bedding the stone pieces in mortar and filling joints with grout
    • Coated with multiple applications of clear sealer and waxed to bring out the color and figure of stone
  • **Brick and Brick Pavers:** may be laid with largest surface horizontal or on edge
    • Decorative joint patterns can be designed for each application
  • **Quarry Tile:** large fired clay tiles available in many earthen colors
    • Set in a reinforced mortar bed
  • **Ceramic Tile:** smaller than quarry tiles, and glazed
    • Grout color has a strong influence on the appearance of tile surfaces
    • Many premixed colors are available or can be done custom
  • **Terrazzo:** girding and polishing a concrete that consist of marble or granite chips selected for size and color in a mix of portland cement and other binding agents
    • Polishing brings out pattern and color and sealer is applied to enhance the appearance of the floor
    • Can be cast in place or precast
    • Installed over a thin bed of sand that isolates it from the structural floor slab
  • **Wood Flooring:** used in several forms as a finish material, the most common of which is wood tongue and groove **strip flooring** made of oak, pecan or maple
• Strips are held together by blind nailing (diagonally nailed through the upper interior corners of the tongues) and concealed from view. Strips against the wall are face nailed, and a little gap is left for expansion
• Floor is sanded smooth, stained, and finished with vanish or other clear coating
• Sanding and refinishing can bring a warm floor back to life

• **Resilient Flooring:** oldest type is linoleum, a sheet material made of ground cork in a linseed oil binder over burlap backing
  - Asphalt tiles were later developed as an alternative
  - Most are made of vinyl with mineral reinforcing fibers
  - Glued to concrete or wood of the structural floor
  - Wide range of colors and patterns, high degree of durability, and low initial cost
  - Vinery composition tile has the lowest installed cost of any flooring material except concrete

• **Carpet:** manufactured in fibers, styles, and patterns to meet almost any requirements except for rooms that need thorough sanitation (hospital rooms, food processing, kitchens)
  - Either glued directly to the floor or stretched over a carpet pad and attached around the perimeter of a room by means of a tackless trip

• **Windows**
  - **Prime Window:** window made to be permanently installed in a building
  - **Storm Window:** removable auxiliary unit added seasonally to a prime window to improve its thermal performance
  - **Combination Window:** alternative to a storm window that incorporates both glass and insect screening
  - Most common window types used in residential building:
    - Fixed
    - Single Hung
    - Double Hung
    - Sliding
    - Casement
    - Awning
  - Skylight
  - Roof Window
  - Terrace Door
  - French Door
  - Sliding Door
  - Hopper

  • Fixed are the least expensive and least likely to leak

• Elements of a window:
  - **Head**
  - **Jamb**
  - **Bottom Rail**
  - **Muntin**
  - **Panes**
  - **Sill**
  - **Top Rail**
  - **Stile**
  - **Frame**
  - **Shash**

• **Window Frame Types:**
  - **PVC:** most common in USA, good thermal insulation, 1/3 price of wood, high coefficient of thermal expansion, not very stiff
  - **Wood:** Inexpensive, durable, and readily available
  - **Aluminum:** Complex extruded configurations possible, strong, light, and durable
  - **Steel:** Hot rolled solid sections or cold rolled strip steel, slender and strong
  - **Stainless Steel:** Corrosion resistant

• At least one window in each bedroom in a residence must open wide enough to allow escape or for firefighter entry... typically about 5.7 square feet
• Doors:
  • Doors are either interior or exterior
    • Exterior: solid, glass, storefront, storm doors, screen doors, vehicular doors, revolving, cellar doors, etc.….
    • Interior: single, double, sliding, pocket, bi-fold, etc...
  • Weather resistance is usually the most important functional factor in choosing an exterior door
  • Fire resistance is the most important when choosing an interior door
• Door Types:
  • Wood: most popular, waterproof adhesive exterior, and water resistant adhesives in the interiors
    • Flush: solid core or hollow core door
    • Panel: wood plywood, glass, or fixed wood lovers, section held in place by stiles or rails
  • Steel Flush Doors: faced of painted sheet steel are most common in nonresidential buildings, permitted to have hollow cores inside, but solid cores are required for outside/fire protection
  • Hollow Metal: steel frame covered with sheet metal, and are rigid, permanent, and meet any fire rating
  • Metal Clad: Solid wood core covered with sheet metal
  • Aluminum: Used in curtain wall/storefront applications, rarely used for fire doors
  • Speciality: Lead lined X-ray shielding doors, cold storage doors, bank vault doors

• Fire Doors:
  • Fire doors serve four main purposes:
    • Serve as a regular door at all times
    • Provide ready egress during a fire
    • Keep fire from spreading throughout the building
    • Protect life and property
  • Fire rating classification of a wall dictates the fire rating of the door in it
  • Steel fire doors are rated by time that a door can withstand exposure to fire test conditions from 1 1/2 hours to 3 hours

<table>
<thead>
<tr>
<th>Door Class</th>
<th>Door/Frame Rating</th>
<th>Wall Rating</th>
<th>Use</th>
<th>Allowable Glazing</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>3 hours</td>
<td>4 hours</td>
<td>Fire walls or fire areas</td>
<td>None Allowed</td>
</tr>
<tr>
<td>B</td>
<td>90 min</td>
<td>2 hours</td>
<td>Vertical enclosures (stairs, elevators)</td>
<td>100 sq in (4” min)</td>
</tr>
<tr>
<td>C</td>
<td>45 min</td>
<td>1 hour</td>
<td>Corridor/Partitions</td>
<td>1,296 sq in (54” max)</td>
</tr>
<tr>
<td>D</td>
<td>90 min</td>
<td>2 hours</td>
<td>Exterior walls with severe fire hazard</td>
<td>None</td>
</tr>
<tr>
<td>E</td>
<td>45 min</td>
<td>1 hour</td>
<td>Exterior walls with moderate fire hazard</td>
<td>720 sq in (54” max)</td>
</tr>
</tbody>
</table>

  • 1/4” wire glass and ceramic glass are the most common types of glazing used
  • Some fire doors are required to minimize transmission of heat from one side of the door to the other (eg: in a stairwell)
• Fusible link type louvers up to 24” x 24” are allowed in the bottom half of a 45 minute or 90 minute door provided they don’t have glazing or fire exit devices
• Must be equipped with fire listed hardware
  • Steel bearing type hinges
  • Automatic latching device to engage the strike
  • Exit device hardware (meets panic loading tests and fire tests)
  • Closing device
  • Avoid mechanical hold-open devices and hold open arms, electromagnetic release devices are okay
• Doors that open onto corridors used as a means of egress may be required to have smoke and draft control rating which test for both air leakage and fire resistance
• Gaskets are required for doors to pass smoke and draft control test

**Door hardware**
• Typically includes hinges, closers, locking devices, panic hardware and weather-stripping.
• **Knobs:** located 38” from finish floor,
• **panic bolts:** 42” from finish floor.
• **Hinges:** exposed, concealed or invisible.
  • 8” from the head,
  • 10” from the floor.
• **Types:** mortised, ball bearing, t-strap, cabinet pivot hinge, olive knuckled and invisible.
• **Full mortise, half mortise, half surface, full surface.**
• **Closers:** Parallel arm type and bracket-mounted type.
  • Doors close quickly & quietly on their own.
• **Operating devices:** Knobs, level handles, pulls, push plates, kick plates, escutcheons, etc.
• **Locking devices:**
  • Beveled: latch
  • Rectangular: dead bolt.
  • When a bolt is used with a latch: lock.
  • Lockset types: cylindrical, unit, rim and mortise
• **Panic hardware:** Push bars are usually 3/4 the width of a door leaf and allow door to unlatch when pressure is applied
• **Tactile finish** on doors leading to hazardous areas are typical
• **Weather-stripping:** make exterior openings weathertight.
  • Interlocking or friction devices

**Thermal Resistance / R-Values of Materials**
• Under uniform conditions it’s the ratio of the temperature difference across an insulator and the heat flux (or heat transfer per unit area)
• The higher the number, the better the building’s insulation effectiveness
• The reciprocal of the U-value (R Value = 1/U Value)
<table>
<thead>
<tr>
<th>Material</th>
<th>R-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyurethane rigid panel (initial, after 5-10 years)</td>
<td>R7- R8, R-6.25</td>
</tr>
<tr>
<td>Foil Faced Polyisocyanurate rigid panel</td>
<td>R6.8</td>
</tr>
<tr>
<td>Spray Foam Insulation</td>
<td>R4.3 - R8.3</td>
</tr>
<tr>
<td>Polystyrene board</td>
<td>R5</td>
</tr>
<tr>
<td>High Density Fiberglass Batts</td>
<td>R3.6 - R5</td>
</tr>
<tr>
<td>Loose Fill</td>
<td>R4</td>
</tr>
<tr>
<td>Air Entrained Concrete</td>
<td>R3.9</td>
</tr>
<tr>
<td>Fiberglass Bats</td>
<td>R3.1 - R4.3</td>
</tr>
<tr>
<td>Blue Jean Insulation</td>
<td>R3.7</td>
</tr>
<tr>
<td>Fiberglass Loose Fill</td>
<td>R2.5 - 3.7</td>
</tr>
<tr>
<td>Polyethylene Foam</td>
<td>R3</td>
</tr>
<tr>
<td>Wood sheathing panels</td>
<td>R2.5</td>
</tr>
<tr>
<td>Fiberglass Rigid Panels</td>
<td>R2.5</td>
</tr>
<tr>
<td>Vermiculite</td>
<td>R2.13</td>
</tr>
<tr>
<td>Strawbale</td>
<td>R1.45</td>
</tr>
<tr>
<td>Hardwood</td>
<td>R0.71</td>
</tr>
<tr>
<td>Brick</td>
<td>R0.2</td>
</tr>
<tr>
<td>Glass</td>
<td>R0.14</td>
</tr>
<tr>
<td>Poured Concrete</td>
<td>R0.08</td>
</tr>
</tbody>
</table>
Construction Sequencing

Vocabulary:

- **Sequence**: the order in which activities occur

Facts/Rules:

- Projects follow different types of construction schedules:
  - **Gantt/Bar Chart**: illustrates start to finish dates of a project broken out by activity.
  - They focus primarily on schedule management rather than the size of the project or the relative size of the work elements/activities.
  - Can’t show the relationship between activities
- **Critical Path Method**: all events expected to occur and operations to be performed in completed a given process are rendered in a form permitting determination of the optimum sequence and duration of each operation.
  - The diagram is called a **Network Diagram**
  - Circles are are start and finishes, arrows are tasks, numbers show the time for each task to occur.
  - **Critical Path**: the path with the longest required time from start to finish is the basis for the schedule. Activities on this path are called **critical activities**.
  - **Float**: range of time during which non critical activities can start/end without affecting the overall schedule
  - **Total Float**: individual float times added together don't influence the critical path time

Concepts/Goals:

- Determining construction sequencing is part of the larger construction planning and scheduling process.
- People/communities need to be aware of the interaction of the natural systems in the landscape, and need to make planning/design/development decision that will protect and enhance the interaction of those systems in the landscape.

Processes:

- **Stake Lot**: A Surveyor accurately drives stakes to locate boundaries and building lines
- **Install Temporary Utilities**: includes water, power, phone/data, toilets, job shack, etc.
- **Clear and Rough Grade**: Remove necessary trees and undergrowth from the site and grade site for approximate drainage patterns, yards, driveways, walkways, etc.
- **Apply surface stabilization**: including graded areas, channels, dikes, streams, and disturbed areas where work won't take place for 30+ days by temp seeding/mulching.
- **Excavate**: for foundation, slurry walls, basements
- **Pour footings/piles/caissons**: depending on site, soil, and seismic requirements
- **Pour Foundation**: slab on grade, crawl space, basement, etc.
- **Install Waterproofing and Foundation Drain**: locate below grade to minimize water accumulation
- **Install sewer and Water Taps**: connect to municipal system mains
- **Backfill**: push excavated dirt into ditches surrounding foundation and grade for drainage away from the building/foundation wall.
- **Install slab plumbing**: any plumbing that would go in the slab on grade/basement floor.
• **Pour slab:** for slab on grade or basement.
• **Install exterior framing, windows, doors:** includes flashing/waterproofing at openings
• **Install Roofing Materials:** shingles, bitumen, etc.
• **Install Siding and Trim:** remember vapor barrier goes on warm side of the insulation. Prime, seal, and paint as required as soon as possible.
• **Install Gutters/Downspouts:** get water away from building
• **Continuing Outside...**
  - **Build Retaining Walls:** can be structural or decorative
  - **Pour Sidewalks, Driveways, Patios, Curbs:** typically concrete
  - **Install Asphalt:** parking lots, roads, etc.
  - **Finish Grading and Landscape:** ensure proper drainage and landscape. Remove any unstable sentiment, remove any temporary structures.
• **Meanwhile inside...**
  - **Install Interior framing:** includes partitions, walls, soffits
  - **Install Stairs:** rough frame with finishes to follow
  - **Install rough HVAC/Plumbing/Electrical:** run major ductwork, install pipes, run wires, and install electrical boxes
  - **Install Electric/Gas meters:** set up for heating and conditioning the interior spaces
  - **Insulate:** vapor barrier goes on warm side of insulation (inside in northern climates)
  - **Hang Drywall:** then tape, mud, and texture
  - **Install Casework:** uppers and lowers
  - **Install Interior Doors and Trim:** includes moulding, window casing, built in casework, stair rails, baseboards, wainscot.
  - **Paint and/or Install Wall Finishes:** prime/sub layers as required for desired finish.
  - **Install Countertops and Lay Tile:** typically in wet or work areas.
  - **Finish Plumbing/Electrical/HVAC:** includes sinks, toilets, lavatories, faucets, light switches, outlets, fixtures, fans, registers, thermostats.
  - **Install Appliances/Specialty Equipment:** either owner or contractor supplied.
  - **Install Finish Accessories:** including mirrors, toilet accessories, etc.
  - **Install Finish Flooring:** carpet, hardwood, etc.
  - **Install Interior Doors/Relights:** includes closets, window screens, glazing partitions, and door hardware
  - **Final Cleanup and Touchup:** fix any drywall, trim, paint, accessories.

Cost Estimating, Value Engineering, + Life Cycle Costing

**Vocabulary:**
- **Preliminary Costs:** SF Cost Estimates; based on occupancy, size & type of construction
- **Detailed Costs:** itemized break down
- **Utilization Ratio:** Used by firms to determine the amount of time spent on billable work as a % of total time the employee is compensated. UR = billable hours / total hours
- **Value Engineering:** process to get the best value for the project using similar, but more affordable materials and techniques
- **Pro-forma:** financial analysis of a building project which involves cost/return on investment
- **Cost of money or debt service:** principal and interest payments
- **Depreciation:** federal tax benefit with the idea that a building loses value as it ages
- **General Obligation Bond:** used to finance non revenue collecting facilities
- **Revenue Bond:** Used to finance revenue collecting projects (tolls, etc)
Facts/Rules:

- There are multiple methods of calculating fees for architectural services:
  - **Multiple of Direct Salary Expense (DSE):** everyone’s direct salary/wages multiplied by a factor to cover fringe benefits (e.g. Employee health insurance), overhead, and profit.
  - **Multiple of Direct Personnel Expense (DPE):** fringe benefits are included in direct salary/wages...that expense is multiplied by a factor to cover overhead and profit.
  - **Professional Fee plus Expenses:** professional services are separated from the services from identified costs (reimbursable, consultants, etc).
  - **Hourly Billing Rate:** project is billed at standard rates for every hour worked. Often this is to a “not to exceed” value without consent of the owner.
  - **Stipulated/Lump Sum:** a specific amount is agreed upon for the total payment.
  - **Percentage of the cost of work:** based on a percentage of construction cost.
  - **Unit price contract:** based on acceptance and incorporation of unit price quotes for the various portions of the project.
  - Add a fixed percentage contingency (5-10%) in complex or remodel jobs to address any unforeseen problems or issues that come up during the design and/or construction.
  - **Traditional design fees:**
    - Architecture = 10% of construction cost
    - Mechanical = 15%
    - Electrical = 12.5%
    - Civil = 10.5%
    - Structural = 9.4%
  - **Traditional contractor fees:**
    - General Overhead = 8-10% value of firm value
    - Project Overhead = 4-10% of construction cost
    - Profit = 15-20% small jobs
    - = 10-15% large jobs
    - = 5 - 10% very large jobs
  - **Traditional construction fees:**
    - Construction Cost = Amount of $$ to build
    - Construction Budget = 85% construction cost
    - Contractor’s OH/Profit = 15 - 40% construction cost
    - Surveys, testing, fees, FF&E = 15%
  - **Traditional project budget:**
    - Site Acquisition = not included in project budget
    - Utility/Off Site Construction = not included in project budget
    - On Site construction = 10-20% of construction cost
    - Building construction = 10-15% of construction cost
    - Contingencies = 5-10% of construction cost
    - Professional Services = varies
    - Inspection and Testing = varies
    - Financing = varies
  - It is normal practice to anticipate construction cost escalation on the basis of an annual increase projected to the midpoint of construction.
Concepts/Goals:

- Cost Projection Objectives:
  - Complete the project within the financial limits set by the owner
  - Provide an appropriate use of resources/value for the money within the budget
  - Optimize longer-term life cycle costs by examine alternative that offer the best balance between upfront costs and maintenance costs
  - Provide the owner with relative implications to the budget based on owner decisions throughout the project duration.

- Cost Projections for a project are based on four factors:
  - **Cost Factors:** what influences the project
  - **Project Scope:** what’s included in the building
  - **Quality:** how nice the building will be (construction, technologies, finishes)
  - **Budget:** how much the owner can spend

- Typically architect estimates cannot account for inflation, market conditions, and contractor means and methods.

- Other factors that influence the construction budget include:
  - Availability of labor and materials (if there’s no work, people will do jobs for cheap, if there is work, prices go up...basic supply and demand principle)
  - Labor rates fluctuate depending on cost of living, demand, project location, deadline
  - Material prices fluctuate depending on the market, where they ship from, etc
  - Convenience of transportation
  - The more remote the location the more expensive
  - Costs are less predictable in rural areas

Processes:

- The appropriate type of cost estimating for a building depends on the phase of the project it is developed to:
  - **Pre-Planning/Proposal:** based on unit costs (the cost/person, cost/bed, cost/sf, etc)
  - **Programming:** based on unit cost system (cost per sf) based on similar building types and/or functions of spaces
  - **Schematic Design:** based on the major elements of each building system (mechanical, electrical, plumbing, structure)
  - **Design Development:** based on detailed components (curtain walls, storefronts, lay-in ceilings, etc)
  - **Construction Documents:** based on unit rates for construction competes, assembles and systems. This estimate is what pre-bid cost checks and cost breakdowns are based on.

Project Schedule Management

Facts/Rules:

- Typical phase breakdown for architectural services (programming is an extra service):
  
<table>
<thead>
<tr>
<th>Phase</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schematic Design</td>
<td>15%</td>
</tr>
<tr>
<td>Design Development</td>
<td>15%</td>
</tr>
<tr>
<td>Construction Documents</td>
<td>35%</td>
</tr>
<tr>
<td>Bld/Negotiation</td>
<td>5%</td>
</tr>
<tr>
<td>Construction Administration</td>
<td>30%</td>
</tr>
<tr>
<td>Sometime Project Closeout</td>
<td>2-5%</td>
</tr>
</tbody>
</table>

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• Project calendar days = number of working days x 5 or 7
• Schedules are impacted and influenced by:
  • The size of the project
  • The complexity of the budget
  • The number of people working on the project
  • Client action/reaction time (and to an extent, municipal review time)
• Risks of extending the schedule:
  • Can increase costs due to inflation
  • Team members could change, causing a learning curve
• Risks of shortening the schedule:
  • Requires people to work overtime (costly/inefficient)
  • Requires the need to hire more people (learning curve to project and office standards)
  • If no employee changes are made, drawings can turn out poor, uncoordinated, etc
  • Generally causes higher costs for design and construction for a lower quality project

Concepts/Goals:
• Fast Track Schedule: Construction documents are issued in phases and construction begins while design is still being finishes.
  • Requires coordination between architects, contractors, and construction managers
  • Requires staged bidding, which might result in multiple contractors.
  • Can reduce time of project by 10-30%

Processes:
• Scheduling the five phases of the design process varies depending on the project size and complexity, the quality of the client’s program, the design team, and the decision making ability of the client. Generally the following applies:
  Schematic Design = 1 - 2 months
  Design Development = 2 - 6 months
  Construction Documents = 3 - 7 months
  Bid/Negotiation = 3 - 6 weeks
  (contractors get 2 weeks to bid)
  Construction Administration = Varies
  Contingencies = 25-50% of length of project
• The planning and scheduling phases of the construction process follow these steps:
  • Establish an objective:
    • an exact, measurable project goal. (Eg: install a plant a tree, grade a site, construct a parking lot.)
  • Identify project activities:
    • Break down the project into definable work activities that, when complete, reach the objective
    • Activities should be action-oriented, visible, and measurable
      • Eg: Survey and layout site, form footings, plant shrubs and trees
  • Determine activity sequence:
    • Decide in what order activities will occur by examining each activity independently.
      • What activity must proceed this activity?
      • What activity must succeed this activity?
    • The more activities that can occur concurrently, the faster the job will go.
  • Determine activity durations:
    • Decide how long it takes to do each activity in the most effective manner.
Determine the critical path, and then expedite only those actuates that are deemed critical to meet deadline.

**Perform schedule calculations:**
- Add up the durations of the different activity sequences, the longest path is the critical path and determines the total duration of the project.

**Revise and Adjust:**
- Adjust the original schedule to account for crew size, resources, and changes in completion date.

**Monitor and Control:**
- As the work proceeds, changes in the schedule may occur. Revise durations, calculations and adjustments as necessary to meet new deadlines and solve any issues that may arise.

Risk Management

**Vocabulary:**
- **Mediation**: not legally binding. Use of a mediator to reach agreement between parties
- **Arbitration**: legal technique for the resolution of disputes outside the courts. It’s a form of binding dispute resolution, equivalent to litigation in the courts.
- **Litigation**: conflicts/disputes that are resolved in a court of law. Typically a last option.
- **Subrogation**: legal technique where an insurer takes over for a party for whom it has made a payment. (e.g. damage to a property under construction caused by a subcontractor is covered by insurance who then sues subcontractor in the owner’s name)

**Facts/Rules:**
- Architects should carry multiple types of insurance for their protection.
- More than the required minimum insurance may be needed for a job. Anything extra is noted in the supplemental conditions
- Types of Insurance include:
  - **Professional Liability**: Held by architects/design professionals. Liability due to negligence or not meeting the standard of care expected of them. (e.g: not designing ADA compliant restrooms in a public building)
  - **Workers Comp**: Held by almost everyone. Liability to employees for injury or sickness as a result of their employment.
  - **Property/Builders Risk**: Held by owner. Covers any damages, loss of work on site/off site/in transit.
  - **Loss of Use**: Held by owner. Covers any financial loss due to delay in construction because of damage, accidents, fire, other hazards needed to be dealt with.
  - **Product & Completed Operations**: held by contractor. Liability for damages caused by installed goods after the construction phase and transfer of title.
  - **Contractual/Indemnification**: Liability assumed by contract where contractors agree to hold owners/architects harmless for damages that are the result of specific events.
- The owner can require the contractor to submit a certificate of insurance with a bid to prove what insurance he carries and what his limits are.
- **NO SUBROGATION.** Owner/Contractor should keep this provision in the AIA 201 document, so the insurance company, after paying out, can put themselves in the shoes of their client and go after whoever might be responsible for the damage that’s otherwise “No-Fault”. You don’t want the owner’s insurance company going after the contractor if there’s some sort of freak fire in the middle of the night that could somehow be tied back to him.
Concepts/Goals:
  • **AIA Ethical Standards**
    • Code applies to all AIA members regardless of membership category
    • Common ethics violations:
      • Attribution of credit
      • Accurate representation of qualifications
      • Attainment and provision of examples of work
    • Basic honesty Penalties for Violations:
      • Admonition (private) – letter of ruling sent to the parties and kept in the member’s file
      • Censure (public) – letter is sent and notification of the case and ruling is published to AIA membership
      • Suspension of membership – membership is suspended for period of time; 1 or 2 years & ruling is published
      • Termination of membership – membership is terminated & ruling is published
VIGNETTE: ACCESSIBILITY/RAMP

Steps
1. Open floor plan and take a good look at the shape of the space and where
2. While you’re there, turn on ortho, the grid, and the full screen crosshairs.
3. Open the Program and write down the following information:
   - Required Handrail Protrusion = ______________________
   - Minimum Ramp Width = ______________________
   - Minimum Stair Width = ______________________
4. Sketch the door clearance diagrams…it’s good to have for verification
5. Sketch rectangles for clear door area at all existing doors. Remember, you can’t build in
   this area.
6. Draw the new wall and door, and add the sketch rectangles for clear door area for this
   new constriction too.
7. Draw the top landing for the stair and ramp. The width should equal the width of the
   existing corridor and the depth will depend on how much turning area is required for a
   wheelchair.
8. Write the proper elevation height in the middle of the landing.
9. On scratch paper, calculate the ramp length by using the elevation of the
   landing and a 1: 12 ramp:
   _____ inches of elevation change = _____ feet in ramp length
10. On scratch paper, calculate the number of stair risers by using the elevation of the
    landing and 7” risers”
    Number or risers = _____ inches of elevation change / 7” per riser
    (Note: Round up to a whole number… ie: 4.56 risers = 5 risers)
11. Double check your calculations…better now than finding a mistake later!
12. Using the sketch tool, sketch a rectangle the full ramp length and drop it on the floor
    plan. You probably won’t be able to have a full run without any landings, and this step
    helps you guess how many landings you’ll need.
13. Erase the sketch rectangle (or move it to the side) and sketch landings and ramps in a
    configuration that works. Ramps should hug the walls as much as possible. Keep it
    compact!
14. Draw the actual ramp and landings. Be sure to fill in the elevation markers.
15. Add stairs based on the number of risers calculated above. Use a sketch rectangle to
    make sure required clearances are met.
16. Add handrails to both sides of the ramps and stairs, they should be close to the edge,
    about 2 clicks away should be fine. Note that a handrail is NOT required on a ramp of
    6” rise or less. If it’s open to a fall (not up against a wall) then a guardrail is still
    required.
17. Extend handrails 12” beyond the end of the stairs/ramps. Note that handrails don’t
    have to continue onto landings that are against walls
18. Double check all the elevations
19. Use a sketch circle with the minimum ramp width as the diameter and drag it through
    the ramp to verify that the clear dimension has been met
20. Use a sketch circle with the minimum stair width as the diameter and drag it through
    the stair to verify that the clear dimension has been met
21. Use the Check tool to make sure there are not overlaps or missing elevations.
Tips

• This vignette is about meeting code requirements... don’t get fancy or design savvy.
• Use the steepest slope allowed for the ramp: 1:12
• Use the shortest run for the stairs: 7” rise : 11” run
• No ramps should be less than 48” long/ 4” tall, per recommendation on areforum
• Doors must swing in direction of egress travel
• Try to place stay exit and ramp exit in the same general area...try not to make someone have to go out of their way in order to use the ramp
• Handrails don’t have to continue on landings that are against walls
• Keep handrails 2” off the wall
• Note: this vignette can be done in about 15 minutes or so... allot 45 minutes most.

VIGNETTE: STAIR DESIGN

Steps

1. Open floor plan and take a good look at the shape of the stairwell. Look where doors are placed on both levels
2. While you’re there, turn on ortho, the grid, and the full screen crosshairs.
3. Open the program and make any general notes
4. Sketch the door clearance diagrams...if they’re the same as the Ramp/Stair Vignette just refer to that
5. Open the Code and complete the following information and chart:

| Required Handrail Protrusion = | __________________________ |
| Headroom Requirement = | __________________________ |
| Structure Depth = | __________________________ |
| Required Landing Clearances = | __________________________ |

Where:

- Occupant Load = Total Occupancy / Number of Exits
- Minimum Exit Width = Occupant Load x 0.3”

<table>
<thead>
<tr>
<th>Level</th>
<th>Total Occupancy</th>
<th>No. of Exits</th>
<th>Occupant Load</th>
<th>Min. Exit Width</th>
<th>Min. Width per Code</th>
<th>Is there an Area of Refuge?</th>
<th>Minimum Stair Width per Area of Refuge</th>
<th>Elevation</th>
<th>Door Heights</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
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<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Second</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
6. Note the widest minimum exit width from either the “exit width” or “minimum stair width per area of refuge” columns, this is the width of ALL the stairs…they can’t get narrower just because the occupancy is lower.

7. Verify if the code says the stair width is “clear between handrails”…make a note of it!

8. Calculate the amount of stair risers needed for each elevation change
   - Total first set of risers = (Middle Elevation - Ground Elevation) / 7” per riser
   - Total second set or risers = (Second Elevation - Middle Elevation) / 7” per riser

9. Open the section and quickly sketch it to use as reference if desired…it helps having it in front of you as you’re drawing the stairs in plan

10. Open the level one layer and draw the landings required at the doors. Remember clear floor areas start at the door swing per the diagram in the code…not the wall. Also, don’t forget the clearances for handrails, and the total clear area for the Area of Refuge which can’t be included in the clear floor area of the door

11. Set the elevations, which should match the floor heights

12. Use the sketch tool to rough out stair sizes and locations, the width is calculated by the minimum require in the table + 4” on either side for handrails. The length is calculated by the (total number of risers calculated in step 8) x 11” per riser.

13. Check headroom clearances and floor area clearances. Make sure there are no problems

14. On the level one layer, draw the ground to first floor stairs, and set the top and bottom elevation for both

15. Switch to the level two layer, draw an intermediate landing (maintain required landing areas per the code) and set the elevation. Note you might have to sketch a few practice rectangles to get the landings and number of stairs to work out correctly

16. Draw a stair from the intermediate landing to the second floor and set the elevations at each end.

17. Draw a cut stair from the intermediate landing down to the landing on level one (which will look gray). Set the elevations

18. Switch to the level one layer and draw a cut stair on top of the one you just drew from the lower landing to the intermediate landing. Set the elevations

19. Check elevations and clearances once more…just to be safe

20. Sketch 12” rectangles at the landings and 2” rectangles off the walls for handrails

21. Draw the handrails on the level one layer. Handrails should extend to the edge, or one click beyond if necessary, of the cut line

22. Switch to the level two layer and draw all handrails required

23. Double check everything again…do the elevations work out? Are all the clearances met? Are there any unnecessary overlaps?

Tips

- Read the provided Code carefully, it probably doesn’t match the code you’re used to!
- Variations might be: rails need to extend at top and bottom of flights of stairs on only one side and an Area of Refuge might be required on certain levels.
- Remember with an Area of Refuge required widths must be taken from inside the handrails despite whether the Code allows handrails to project within the allowable width.
- Handrails should be held 2” off the wall
- Continuous handrails should touch or overlap, but not cross.
- Note: this vignette is the trickiest, but can be done within 45 minutes
VIGNETTE: ROOF PLAN

Steps
1. Open floor plan and take a good look at the shape of the building and location of rooms
2. While you’re there, turn on ortho, the grid, and the full screen crosshairs.
3. Open the program and jot down all of the required information:
   - Ceiling Height = ____________________________
   - Lower Roof Structure Thickness = ____________________________
   - Lower Roof Minimum Pitch = ____________________________
   - Double Height Room = ____________________________
   - Upper Roof Structure Thickness = ____________________________
   - Upper Roof Minimum Pitch = ____________________________
   - Clearstory Location = ____________________________
   - Skylight Locations = ____________________________
   - Number of fan vents/locations = ____________________________
   - Number of vent stacks/locations = ____________________________
   - HVAC unit location/setbacks = ____________________________
4. Open the plan and draw the high roof and the low roof in as many sections needed. Keep it as simple as possible, gables are better than hips
5. Use the check tool to verify that they aren’t any overlaps
6. Click on the arrow indicating the direction of the slope on the lower roof with the Set Roof tool. Keep clicking it until the slope is pointing the correct location. Then click the numbers and set the pitch. Use the minimum allowable pitch
7. Calculate the lower elevation of the low roof
   Low Roof Elevation = (Ceiling Height) + (Lower Roof Structure Thickness)
8. Set the lowest roof elevation by using the Set Roof tool and clicking until an elevation marker is in the lowest desired spot. Then click the marker to set the elevation.
9. Click the same roof with the set roof tool until the high point elevation is indicated. Write down that elevation scratch paper for the next step
10. Calculate the lower elevation of the high roof
    High Roof Low Elevation = (High Point of Low Roof Elevation) + (Clearstory Heigh) + (Upper Roof Structure Thickness)
11. Set the lowest roof elevation by using the Set Roof tool and clicking until an elevation marker is in the lowest desired spot. Then click the marker to set the elevation.
12. Click on the arrow indicating the direction of the slope on the lower roof with the Set Roof tool. Keep clicking it until the slope is pointing the correct location. Then click the numbers and set the pitch. Use the minimum allowable pitch
13. Draw the clearstory in the required location
14. If needed, add a cricket where a sloping roof runs into a face of a chimney. It should be the width of the chimney, and the angle of the cricket should be about 45 degrees
15. Draw flashing where walls from the upper roof meet the lower roof and where the chimney intersects the roof. Do not place any on the outer perimeter of the building
16. Draw gutters on the low side of each roof. You must have a gutter on upper roof that is adjacent to the lower roof...water can’t fall freely from one to the other
17. Place downspouts being careful not to put them in front of doors or windows. There should be one at each end of the gutter, and an additional one somewhere in the middle if the span is over 40’-0” long
18. Locate any skylights required by the program. If the skylights are rectangular the long side should run parallel with the roof slope. Try to center them in the space.

19. Locate plumbing vents and exhaust fans. Vents can accommodate two back to back toilets and should be placed in the wall.

20. Exhaust fans should be located over the space they’re serving unless is shared between spaces, then it should be in the wall.

21. Locate the HVAC unit per the required clearances, and ideally above a low occupancy room in the program.

22. Double check all the requirements with the program just to be safe. Do the same for calculations of roof elevations.

23. Use the check tool one last time to make sure nothing got bumped in the process.

Tips

- Draw roof planes over chimneys, not around them.
- Always use the lowest roof slope allowed. It’s the most economical.
- Don’t put gutters against a chimney that is flush with the roof edge, it’s unnecessary.
- Note: this vignette is moderately challenging and can be done in about 20 minutes... allot 45 minutes just to be safe.
REFERENCES

areforum

ALS MM summary from the forum FTP site
http://www.areforum.org/up/Materials%20and%20Methods/

Lee’s Notes - ALS sustainability chapter-MM & ME from the forum FTP site
http://www.areforum.org/up/Materials%20and%20Methods/

Steel Door Institute Basic Fire Door Requirements from the forum FTP site
http://www.areforum.org/up/Materials%20and%20Methods/

Strategies for BDCS Vignettes, ML’s suggestions

other websites

Fair Housing/Equal Opportunity by US Department of Housing and Urban Development

Galvanic Action. Archtoolbox

Structural Steel Detailing, Rebar Detailing and Estimating by GVS-CORP
http://www.gvscorp.biz/Rebar_Samples.php

How to Control Fire: Protecting the Structure of the Building
http://www.compactdynamics.com/223.html

How Innovative Building Materials Are Saving the World by Sustainable Cities Collective

Lead in Paint, Dust, and Soils by United States Environmental Protection Agency
http://www.epa.gov/lead/

Left and Right Handed Doors by Architecture 365 Days A Year

Passive Solar Heating by Whole Building Design Guide
http://www.wbdg.org/resources/psheating.php


R-Value (Insulation) http://en.wikipedia.org/wiki/R-value_(insulation)
**Solar Controls and Shading** by RIBA Sustainability Hub
http://www.architecture.com/SustainabilityHub/Designstrategies/Fire/1-4-1-6-
Solarcontrolsandshading.aspx

**Strategies and Technologies: Controlling Indoor Air Quality** by Filtration + Separation
http://www.filtsep.com/view/2695/strategies-and-technologies-controlling-indoor-air-
quality/

**What is the Flame Spread Rating?** by Acoustical Surfaces

---

texts

**Allen, Edward and Joseph Iano.** *Fundamentals of Building Construction Materials and


Brenner, Diana M.H. “Furniture, Furnishings, and Equipment Services”. Excerpt from *The

Burley, Robert and Dan Peterson. “Historic Preservation” Excerpt from *The Architect’s

Jackson, Mike. “Embodied Energy and Historic Preservation: A Needed Reassessment”.

Practice Fourteenth Edition.* 2008