Architectural Registration Examination

Structural Systems

Site Planning and Design

Programming Planning and Practice

Building Systems

USC School of Architecture

Absolute Consulting Engineers
3839 Birch, Newport Beach, Ca

Architectural Registration Examination

Structural Systems

USC School of Architecture

"Dr. Saum K. Nour, Ph.D."
PE Civil, PE Electrical, PE Mechanical, CPD, CIPE, CFPE, **LEED AP, AIA**

snour@Absoluteco.com

3839 Birch, Newport Beach, Ca 92660.
949 852 8700. 949 852 1918 fax

Covering the Nation

Part I - ARE 4.0 a Structural Systems

Content Areas

1. GENERAL STRUCTURES	%38- %42 percent of scored
2. SEISMIC FORCES	%28- %32 percent of scored
3. WIND FORCES	%14- %17 percent of scored
4. LATERAL FORCES	%13- %16 percent of scored

Who is a Structural Engineer?

Any element, component, structure, building, monument, equipment must be held from free fall, gravity, seismic, wind, hurricane, heights, tsunamis, man-made or natural disasters. Otherwise that element will fall.

Of course the famous Hammurabi's building code states that if the building fails, and kills the son or daughter, the building owner can kill equivalent son or daughter of the designer.

When component is placed on 3rd floor of a building, the forces of the loads transfer from one member to another finally through columns; they are transferred to ground soil. This transfer requires a foundation. Foundation is like a shoe that permits a stable building. Eskimos wear shoes not to sink in snow in complete contrast to mountain hikers. The soil below the building is classified from A to F, from rock to very unstable soil. Foundation design is an art itself and correlates to geotechnical engineers' science.

If you begin designing and accommodating the load on that level, basic components of structural design are as follows:

o Basic Theories: Very simple static and strength of materials can provide necessary knowledge to understand the concept, even design a system. More advanced theories get involved with micro issues, joints, connections, curves, more elaborate structures. However, one can break down any structure to simpler and through superposition method, one can provide complete understanding of the forces acting on the structure and each component.

o Modeling: Modeling a structure comprises of geometric shape, coordinates, segments, angles, and properties of material. The statistical quantities are loads, reactions, and stresses. The resultant deformations must be checked with allowed deformation; hence the material or material size is altered till full code compliance is met.

o Assumptions: The materials are homogenous, continuous, isotropic and act as spring (Hooke's Law). The deformations do not alter the original geometry significantly. Since the loads applied are gradual, the superposition concept is valid. In superposition, one can apply each load independently and add the results. Therefore sum of effect of system of loads is equal to sum of effect of individual loads. Materials are constant and independent of time, therefore the system is assumed to be in static equilibrium.

o Type of loads:

- Single loads:

- concentrated load,
- moment applied by single load,
- uniformly distributed load,
- regularly varying load,
- irregularly varying load,

- Systems of loads:
  - the combination of single loads,
  - symmetrical loads,
  - asymmetrical loads,
  - cyclo symmetrical,
  - cyclo antisymmetrical, and
  - unsymmetrical loads.

Forces acting on members can be complex and number of equilibrium conditions required to solve these forces vary from one type of force to the other.

Coplanar force system or single concentrated load in two dimensional (2D) and three dimensional (3D) requires 3 and 3 equations, respectively.

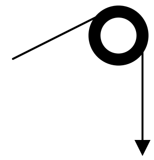
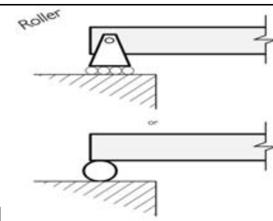
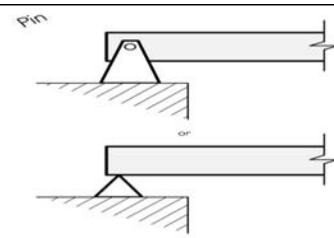
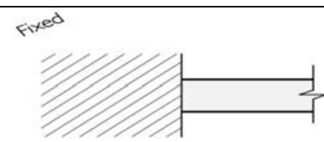
Collinear force system where all the forces share same line of action in 2D and 3D require 1 and 1 equilibrium conditions, respectively.

Parallel forces where all forces are in parallel (both directions) in 2D and 3D require 2 and 3 equilibrium conditions, respectively.

General three dimensional forces where all forces are in one plane (all directions) in 2D and 3D require 3 and 3 equilibrium conditions, respectively.

o Effects of the loads: Loads produce reaction forces on members, the produce stresses on members, and they deform the structural members.
Effect of loads produce reactions on the connections.

o Connections: Connections are movable hinged end, immovable hinged end, guided end, and rigidly fixed end. These connections carry moments and forces. If the member is free and able to move in a direction, reaction forces in that direction does not exist.

Two Dimensional Supports and Connections			
Type of connections	**Moments**	**Reaction Forces**	**Number of Unknowns**
Cable in tension, Link	None	Reaction in direction of link or cable	1 
Simple, roller, rocker, ball, frictionless surface	None	Forces normal to surface	1 
Frictionless guide or collar	None	Forces normal to surface of rail or guide	1
Frictionless Joints, pin connections, rough surface	None	Forces in any direction on hing	2 
Fixed support	One	Two forces acting in x and y	3 

o Static equilibrium: Since the body under load is assumed to be in equilibrium, algebraic sum of all forces are zero, and sum of al moments at any point is zero. The vector form of these forces can be broken into any coordinate systems, ie. Cartesian, cylindrical, spherical coordinates.

o Stresses: Three stresses at center of any materials are: Normal forces, shear forces, and bending moments.

Procedure to perform a design:
One begins with the statement of the problem. A single or multiple or complex load is on top of the structure. Is the structure fit to support the component, say in Los Angeles. As the steps was described, first, you model the building in simple

lines and provide all elements that support this component from top to bottom, to foundation, and to the characteristics of the soil.

For example, a battery rack is on 6th floor. The load of the battery rack is on several floor joists. Each floor joist must carry tributary load of the component. Each joist acts as a beam supported by sub-purlines. sub-purlines can be supported by beam, beams sit on columns, columns sit of foundation. The floor joist acts as beam. Beams designs are checked by insuring the can carry the stress, shear, and deflection. Floor joists transmit the load to sub-purlines. The sub-purlines act as uniformly distributed loads plus the contribution of the batteries as concentrated load. Using the superposition, the resulting parameters will be added. Same pattern must be devoted to the purlines, then to main beams. Finally the load is transferred to the column. Then the column is checked for stress, deflection, and buckling. The load on the column is transferred to the foundation. The soil has a capacity, for stable soil, worst case is 1000 lbs per square feet. If the load is 5000 lbs, the base of the foundation area is 5 square feet. There are other issues such as bending of the building and its impact on the soil is also defined.

What we did not discuss was materials, localities, and equations. Materials vary from steel, wood, concrete, timber fiber composites, and non-traditional materials such as bamboo. Location of the building is also critical. The wind, hurricane, earthquake, seaside, and mountain sites make quite difference.
There are two methods of calculations: LRFD and ASD.

Allowable stress Design or ASD is very simple. The allowable stress of the materials is reduced by a safety factor and then the load effects are compared to this reduced value.

Load and Resistance Factor Design or LRFD simply increases the load effects introduced by components and then it compares them to allowable material capacities. There are also resistance factors as multipliers on load effects that play a role in final design.

In eater cased, ASD where material capacity is reduced, or LRFD where the load effects are increased, the safety factors built in varies and has created two separate philosophies in structural engineering.

Capacity is the capability of the building to carry demand, the load. The C to D ratio is a common terminology used by structural engineer in evaluating existing buildings.

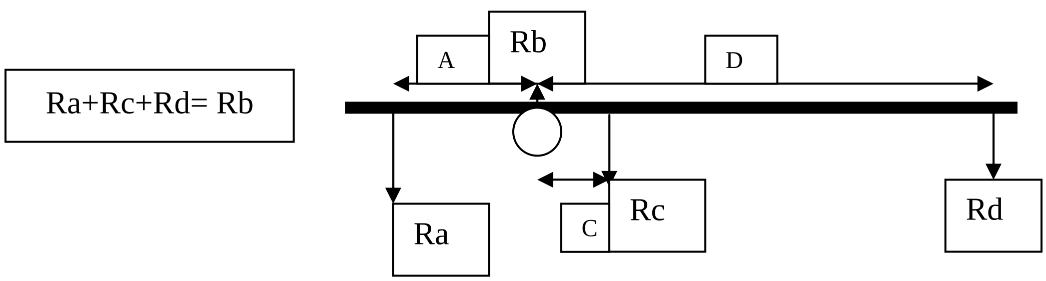
Equilibrium or Static

An object, i.e. a beam, a building is at equilibrium when sum of all forces in all directions (algebraic sum), moments and torques are at rest (or is zero) and are not moving, otherwise we would be in a mechanical engineering world called dynamics. Therefore, sum of all the (a) moments acting on the body, (b) vertical forces acting on the body, and (c) horizontal forces acting on the body must equal zero.

Equilibrium:
it must: (1) • Have no unbalanced force acting on it (aka: it can't move!) (2)
• Have no unbalanced moment acting on it (aka: it can't rotate!)
• The three conditions of equilibrium may be stated as follows:
• The summation of all the horizontal forces acting on the body must equal zero.
• The summation of all the vertical forces acting on the body must equal zero. _
• The summation of all the moments acting on the body must equal zero.

Example:

Assuming the beam's weight is negligible, the forces in the vertical direction algebraically are zero. Summation of all vertical forces are



Forces

he unit of force is pounds, lb or # (Newton (SI), N) or thousand pounds, Kips (KiloNewtons, KN). The issue is the seesaw created is stable and not move? To respond to this question, one must take a moment.

Moment at any point is similar to the seesaw, the hammer, the wedge science class in 5th grade. Moment is the force time the arm distance. Arm distance is from the pivot to the position where the force is applied. This is the reason for monumental constructions of the pyramids, temples, and castles nearly 3 thousand years ago.

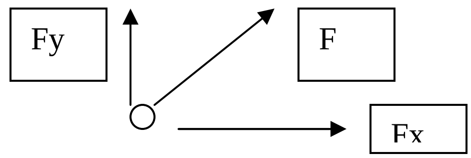
Moment at point b, or any other point, must be zero.

Therefore,

A.Rb= C.Rc+D.Rd

where the A, C, or D are arms or distances creating the torque.

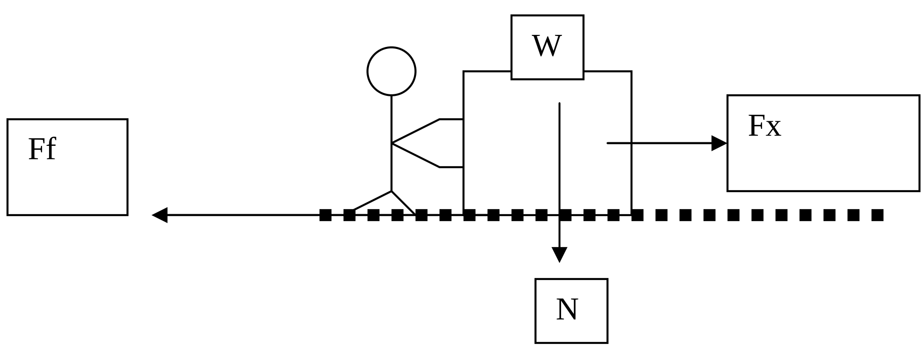
Algebraic sum is the sum of components of vectors.



Force is divided into X component and y component. Applying the equilibrium, sum of all forces in x direction must be zero. Then apply this to y directions.

Please note that Pythagorean theorem and trigonometric sine and cosines can also be used in these calculations.

Any load can be converted into simple diagrams, namely, free body diagram, where vectors correspond to forces acting on a body. Fx is the force pushed by guy, Ff is the surface friction opposing the Fx, W is the gravity force applied on the box, and N is the normal force acting against the box by earth. (You can omit the picture of the guy in structural engineering).



Definitions/Key Words

	Allowable Stress: maximum permissible unit stress
	Collinear forces: vectors lie along the same straight line
	Composite Structural Member: more than one material working together (eg: reinforced concrete, box beam, flitch beam)
	Concurrent forces: lines of action meeting at common point
	Coplanar forces: lines of action all lie within the same plane
	Deflection: the displacement of a structural element under a load
	Ductility: ability of a material to absorb energy prior to fracture toughness!
	Eccentric Load: A load imposed on a structural member at some point other than the centroid of the section
	Factor of Safety: ratio of the ultimate strength of material to its working stress
	Force: the push or pull exerted on an object, including its magnitude, direction, and point of application
	Hook's Law: unit stress is proportional to unit strain up to the elastic limit
	Load (p): a force applied to a body (also called an external force)
	Modulus of Elasticity: a material's resistance to non permanent (or elastic) deformation
	Moment of Inertia: measure of an object's resistance to changes to its rotation
	Moment: the tendency of a force to cause rotation about a given point or axis
	Non concurrent forces: lines of action do not pass through a common point
	Reaction: the force acting at the supports of a beam that holds it in equilibrium
	Resilience: ability of material to absorb energy while undergoing elastic range stresses
	Section Modulus: is the ratio of a cross section's second moment of area to the distance of the extreme compressive fiber from the neutral axis
	Shear: a strain produced by pressure in the structure when its layers are lateral shifted in relation to each other

	Strain: the deformation of a material caused by external loads Tensile loads stretch, and compressive loads shorten
	Stress (f): the resistance of a body to a load (also called an internal force) and measured in kips (K)
	Structural forces: any combination of forces (eg: truss is sets of concurrent coplanar forces)
	Truss: framework consisting of rafters, posts, and struts
	Unit Stress: stress/unit of area at the section, measured in psi or ksi (kips/sqin)
	Yield Point: the amount of stress that causes a material to deform without additional load added
	Arch: a curved symmetrical structure spanning an opening and typically supporting the weight of a bridge, roof, or wall above it.
	Beam: a member that supports loads perpendicularly to its longitudinal axis
	Cantilever Beam: supported at one end and restrained from rotation at that end
	Fixed End Beam: fixed against rotation at both ends
	Frame: a structural system that supports other components of a physical construction
	Gage line: standard dimension from corner edge of an angle to centerline of bolt holes. depends on size of angle
	Overhanging Beam: rests on 2+ supports and has one or both ends cantilevered beyond the support
	Post: long, sturdy piece of timber or metal set upright in the ground used to support
	Simple Beam: rests on a support at each end and ends are free to rotate
	Truss: a framework, typically consisting of rafters, posts, and struts, supporting a roof, bridge, or other structure
	Bearing Type Fasteners: (shear plates) that transmit lateral loads only by shear forces via bearing on the connected materials
	Connection: two or more members joined with one or more fasteners which provide continuity to the members and strength/stability to the system
	Connectors Spacing: the distance between centers of connectors, the minimum of which is typically given in building codes

	Counter forts: reinforced concrete webs act as diagonal braces
	Critical net section: section where the most wood has been removed
	Dowel Type Fasteners: (nails, screws, bolts) that transmit lateral loads via bearing stresses between the fastener and members of the connection OR that transfer withdrawal loads parallel to the fasteners axis via friction or bearing to the connected materials
	Edge distance: distance from edge of member to center of connector closest to it
	End distance: distance measured parallel to the grain from the center of connector to square cut end of member
	Hangers: combination of dowel and bearing type fasteners that support one structural member and are connected to another member by a combination of dowel and bearing action
	Plate Girder: assembly of steel plates, or plates and angles, fastened together to form an integral member
	Shoring: supporting a structure in order to prevent collapse so that construction can proceed. (e.g.: support beams and floors of building while a column/wall is removed, shoring in trenches for worker safety in excavation)
	Stabilization: retrofitting of platforms/foundations as building for the purpose of improving the bearing capacity of the supported building.
	Underpinning: the process of strengthening and stabilizing the foundation of an existing building
	Abrams Law: compressive strength of concrete is inversely proportional to ratio of water to cement
	Coefficient of Thermal Expansion: ratio of unit strain to temperature change, a constant, given for each material.
	Creep: tendency of a material to move slowly or deform permanently under stress
	Fatigue: progressive damage that occurs when a material is subject to cyclic loading
	Hydration: chemical hardening of concrete
	Laitance: an accumulation of fine particles on the surface of fresh concrete due to upward movement of water. Occurs when there's too much water in the mixture. Concrete appears "chalky"

	Moisture Content: weight of water in wood as a fraction of the weight of oven-dry wood
	Fire Code: set of standards established and enforced for fire prevention and safety incase of fire. Addresses fire prevention and building construction features/ratings
	Life Safety Code (NFPA 101): consensus standard widely adopted (but NOT a legal code) that addresses construction, protection, and occupancy feature necessary to minimize danger to life from, including smoke, fumes, or panic.
	Strength Design: method of proportioning structural members so that computed forces produced in the member by factored loads don't exceed the member design length (LRFD). Used in the design of concrete and masonry structural elements
	Implications of Design Decisions
	Triggers: events or actions that require seismic retrofit
Aerodynamic Pressure:	the interaction between the wind and the building
Basic Wind Speed:	the wind speed with a 50 year average recurrence interval measured at 33'-0" above grade in Exposure C (flat, open terrain) It is a peak gust speed
Building drift:	the distance a building moves in wind
	CONTENT AREA: WIND FORCES
Down Slope Wind:	wind that flows down the slope of a mountain
Downburst:	An area of significantly rain-cooled air that, after reaching ground level, spreads out in all directions producing strong winds. Associated with thunderstorms
Exposure:	classification for the characteristics of the ground roughness and surface irregularities in the vicinity of a building
Hurricane:	spiraling wind systems that converge with increasing speed towards the storm's center (eye)
Main Wind Force Resisting System (MWFRS)	: a structural assembly that provides for the overall stability of the building and receives wind loads from more than one surface (eg: shear walls, diaphragms, rigid frames, space structures)
Northeaster:	cold, violent storm that occurs along NE coast and last for days

Special Wind Regions:	mountainous areas in the continental US
Straight Line Wind	: most common wind type, blows in a straight line
Thundersto rm:	rapidly forming storm that produces high wind speed
Tornado:	rotating column of air that extends from base of thunderstorm to the ground
	Allowable Stress Design: method of proportioning structural members, such that elastically computed stresses produced in the members by nominal loads don't exceed specified allowable stresses
	Building Design
	Design Strength: the product of the nominal strength and a resistance factor
	Duration of Load: the period of continuous application of a given load or the aggregate of periods of intermittent application of the same load
	Dynamic Load: when load is applied suddenly or changes rapidly
	Essential Facilities: buildings or structures that are intended to remain operational in the event of a natural disaster or major storm (eg: hospital, fire station)
	Factored Load: the product of a nominal load and a load factor
	Impact Load: the load resulting from moving machinery, elevators, vehicles, etc., and kinetic loads, pressure and possible surcharge from fixed or moving loads
	Lateral Loads: loads that act in the direction parallel to the ground
	Limit State: a condition beyond which a structure or member is no longer useful for its intended function or is considered unsafe
	Load Effects: forces and deformations produced in structural members by the applied loads
	Load Factor: a factor that accounts for deviations of the actual load from the nominal load, for uncertainties in the analysis that transforms the load into a load effect, and for the probability that more than one extreme load will occur simultaneously
	Load Path: the path taken by a force acting on a building through the building

	Loads: forces or other actions that results from the weight of buildings, materials, occupants and their possessions, environmental effect, movement, and restrained dimensional changes.
	Nominal Strength: the capacity of a structure or member to resist the effects of loads, determined by equations, field/lab tests of models, using specified material strengths and dimensions, etc.
	Permanent Loads: loads where changes over time are rare or small (eg: dead loads)
	Require Strength: strength of a member, cross section or connection required to resist factored loads or related internal movements and fces
Variable Loads	**Variable Loads:** all other loads that aren't considered permanent loads (eg: live loads)
Vertical Loads	**Vertical Loads:** loads that act in the up/down direction. (eg: dead loads and live loads)
η overturning	increase unstable restoring moment [UBC 1630.8.1]. Over turning effects on every element should be transferred to the foundation.
"Largest" Earthquake	ground motion expected to occur during the life of a structure to be built at a specific site is the maximum **"Probable"** earthquake. 1655 Div IV
[UBC 1630.8.1]	Resisting moment of the parallel walls one story is less than the overturning moment in direction of applied lateral force.
1/R fixed = FH3/12EI + 1.2Fh /A EG ;A=td ;I= td3/12	Rigidity depends on depth d, thickness, t, height, h, &modulus of elasticity, E, & shear modules of elasticity, EG, &condition of its rotation
1933 Riley Act	set the minimum base shear of typical 0.02 W
5oo m.p.h.	sudden rise in sea floor creates water velocity = 500 mph
Acceleration	Rate of change of velocity with time.
Actions needed:	anchor wall panels to foundation; increase walls weight; increase length of walls. Based on UBC 1630.8.1 design overturning moment to distribute to vertical resisting elements & carried to foundation over turning. Is resisted by weight of parallel walls & distributed (dead load tributary) of roof: anchor walls & increase wall weight. Larger wall have longer resisting moment are make walls longer (except concrete tilt up panels).

Aftershock	An earthquake, usually a member of an aftershock series often within the span of several months following the occurrence of a large earthquake (main shock). The magnitude of an aftershock is usually smaller than the main shock.
Allowable stress levels	UBC permits 33 %(usually) additional stress levels for alternative load combinations (ASD, or working stress design). This addition is allowed when seismic loads are combined with other vertical loads. Vertical loads alone will not comply.there are tow one – third increase in stress when working in timber design. One is related to wind and seismic force, and the other is specific to wood members by way of the load duration factor.When using the alternate basic load combinations for all materials other than wood, the UBC-97 (sections 1612.3.2 and 1612.3.3) permits a one- third increase in allowable stresses for all combinations including W (wind) or E (earthquake)
Alquist-Priolo Act 1	California state mandates the Sate Geologist to regulate zones around active faults 1972, based on 1972 San Fernando Earthquake.
Alquist-Priolo Act 2	Prevent construction of human occupancy outside of the 50 ft of active trace fault. Exempt: Single family home 2 story or less and not part of 4 unit or more structure built prior to May 4th 1975
Alquist-Priolo Act 3	Construction of single family homes (wood or steel) up to 2 story excluding basement with development of up to 3 units (not for 4 units of more)
Alquist-Priolo Act 4	Addresses hazard surface rupture that occurs when a movement of deep fault within breaks through to surface, does not address ground shaking, liquefaction, fires, etc.), Construction of storage for hazardous or explosive is permitted if AHJ accepts. No restriction on building content
Amount of energy, E, Radiated	Micro, M= 2; Moderate M=5.3; Strong M=7.3; Great, M >7.5
Amplification	A relative increase in ground motion between one type of soil and another, or an increase in building response as a result of resonance.
Amplitude	Maximum deviation from mean of the center line of a wave.
Attenuation	decrease of seismic energy with distance through rocks and geological material. Attenuation is not influenced by earthquake magnitude.

Base Isolation	A method whereby a building superstructure is detached from its foundation in order to change the characteristics of earthquake forces transmitted to the building. is based on shifting the building period towards the long period of the spectrum where the response is reduced. common for rehabilitation of historic structures; superstructure of the building is partially isolated from ground by motion and use of bearings
Base Shear	Calculated total shear force acting at the base of a structure, used in codes as a static representation of lateral earthquake forces. Also referred to as "equivalent lateral force." the reaction at the base of a wall/structure due to an applied lateral load
Bearing Wall	A wall providing support for vertical loads; it may be interior or exterior.
Bearing Wall System:	A structural system with bearing walls providing support for all or major portions of the vertical loads. Seismic resistance may be provided by shear walls or braced frames.
Blocked Diaphragm:	in light frame construction, all sheathing edges not occurring on a framing member are supported on and fastened to blocking…more nailing provides a greater number of fasteners able to transfer shear from one panel to another
Body Wave	MB: Body wave magnitude 1.0 to 5.0 Sec Body wave is beyond regional distance
Box-Type Structure:	term used to when diaphragms and shear walls are used in the lateral design of a building
Braced Frame:	One which is dependent upon diagonal braces for stability and capacity to resist lateral forces. In concentric braced frames, diagonal braces are arranged concentric to column/beam joints; in eccentric braced frames, they are eccentric. Act like shear walls but may be of lower resistance and stiffness depending on design; Vibrating forces may cause bracing to elongate or compress...and then it loses its effectiveness and permits large deformations or collapse; Can be designed in a variety of systems; an essentially vertical truss system that provides resistance to lateral forces and provides stability for the structural system
Bracketed duration:	the time between the first and last peaks of motion that exceeds a threshold acceleration value of 0.05g
Brittle Failure:	Failure in a material which generally has a very limited plastic range; material subject to sudden failure without warning.

Building acceleration and ground acceleration:	generally lower than the ground acceleration which is function of mass and stiffness. Building acceleration is the same as ground acceleration for Infinitly high stiffness values, same as zero natural period, T α 1/K= 1/infiniti
California Hospital Zone Act:	act mandates all hospital to be operational after earthquake. 1933 Long Beach
cause of earthquake damage	ground shaking: Affects the building in three ways: internal forces, period/resonance, and torsion; Shaking causes damage by internally generated internal forces that come from the vibration of the building's mass
Chord:	the edge members of a diaphragm (e.g.: joists, ledgers, truss elements, double top plates)
Close to Fault:	Locations closer to the fault from where the energy is release will experience higher frequency/shorter period ground motion. The farther the building is from the earthquake touch may be subjected to considerable long-period motion
Code "provisions are":	minimum requirements
Creep	continuous or intermittent movement without noticeable earthquakes characterizes creep.
Damping	Damping is the dissipation of energy. There are several sources of damping. System in oscillatory motion dissipates energy till it stops.
Damping affects:	the dynamic behavior of the building and modifies its response to ground motion. When damped, buildings are inefficient in their vibration and when set in motion, return to their starting position quickly.
Damping ratio of buildings:	Buildings with natural periods of less than 1.0 sec may have damping ratios tow to three times higher than buildings with similar construction but natural periods greater than 1.0 sec**.** Expressed as a percentage of critical damping (Concrete frame w / flexible internal wall & exterior cladding =0.07

Deep earthquakes	may have focal depths of up to 450 mi (700 Km).
Design earthquake ground motion:	the earth quake ground motion that buildings and structure are specifically proportioned to resist in the IBC
Diaphragm	flat structural unit acting like a deep, thin beam. Typically applies to roofs/ floors designed to withstand lateral loads; Horizontal resistance elements (floors/roofs) transfer lateral force between vertical resistance elements; Size and location of penetration is critical to the effectiveness of the diaphragm
Diaphragm Boundary:	in light frame construction, a location where shear is transferred into or out of the diaphragm sheathing, either to a boundary element or to another force resisting element
Diaphragm chord	a diaphragm boundary element perpendicular to the applied load that is assumed to take axial stresses due to the diaphragm moment
Diaphragm flexible	a diaphragm is flexible for the purpose of distribution of story shear and torsional moment
Displacement:	the distance that points on the ground are moved from their initial locations by the seismic waves, measured in inches.
Drag Strut	structural component that distributes the diaphragm shear from one shear resisting element to another...served by the double top plate.
Drift, P Delta, Damping, K	
Drift, Δ:	Vertical deflection of a building or structure caused by lateral forces. displacement between adjacent stories due to applied for ces. (Components are: shear drift & chord lift + f (nature of loading & displacement) .variables is: building & story height shear loads, girder length & depth column length & height & frame length. 2% of its total height at the roof level, there are three components of drift: column and girder bending and shear; joint Rotation, and frame bending. UBC 1630.10 measure of seismic performance; Δm story drift (T <0.7 SEC) ≤ 0.025 H STORY;T>0.7 SEC <0.02 H STORY; The drift value should correspond to the drift that would occur when the structure responds in elastically to 10% in 50-year earthquake

Dual moment frame/shear wall	combines ductility with rigidity
Ductility	Property of some materials, such as steel, to distort when subjected to forces while still retaining considerable strength. the property of certain materials, typically steel, to fail only after considerable inelastic (permanent) deformation occurs; Good ductility requires special detailing of joints
Ductility factor at high frequencies:	energy absorption effects dominant, and a ductility factor based on energy (rather than strain) ηu, is more appropriate for use in determining the inelastic response spectrum
Ductility factor, η:	number of definitions, all of which represent the ratio off some property at failure (fracture) to that same property at yielding. Modern seismic codes is 2.2,the value of the ductility factor 4 to 6 for concrete frames and 6 to 8.5 for steel frames, in excess of 6 are not often used. (Up to 10 for ductile steel structures)
Dynamic structural analysis:	the overall building and story stiff nesses and rigidities are calculated. Tall buildings with complex shapes or unusual conditions a computer. Model is used to study what forces are developed
Earthquake Damage:	Function of PGA and duration of motion; Soil Conditions at site and period of site; Distance from epicenter to structure; Natural period and damping of structure; Function of distance from structure to epicenter, ground acceleration, duration, frequency, soil type, rocks between the epicenter and structure, distance between epicenter and structure, natural period, time of event)
Earthquake Design:	against the vibrations caused by fault slippage and try to ensure that building are not built over fault zones. Earthquakes also trigger failure in the form of landslides, liquefaction, and subsidence
Earthquake effect	influenced by frequency, duration, ground acceleration which in turn affect the seismic damage.
Earthquake Fault Zone Act	Prior to January 1994, "Specialized Studies Zones
Earthquake magnitude	is not function of acceleration and duration, i.e. Loma Prieta, M= 7.1, 0.65g; Northridge, M=6.7, 1.80g;1971 San Fernando, M =6.6, 0.75g;1940 El Centro, M =6.4, 1.65g
Earthquake Magnitudes:	ML=Local Magnitude “Richter” 0.1 TO 1.0 SEC

Earthquake provisions:	safeguard against major structural failures & loss of life
Earthquakes	are initiated when (due to slowly accumulated pressure) the ground slips along a fault plane on/near a plate boundary. Earth's crust is divided into several major plates
Eccentric bracing	combines the ductility of the moment frame with the rigidity or drift control of the conventional brace
Effectiveness of seismic provisions:	In many cases of structural failure in modern buildings, earthquake severity, duration, soil conditions, inadequate design, poor control or material quality, and poor workmanship are found to be the major factors contributing to collapse, modern seismic codes cannot be blamed when pre -1973 structures fail
Elastic:	The ability of a material to return to its original form and condition after a displacing force is removed.
Energy Dissipation -	Reduction in intensity of earthquake shock waves with time and distance, or by transmission through discontinuous materials with different absorption capabilities.
Energy Realease	Energy released during earthquake: Amplitude of Richter of 1 equals 10 times the earthquake magnitude (logarithmic scale).
Epicenter	the point on the earth's surface directly a above the focus (hypocenter). occurs on surface directly above the focus point or fault rupture.
Essential facilities	emergency facilities that must remain operational after an earthquake (UBC -97 sec 16270)
External viscous damping	caused by the structure moving through surrounding air or water in some cases.
Failure of vertical elements:	like columns or walls can occur by buckling, when mass pushed down due to gravity experts its force on a member bent or moved out of plumb
Fault	fracture of earth's crust
Field Act:	Special seismic design for public school building subject to Division of state architects. Does not apply to private school. K thru 12. Later added: Jr Colleges (added based on 1969 Garrison act)
First mode=	Fundamental mode= Longest period= First mode = Shortest (smallest) frequency
Flexibility	Total deflection when a unit lateral force applied = 1/stiffness = 1/K
Focal depth:	the focal depth of an earthquake is the depth from the earth's surface to the focus.
Focus	location of the earthquake.
For timber	Z (1/3) one third increases in stress

Frequency	the inverse of period, or the number of cycles that will occur in 1 second measured in **Hertz.**
Fundamental Period, T:	the rate at which an object will move back and forth if they are given a horizontal push. When heavy equipment are added to a building, then the period increases, then the stiffness, K, decreases. Period is inverse of natural frequency, f. T= 1/f
Geotechnical:	other P.E proof license /authority beyond a civil other than S.E..
Height of structure	Height above the base to the nth level. nth level is upper most level (main portion). Penthouse is not portion of building
Hertz:	a measurement of frequency, 1 Hertz = 1 cycle per second.
High rises	have longer periods than the low rises. T is function of h.
Hook's Law:	K=F/X =1/Flexibility =Stiffness
Hospital & surgery & emergency treatment	Facilities to be maintained operational after earthquake (Essential facilities) TABLE 16-1 CATEGORY 1
IBC design criteria:	Maximum **probable** earthquake having 10% probability of being exceeded in 50 years (475 year return) and Maximum **capable or considered** earthquake in zone **3 and 4** is defined as having 10% probability of being exceeded in 100 years
IBC Design Criteria:	No building collapse during sever earthquake
Inelastic -	The inability of a material to return to its original form and condition after a displacing force is removed; permanent distortion.
Intensity -	A subjective measure of the force of an earthquake at a particular place as measured by its effects on persons, structures and earth materials. Intensity is a measure of energy. The principal scale used in the United States today is the Modified Mercalli, 1956 version.
Intermediate earthquakes	whose causes are not fully understood, have focal depths ranging from 40 to 190 mi (60 to 300 Km).
Internal viscous damping	commonly the only type of damping actually modeled is related to the viscosity of the structural material. Body- friction damping also known as coulomb friction, radiation damping, occurs as a structure vibrates and becomes a source of energy itself

Levels of Mercalli	1- Felt only by a few persons at rest, especially by those on upper floors of buildings. Delicately suspended objects may swing2- During the day, felt indoors by many, outdoors by a few. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing vehicles rock noticeably.3- Felt by all, many frightened. Some heavy furniture moved. A few instances of fallen plaster. Damage slight;4- Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.;5- Few, if any, masonry structures remain standing. Bridges destroyed. Rails bent greatly
Liquefaction -	Transformation of a granular material (soil) from a solid state into a liquefied state as a consequence of increased pore-water pressure induced by vibration.
Load and Resistance Factor Design	a method of proportioning structural members and their connections using load and resistance factors such that no applicable limit state is reached when the structure is subjected to appropriate load combinations. Used in the design of steal and wood structures.
Lumped masses and many modes:	Higher modes have higher frequencies then lower periods. T= 1/f
Maps:	in California Division of mines and geology, based on Alquist-Ptiolo Act
Mass and Earthquake	Increase in mass (or the weight of the building) will result in an increase in the force for a given execration (lightweight construction preferred)
Maximum "Considered (capable)" earthquake	ground motion at a specific location is maximum "**possible**" earthquake.
Maximum Acceleration:	When building natural period is equal to earthquake period T (period)=f(m&k) Functions of mass and stiffness As mass increases, period increases and then decreases.
Maximum considered earthquake ground motion:	the most severe earthquake effects considered by IBC

Mechanical systems:	in terms of seismic design, this includes HVAC and plumbing • **Orthogonal:** to be in two horizontal directions at 90degrees to each other
Mexico City Earthquake	1985 Mexico City 365 Km away from epicenter was damaged due to resonances. Many buildings were damaged and lake bed soil accelerations were examined.
Modified Mercalli Intensity Scale	Measures the intensity of the observed effects and damages caused by an earthquake. Twelve Roman numeral levels numbers assigned from un-apparent shaking to total devastation. If M=7.5 & P.G.A= 0.45 G = Rating # = 0.25-0.45; 1x=0.45-0.60
Moment Frame:	A space frame in which members and joints are capable of resisting lateral forces by bending as well as along the axis of the members. Varying levels of resistance are provided by Ordinary, Intermediate and Special Moment Frames as defined in the NEHRP Provisions with Special Frames providing the most resistance. Lateral forces are resisted by rotations of the beam/column joints; Induces shear and bending forces in the frame members; Joints become highly stressed and design and construction becomes critical; Most are steel structures with stiff welded joints in which the natural ductility of the material is of advantage; Use of moment frames obviates the need for shear walls or braced frames and the tend to be much more flexible than shear walls type structures
Moment Wave	Mw : Moment magnitude >700Sec
Multiple degrees of freedom:	lumped masses at each floor& roof
Natural period T:	Linear natural frequency, f or just natural frequency the circular frequency, angular natural frequency, or just **angular frequency**
Natural period:	time to complete cycle of oscillation of a single degree of freedom
Non ductile concrete frames:	subject to sudden shear failure of the weak unconfined columns
Nonbearing Wall (Partition):	A wall that does not provide support for vertical loads other than its own weight as permitted by the building code. It may be interior or exterior.

Nonstructural:	systems and components that are part of a building that don't like in the primary load bearing path of the building
Not good periods:	stiff building with short period isn't appropriate on a soft site with a long period. Earthquake shaking tends to be greater on soft ground than on hard ground. Earthquakes are more sever in areas of soft ground
Occupancy categories:	Certain facilities such as hospitals and police and fire stations cannot be shut down under these circumstances. Accordingly, low requires that these facilities be designed to remain operational after an earthquake.
Over strength:	a characteristic of structures where the actual strength is greater than the design strength, A seismic force amplification factor, or over strength factor :Ώo
Overturning	what happens when a lateral force acts on a wall or building and the wall restrained from sliding
P Δ effect	is not primary or overall moment
P –Δ effect 3:	Secondary effect shears, axial forces and moments of frame members indicated by vertical loads acting on laterally displaced building system. Additional column bending stress cussed by earthquake first (live &dead loads are vertical ,constant, concentric with base of building . when drift occurred , horizontal forces cause vertical forces to be eccentric with base, those condition caused tow types of moment:1- Primary moment: bending moment due to bending of column under lateral loads (fh). 2- Secondary vertical loads act on buildings displace laterally by Δ form the base:P -Δ or secondary moment effects on shear, axial forces, and moments of frame members should be considered in building design as outlined in UBC [sec .1630.13]
P- Δ Effect 1	this secondary effect on shears, axial forces, moments, and displacements of frame members. If the overturning moment increases faster than the restoring moment from the frame stiffness, the frame will be unstable. P- Δ has very little effect on structural response until dynamic instability is approached. Wall X- bracing and thick shear walls provide protection against instability failures. need not be consider in the analysis of the entire structure when: (1) The ratio of secondary moment to primary moment (stability coefficient) in any story is equal to less than 0.10 (2) The story drift ratio dose not exceeds 0.02/R in seismic zones 3 and 4 for all stories
Panel	the section of a floor, wall or roof comprised between the supporting frame of two adjacent rows of columns and girders or column bands of floor or roof construction
Parallel	F= (K1+K2)X sum of the K`s

springs	
Peak Ground Acceleration:	The maximum PGA is easily measured by a seismometer or accelerometer and is one of the most important characteristics of an earthquake.
Perforated Shear Wall	shear wall that contains door/window openings that is treated as a single shear wall with a slightly lower capacity than a full height shear wall segment
Period	the time (in seconds) that is needed to complete one cycle of a seismic wave
Period of an earthquake	the period of waves by Fourier Analysis.
Period of Site	from geological data with fundamental or natural period.
Period of the Building	determined from analysis of structure and fundamental natural period. None of the periods have the same definitions.
Period:	All objects have a natural/fundamental period...the rate at which they will vibrate if they are given a horizontal push; Natural period for a building varies from 0.05 to 2 seconds; Stiffness of construction materials and geometric proportions affect the period; Height is the most important consideration when dealing with period; Natural ground period is 0.4 seconds to 1.5 second; It's possible the motion the ground transmits to the building will be at its natural period; avoid amplification in building vibration not to coincide building period with the ground
PGA (Peak Ground Acceleration)	in California:M=8.0 to 8.5 yields Sa=.5g "Sa=.5g"
Places of public assembly	(5000 or more people) schools (300 or more students) colleges and adult education centers (500 or more students) nursing homes, daycare centers, nurseries, and jails.
Progressive Resistance Systems	combine 2 or 3 systems that progress in load carrying capacity from rigidity to ductility at predetermined load levels
R.C.E/ PE:	can design /caltrans, 40 story bldg, warehouse
Relative rigidities:	of members are a concern of seismic analyst. As soon as a rigid horizontal element or diaphragm is tied to vertical resisting elements, it will force those elements to deflect the same amount

Resist and Dissipate seismic energy:	Three basic characteristics of buildings help resist and dissipate the effects of seismically induced motion: damping, ductility, and straight/stiffness
Resonance	occurs when forcing & natural frequencies are same. Occurs when the building period coincides with earthquake period or when earthquake period coincides with site period or when site period coincides with building period. TB=TEQ TEQ=TSITE TSITE=TB. best condition for structural resonance occurs with High frequency wave (low period) on bedrock and low frequency wave (high period) on soft soil
Response spectrum:	plot of period versus acceleration. shows the accelerations that may be expected at varying periods
Richter amplitude	M =Log(A_1/A_0)= 5 & M =Log(A_2/A_0)=2 M=5 - M=2 (5-2= 3 them 103=1000 times stronger); A0=3.94×10 IN (.001mm)
Richter Energy Unit	32 Times more energy for each unit =10 Times increase in measure of maximum amplitude \ on the seismometer trace
Richter Equations	M_L =[log A Peak Displacement of earthquake -2.48+2.76Log Δ-km Distance Epicenter]= =LogA-2.48+2.76LogΔ
Richter Scale, M,	Logarithmic and amplitude displacement. Measurement of earthquake strength using logarithmic recorded amplitude, M. Magnitude is related to length of fault slip. As the length of vertical or horizontal fault slip increases, M tends to increase.
Richter Scle	useful for engineering is the natural period of instrument is the same as the structure (0.7 to 1.255)
Right lateral fault:	or slip or sudden displacement of crust or rock. When a person stands on either side of a right lateral fault and looks across the fault, the fault movement will be on the person's right.
Rigid Diaphragm	a diaphragm is rigid for the purpose of distribution of story shear and torsional moment when the lateral deformation of the diaphragm is ≤2x the average story drift
Rigid Frame	load resisting skeleton constructed with straight or curved members interconnected by mostly rigid connection which resist movements induce at the joints of members. Its members can take bending moment, shear, and axial loads
Rigidity =	stiffness: resistance to rotation. for fixed wall rigidity due to bending & shear
Rigidity of wall	depends on height, thickness e, and modulus of elasticity.

Rigidity, Δ&R,	is reciprocal of deflection 1/Δ. deflection, Δ= 1/R rigidity; When lateral are applied to vertical members the load taken by each member (15 taken) & proportional to the relative rigidity of each member.
S.E:	only S.E. Can work on schools in ca not PE/ do hospital, every damage report
Safety Factors:	Appropriate safety factors ensure that materials never exceed the elastic range of behavior
SAN Andreas Fault of California	600 miles long by 20 miles deep is a Right Lateral Fault (not Left)
Seismic Codes:	intended only to assure life safety; Only the primary structure must be protected to prevent collapse
Seismic Design Category:	classification assigned to a structure based on its occupancy category and the severity of the design earthquake ground motion at the site
Seismic design criteria selection:	the dynamic force procedure is always acceptable for design of any structure. However the UBC -97 specifies that the minimum design seismic force must be 80 to 100 5 (depending on the degree of structural irregularity) of that prescribed by the static lateral force procedure
Seismic design:	One of the approaches is “static”
Seismic force amplification factor: Ωo:	The type of structural system and natural period of a structure significantly influence the structure’s response to ground shaking.
Seismic Force Resisting System:	the part of the structural system that has been considered in the design to provide the required resistance to the prescribed seismic forces
Seismic Rehabilitation of Existing Buildings:	Not appropriate to use new building criteria: Unworkable or uneconomical. Primary goal is prevent or minimize the collapse exposure
Seismic wave	generated by volcanic eruption, deep artificially induced explosions, sudden explosion within earth's crust. Seismic Wave has compression shear, surface
Seismic zone 3:	max acceleration 0.3 g, max .magnitude =6.6=m; mercalli Π

Seismic zone 4:	the seismic response coefficients, Ca and Cv are function of Nv, Nv is the near – source factor related to both the proximity of the building or structure to known active faults with specific magnitudes, for sites more than 9 mi (15 Km) away from major identified faults and more than 1.2mi (2 Km) a way from minor faults, Nv =1.0
Seismic zone factor, Z:	These values are intended to represent the effective peak ground acceleration that have only 10 % chance of being exceeded in 50 years. This corresponds to a ground motion that will be exceeded, on the average, only once in 475 years (the recurrence interval)
Seismometer	an instrument that measures actual displacement of ground with respect fixed reference point.
Seismometer:	measures ground displacement
Several masses and many modes:	Mode shapes are unique and fundamental mode has longest period.
Shallow earthquakes	Earthquake with focal depths of less than approximately 40 mi (60 Km) , generally California Earthquakes
Shear Wall	vertical, cantilevered diaphragm that is constructed to resist lateral shear loads; Vertical cantilever walls designed to receive lateral forces from diaphragms and transmit them to the ground; Size and location is very important
Shear Wall Segment	portion of the shear wall that runs from the diaphragm above to the diaphragm/foundation below… aka **full height segments**… occur between openings (like windows or doors) in a shear wall
Shear Wall:	A wall, bearing or nonbearing, designed to resist seismic forces acting in the plane of the wall.
Simple harmonic motion:	characterized by the absence of a continued disturbing force and a lack of frictional damping
Site Class:	classification assigned to a site based on the types of soils present and their engineering properties (A: hard rock, B: rock, C: dense soil, D: stiff soil, E: soft soil, E: varies, F: varies w/multiple characteristics)

Soil/Earthquake impact:	Avoiding sites with a potential for liquefaction, landslides or subsidence requirements the best design approach; Ground shaking triggers subsidence/liquefaction in soils that are unconsolidated/saturated with water; Shaken sandy, water saturated soils cause the bearing capacity to reduce as it; liquefies and flows both laterally and vertically; Well built structures are vulnerable if site conditions/foundation design are ignored
Space Frame:	A structural system composed of interconnected members, other than bearing walls, that is capable of supporting vertical loads and that may also provide resistance to seismic forces.
Spectra acceleration:	Maximum acceleration occurs in a system in response to a disturbing system/force or due to a perturbation.
Spectra Velocity	Maximum vibration of a single degree of freedom system is measured in terms of Q.V.Δ or acceleration, velocity, or displacement. Maximum velocity of structure relative to ground is spectra velocity. Single degree of freedom means that there only one mass.
State Geologist	to issue active map of surface trace fault (sites to determine surface displacements for future/active faults (11,000 years) based on Alquist-Priolo Acty
Static analysis method	total horizontal shear at base is calculated according to standard formula; Total lateral force is distributed to various floors; Most cases building codes allow a static analysis of the loads
Static analysis:	the equivalent lateral (seismic) force is calculated as simply some fraction of the dead weight
Steel diagonally braced structures:	suffer non ductile fractures of the braces or connections and adding strength alone is not enough to ensure seismic stability
Stiffness (1/Deflection)	Deflection is a measure of stiffness…In the sizing of floor joists, deflection rather than strength governs because no one wants a bouncy floor...even though it's safe. In the design of a floor system, the joists might tolerate a certain deflection but the ceiling finish cannot.
Stiffness of cantilever wall:	when horizontal load applied to top 3 EI/ H2
Stiffness, K:	force deflect a spring a unit distance. As the force deflects the spring with mass m (W/g) by a distance of one unit F=KX = mg = W
Strength	Resisting a given load without exceeding a safe stress in the material is astrength problem

Strength and stiffness	two of the most important characteristic of any structure. Analysis of forces is not precise and deliberately errs on the conservative side.
Structural Configuration -	The size, shape and arrangement of the vertical load carrying and lateral force resistant components of a building.
Structural damage:	caused by frequency content, soil condition, natural period& damping of a structure
Structural engineers	typically equate design capacity with loads imposed on it (live loads, wind loads, etc.)
Structural Seismic System Selection:	(1) Anticipated level of earthquake ground motion; (2) Site geology and its impact on the structure; (3) Building occupancy and impact on building form and structural system; (4) Building configuration which may be arbitrary or dictated by site, zoning, program; (5) Structural system relative to the configuration; (6) Structural details; (7) Non structural components (Cladding, ceilings, partitions, etc.) in relation to the primary structure; (8) Construction quality and its impact on structural continuity
Sub-duction:	When oceanic plate drops and slides beneath a continental plate or Sliding of crystal plates beneath adjacent plates
Surface faulting	is the crack/split on the surface that is the layperson's vision of earthquakes
Surface Wave	Ms: Surface wave magnitude 20 Sec Beyond 600Km
The center of mass, or center of gravity	of an object is the point at which it could be exactly balance without any rotation resulting. Uniformly distributed mass results in the coincidence of a plan's geometric center with the center of mass. If the mass within a floor is uniformly distributed, then the resultant force of the horizontal acceleration of all its particles of mass is exerted through the floor's center. If the resultant of the resistance (walls or frames) pushes back through this point, balance remains
The seismic response coefficient, Ca:	corresponds to the site – dependent effective peak acceleration at grade .Cv corresponds to the site –dependent effective peak acceleration response at 1.0sec.
The story drift ratio	the story drift divided by the height (floor to floor) of the story.
Torsion (very undesirable)	is a twisting action on a building.

Tsunami:	Japanese for seismic sea wave or tidal wave or surface water wave. Wave velocity decreases and wave height increases as it nears land.
UBC 1633.2.4	Deformation compatibility Δm or 0.025 h story for non lateral systems Δm= 0.7 R ΔS ΔS= Design seismic force drift Δm= Inelastic response displacement
Unblocked Diaphragm	diaphragm in which only 4'-0" wide panel ends occur over and are nailed to common framing...most common type of diaphragm used in residential construction
Unit of Richter:	used by general public to measure and compare old and new earthquake sizes. 1 Unit of Richter =
Unreinforced masonry bearing wall building:	with poorly tied floor and roof framing lack integrity and stability and usually fail by wall collapse in out of plane motion
Unstable: structures:	should be designed to resist overturning effects caused by seismic loading. When overturning moment increases faster than the restoring moment from frame stiffness, frame is unstable.
Velocity	refers to the rate of motion of the seismic waves as they travel through the earth in inches per second. It's VERY fast… the **P-Wave** travels at 7,000 – 18,000 mph, the **S-Wave** travels at 4,500 – 11,000 mph
Wall Bracing	building element that resists lateral loads under low load situations
Waves of vibration	in the earth create ground motion on the earth

Legal

Architect professionals has primary legal responsibility for the performance of a building in an earthquake.

Not: Building code official; Structural engineer; Geotechnical consultant

If the building has...	And you want...	Then your options are...
Irregular Form	Simple floor & roof framing fabricated onsite	• Sitecast concrete with any slab system without beams/ribs • Light Gauge Steel Framing • Masonry with concrete slab/wood light floor framing
Irregular Colum Grid	Something without beams/joists in the floor or roof	• Site cast concrete 2 way flat plate • Metal space frame
Exposed Structure	Fire/Heat resistance	• All concrete systems (except ribs) • Heavy timber frame
Minimum Floor Thickness or Minimum Total Building Height	Thinnest floor system	• Pre-stressed Concrete slabs • Site cast concrete 2 way flat plate • Post-tensioned 1 way slab
Minimum area occupied by colums and/or bearing walls	A Long Span System	• Heavy wood trusses • Glue lam wood beams • Glue lam wood arches • Steel frame • Steel trusses • Open Web Structural Joists • Waffle Slab • Single or Double Tee Concrete
Changes in use over time	Short Span, one Way Systems that can easily be modified	• Light Gauge/Conventional Steel Frame • Wood systems (including masonry) • Site Cast 1 way concrete slab • Precast concrete slab
Exposure to Adverse Weather	No reliance on onsite chemical processes	• Steel • Wood • Precast Concrete without toppings or grouting
Minimal off-site fabration time	On site construction with easilty formed materials	• Sitecast concrete • Light Gauge Steel Framing • Platform Framing • Masonry

Minimal on-site erection time	A lot of prefab/modular components	• Single story rigid steel frame • Steel frame with hinged connections • Precast concrete • Heavy timber frame
1-2 stories with minimal construction time	Lightweight/easy to form/prefab	• Any steel • Heavy timber frame • Platform frame
4-20 stories with minimal construction time	Lightweight/ easy to form/prefab	• Precast concrete • Conventional Steel Frame
30+ stories with minimal construction time	Strong, lightweight, easy to assemble	• Steel Frame • Sometime Site/Precast Concrete
Minimal diagonal bracing or shear walls	Rigid Joint System	• Site cast concrete (With beams/ deep slab around columns • Single frame with welded connections • Single story rigid steel frame
Minimal dead load on foundation	Lightweight/Short Span	• Any Steel • Any Wood
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, Load bearing Wall Panels

Span of Beams

Type	Width	Spacing	Spans	Top/Bottom	Use	Advantage
Joists	2" Nominal	12" to 16" On Center	20 to 25 ft	Bridging supports bottom edge, sheathing holds top in place	Between beams or bearing walls	Coventional
I-Joist	1 3/4" to 3 1/2"	12" to 24" On Center	8 to 24 ft	9-1/2" - 16" depth OSB webs and microllam (thick plywood) flanges connect to wall with hangers	Residential/ light commercial	Efficient structural shape as shop fabrication eliminates common defects
Glulam	3 1/8", 5 1/8", 6 3/4", 8 3/4"	Varies	15 to 60 ft	Several layers of timber bonded together with glue and connected with plates and/or bolts	Columns and beams, commercial, public	Exposed or tapered curve
Plank/ Beam Framing	4" to 6"	4' or 6' or 8'	10 to 20 ft	Wood decking span between beams, underside finish ceiling	Between girders or bearing walls, residential	Easy to insulate
Truss	Varies	24" on Center	24 to 40 ft	12 to 36 inch deep made of of strand wood members connected with plates	Residential, Commercial, Public	MEP can pass through
Box Beam	Upto 30 ft	Varies	50 ft	Plywood panels glued & nailed to 2x4	Residential, Commercial, Public	Looks like solid timber, custom made

Equilibrium:			ΣM = 0; ΣV = 0; ΣH = 0
Stress (f) =	Stress (f) =	Total Force (P) / Area (A)	**f = P/A**
Force Equations {units = kips or lbs}			
force:	Force (F) =	Mass (M) x Acceleration (a)	**F = Ma**
shear diagram shear force	Shear Resisting Force (R) = (V) =	uniform load per foot (w) x distance (L) / 2	**R= V = wL / 2**
horizontal force on a retaining wall	Force (F) =	soil pressure (w) x height of wall (h)2 / 2	**F = w2h / 2**
Moment Equations	**{units = kip ft, lb ft, kip in, or lb in}**		
equilibrium by taking moments about a point:	Moment (M) =	Force (P) x distance (d)	**M = Pd**
eccentric load (the same as finding equilibrium)	Moment (M) =	Force (P) x eccentricity (e)	**M = Pe**
uniform load	Moment (M) =	uniform load (w) x length (L)2 / 8	**M = wL2 / 8**
point/concentrated load at the center of a member:	Moment (M) =	Point Load (P) x length (L) / 4	**M = PL / 4**
		To combine Point Load and Uniform Loads:	**M = wL2 / 8 + PL / 4**
Section Modulus Equations {units = inch3}			
Section Modulus (both moment and stress are in kips or lbs)	Section Modulus (S) =	Base (b) x diameter (d)2 / 6	**S = bd2 / 6**
	Section Modulus (S) =	Moment (M) / Bending Stress (Fb)	**S = M / Fb**
	Section Modulus (S) =	Moment of Inertia / given constant (c)	**S = I / c**
Section Modulus for a roof beam	Section Modulus (S) =	Moment (M) / 1.25 x Bending Stress (Fb)	**S = M / 1.25Fb**
Moment of Inertia Equations	**{units = inch4}**		

Moment of Inertia (occurs about the centroidal axis)	Moment of Inertia (I) =	Base (b) x diameter (d)3 /12	**I = bd3 / 12**
	Rectangle Moment of Inertia (I) =	Base (b) x diameter (d)3/ 3	**I = bd3 / 3**
	Moment of Inertia at base (Ibase) =	Moment of Inertia (I) + Area (A) x distance from centroid to base (y)2	**Ibase = I + Ay2**
Stress Equations {units = ksi or psi}			
bending stress (max bending stress occurs at the extreme fibers)	Bending Stress (fb) =	Moment (M) / Section Modulus (S)	**fb = M / S**
(so…the greater the c, the greater the bending stress!)	Bending Stress (fb) =	Moment (M) x constant (c) / Moment of Inertia (I)	**fb = Mc / I**
axial stress (max axial stress occurs along entire cross section)	Axial Tension or Compression Stress (fa) = *(axial stress is the same as both tension and compression!)*	Axial Tension (P) / Area (A)	**Fa = P / A**
shear stress (max shear stress occurs at the neutral axis and is the same at both the vertical and horizontal axis)	Shear Stress (fv) =	1.5 x Shear Force (V) / Area (A	**fv = V / A**
	Shear Stress (fv) =	Shear Force (V) x Neutral Axis of area above plane (Q) /Moment of Inertia (I) x width of beam (b)	**fv = VQ / Ib**
	Neutral axis of area above Plane (Q) =	section area (A) x distance from centroid of rectangle to centroid of section above neutral axis (d)	**Q = Ad**
Modulus of Elasticity Equation	Modulus of Elasticity (E) =	Stress (f) / Strain (ε)	**E = f / ε**
Strain Equation	Strain (ε) =	Deflection (e) / Original Length (L)	**ε = e / L**
Deflection Equations {units = inches}			

shortening of a column or elongation of a horizontal member	Deflection (e) =	Force (P) x Length (L) / Area of cross section (A) x Modulus of elasticity (E)	**e= PL / AE**
deflection of a beam	**Deflection (Δ) =**	5 x weight in lbs (w) x length in feet x 12"4 (L4) / 384 x 12" modulus of Elasticity (E) x Moment of Inertia (I)	**Δ = 5wL4 / 384EI**
Thermal Equations {units = inches}			
shortening or elongation due to temperature change	**Thermal Change (Δ) =**	Coefficient of Thermal Linear Expansion (e) x original length (L) x temperature change (Δt)	**Δ = eLΔt**
thermal strength in a restrained member	Thermal Stress (ft) =	Modulus of Elasticity (E) x Coefficient of Thermal Linear Expansion (e) x temperature change (Δt)	**ft = EeΔt**
Slenderness Ratio (Loading Capacity)	**{units = inches}**		
slenderness ratio of a steel column (should be less than or equal to 200)	**Slenderness Ratio (SR)** =	end condition (k) x unbraced length in inches (L) / radius of gyration (r)	**SR = kL / r**
	Radius of gyration (r) =	√moment of inertia (I) / Area	**r = √I / A**
slenderness ratio of a wood column (should be less than or equal to 50)	**Slenderness Ratio (SR) =**	end condition (k) x unbraced length in inches (L) /cross section width of rectangle (b)	**SR = kL / b**

Loads

Shear force:	acts parallel to area resisting force
Moment	The statical moment of an area with respect to an axis:the area multiplied by the perpendicular distance from the centroid of the area to the axis.
centroid	the center of gravity of the area
No Torsion:	If a load acts through something's center of gravity, then it has no tendency to rotate, but will translate in the direction of the applied force
Ultimate strength	Steel 58,000 - 80,000 psi; Concrete 3,000 - 6,000 psi (higher strengths possible); Wood 2,000 - 8,000 psi
structures:	connect two points (eg: bridge), withstand natural forces (eg: dam), span and enclose space (eg: building), Structure is a 3-D art form, like sculpture, but it exists with a purpose, Most structural failures are during construction
Purpose of structural design:	Resolution of the conflict between the vertical direction of most load forces and the horizontal dynamics of mankind (eg: gravity and the way we work); All structures will be destroyed eventually; Many structural failures are caused by improper load assumptions; Most concerning types of stress in building design and construction are tension, compression and shear
Forces (or Loads) on Architectural Structures:	
External (applied) loads	cause primary stresses.
Vertical forces:	Dead loads and Live Loads, Static and Dynamic, Concentrated versus Distributed, Vertical loads (gravity), People (which are both static and dynamic), Moveable equipment, Vehicles, Rain, Snow, Drifting Snow, Ponding, Buoyancy, Construction Materials (bricks, stockpile, materials, etc)
Dead loads	permanently fixed in a structure, and easier to predict

Live loads	move around on their own, or can be moved, and cause vibration, hard to predict and require a higher safety precaution
Deformation:	Dynamic: the load changes with respect to time, often suddenly (eg: earthquakes, wind), Static: the load moves with building accumulation, slowly. (walking in a classroom is static, siting in a chair is dynamic)
Horizontal forces or LATERAL FORCES:	Wind: hurricanes, tornados (no warning or unpredicted); Ice: Expansion force (as it freezes), footings below frost lines; Earthquakes- ground rupture (in the fault zone), ground failure (sliding, settlement, liquefaction), tsunami (seismic sea waves, called a "seich" on inland bodies of water), ground shaking (vibration, repetitive dynamic motion), People: pushing on a window, balcony, etc. , Vehicles: impact loads (collisions), sudden starts and stops, Machinery: generators, oscillating equipment, vibration of equipment, Earth or Water: pressure on below grade structure, Transportation and Erection: (in transport to site and put in place), Lighting: powerful, Blast: explosions
Internal Forces	secondary stresses (> primary stresses) is the result of system or material characteristics, Movements (if resisted) are elastic (temporary) or inelastic (permanent) strains, Shrinkage: some takes place early (eg: concrete), Humidity Changes (eg: wood), Thermal Changes (eg: steel, metal, thin shell), Fabrication Errors (eg: incomplete concrete pour), Prestressing (they're all the same)
Deconstructive Agents	reduce capacity of structural element, Fire: the biggest issue! Heavy timber construction is the most preventative form, Chemical corrosion: parking lots are the worst, Erosion: wind/water, Insects/Plants/Animals

Materials and Systems	structural material: require high strength (resist the three stresses (tension, compression, shear)), tension (withstand deformation, elongation, and failure mode (tearing), compression (shortening, crushing (strength) or buckling (stiffness), shear (deformation in angle or torsion or buckling, durability, stiffness (resist deformation), predictable, elasticity, resist shear (causing deformation in angle). The higher the strength, the less ductile and more brittle it is
deformation:	primary deflection, predictable, small: high resistance, temporary (elastic), return to original position, Stability, Durability
Inelastic Deformation	Does not return to original position, permanent deformation (elastic is temporary deformation)
line of action	parallel to and in line with the force.
Concurrent Forces:	lines of action of several forces pass through a common point (non-current if it does not pass through same point)
point:	the center of moments or axis of rotation
distance,	moment arm or lever arm, is measured in a direction perpendicular to the line of action of the force
force:	equal in magnitude to the resultant, but opposite in direction and on the same line of action as the resultant is called the **equilibrant.**
Resolving Forces:	to replace one force with two or more other forces that will produce the same effect on a body as the original force.
Temperature	modulus of elasticity reduces and the strength is reduced
Heat and Melting	Heat used to melt and shape a member, but once it is shaped, stiffness will still be altered
Charpy V-Notch Test:	A ductility test with a V notch cut on top of the piece. The specimen will be under the stree, the material is brittle if the time to go through the notch is fast and ductile if the notch is slow progression.
St. Venant's Principle for Direct Stress:	The stresses and strains in a body at points that are sufficiently remote from points of application of load depends only on the static resultant of the loads and not on the distribution of loads.

Direct Stress assumptions for this principle to be satisfied:	(1) The thing being loaded must be perfectly straight (2) Load must be applied axially (ie: the center of gravity at the cross section) (3) Cross section of the thing being loaded must be constant (4) Cross section under investigation has to be some distance away from the support/loaded ends (5) Loaded member must be made of a single material (6) Material must be homogenous (and strong, no soft spots!) (7) Load must be statically loaded (8) Elastic range stresses (don't go past yield stress!) (9)Loading must be pure tension, compression, or shear (no secondary effects)
Structural design Analysis Steps:	(1) Determine the loads (compute) (2) calculate the stresses (analyze) (3) Dimension and proportion the members and detail the connections such that the stresses are within the limits for the structural materials (design)
Finding Equilibrium	Objects that are at rest are at static equilibrium and use Three equations of static equilibrium (Horizontal Translational Equilibrium Equation: Sum of all forces parallel to the x axis and y axis = $\Sigma Fx = \Sigma Fy = 0$, Moment/Rotational Equilibrium Equation $\Sigma Mz = 0$
Solving A Direct Stress Problem:	Determine which equation to use f Allowable= P/A, then the cross section of the area of the form, then Figure out the stress, f = P/A. Ask question: Is it safe? What's the allowable stress we can use? Check the following:Structural Steel Allowable Tension 22,000 psi, Concrete usable, compression in bearing 900 psi, Structural Lumber (doug fir) compression parallel to grain 1,150 psi
Solving a Direct Shear Problem:	Determine which equation to use f Allowable = P/A: Determine the area of the bolts A = (# of bots) x (πr^2) then Find allowable stress Pallowable = A x F allowable

	Allowable Stress Design: method of proportioning structural members, such that elastically computed stresses produced in the members by nominal loads don't exceed specified allowable stresses
	Building Design
	Design Strength: the product of the nominal strength and a resistance factor
	Duration of Load: the period of continuous application of a given load or the aggregate of periods of intermittent application of the same load
	Dynamic Load: when load is applied suddenly or changes rapidly
	Essential Facilities: buildings or structures that are intended to remain operational in the event of a natural disaster or major storm (eg: hospital, fire station)
	Factored Load: the product of a nominal load and a load factor
	Impact Load: the load resulting from moving machinery, elevators, vehicles, etc., and kinetic loads, pressure and possible surcharge from fixed or moving loads
	Lateral Loads: loads that act in the direction parallel to the ground
	Limit State: a condition beyond which a structure or member is no longer useful for its intended function or is considered unsafe
	Load Effects: forces and deformations produced in structural members by the applied loads
	Load Factor: a factor that accounts for deviations of the actual load from the nominal load, for uncertainties in the analysis that transforms the load into a load effect, and for the probability that more than one extreme load will occur simultaneously
	Load Path: the path taken by a force acting on a building through the building
	Loads: forces or other actions that results from the weight of buildings, materials, occupants and their possessions, environmental effect, movement, and restrained dimensional changes.

	Nominal Strength: the capacity of a structure or member to resist the effects of loads, determined by equations, field/lab tests of models, using specified material strengths and dimensions, etc.
	Permanent Loads: loads where changes over time are rare or small (eg: dead loads)
	Require Strength: strength of a member, cross section or connection required to resist factored loads or related internal movements and fces
Variable Loads	**Variable Loads:** all other loads that aren't considered permanent loads (eg: live loads)
Vertical Loads	**Vertical Loads:** loads that act in the up/down direction. (eg: dead loads and live loads)

Arch	
Arches	Have hinged (subject to compressive force)or fixed supports(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 and settlement; uniform loads supported across the span form a parabola changes
Arch Structure	Actually, no arch is subject to compression/ 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 charges are statically indeterminate)Generally, loads acting on an arch force it to spread outUltimate goal of arch design is that thrust must be resisted
span thrust	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). Typical arch spans: Wood: 50' – 240'; Concrete: 20' – 320'; Steel: 50' – 500'

# Trusses	
Trusses	are used commonly in Steel buildings and bridges. Members
Truss structure	All straight members, connected together with pin joints, connected only at the ends of the members and all external forces (loads & reactions) must be applied only at the joints. every member of a truss is a 2 force member and assumed to be of negligible weight (compared to the loads they carry), need to be designed so member is symmetric on both sides of centroid axis in the plane of the truss
depth-to-span ratios	range from 1:10 to 1:20
spans:	40' - 200' and typical spacing: 10' - 40' o.c.
Residential & light commercial trusses	smaller, 2x4 or 2x6 members at 24"o.c.
Flat trusses	less overall depth than pitched trusses
Roof loads	transferred from decking to purlins attached to truss at panel points
Concentrated Loads on Trusses	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 (beams)
Stresses on Truss	Compression in top chord & tension in bottom chords
Forces	in a parallel chord truss increase towards center
Load Type	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. Centroidal axes of intersecting members must meet at a point to avoid eccentric loading

Rigid Fames	In rigid frame construction vertical and 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

Steel

Steel	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'
Steel Material	Composed primarily of iron with small amounts of carbon and other materials (manganese, silicon, phosphorous, sulfur); Medium carbon steel is typical for construction; more carbon in the steel increases the strength but ductility and weldabilty decreases; ASTM A572 grade 50 is the most common type of steel used in structures; Shapes and Sizes of steel shapes
Wide Flange Members (H)	width of flange is deeper than standard I-beams and are suitable for columns because the width of the span almost equals the depth of the section, so it has similar rigidity in both directions
Wide Flange Sections (W)	nominal depth in inches, weight in lbs/ft
American standard I-Beams (S)	flange is more narrow in relation to depth, and unlike wide flanges, Actual depth in any group size is also the nominal depth; Only used for beams; Heavier sections are made by adding thickness to the flanges on the inside face only
American standard Channel Section (C)	"C" shape channel used for frame openings and stair stringers, and a structural member with a flush face; Not usually used as a beam as it buckles due to the asymmetrical shape
Steel Angles (L)	can either have equal on unequal legs, used in pair as members for steel trusses, or miscellaneous bracing
Structural Tubing (ST)	rectangular or round pipes, used as light columns, in large trusses, or space frames
Structural Tee:	made by cutting a wide flange or wide beam, often used for chords of steel trusses

Steel Columns:	support a load based on the area, allowable unit stress, and unbraced length of the column; Area and moment of inertial resist buckling; Square and round tubular sections of steel can also be used, often filled with concrete. Steel Columns are still subject to buckling. Buckling is characterized by a sudden failure of a structural member subjected to high compressive stress.
Built up Sections:	like wide flanges, but MUCH heavier
Open Web Steel Joists	lightweight, efficient members that allow for ductwork; Allowable stresses for structural steel are expressed as a % of the minimum; specified yield point; Percentages used are based on the type of stress; A36 steel = yield point of 36ski; Goal of steel beam design is to find the lightest, least expensive section that will resist bending and shear forces within the allowable limits;
Lateral support of open web steel joist:	When load is applied to the top flange in compression, the beam will buckle; To resist, compression flange needs to be larger or supported laterally by: Steel deck welded to the beam; Top flange embedded in concrete; Composite construction
Allowable Stresses	Expressed as a fraction of the yield stress of the steel and varies with the type of stress the member is under (be it shear, compression, bending, tension) and with the unsupported lengths and geometry of the section: Tension on the gross area Ft = 0.6Fy; Tension on the net effect area Ft = 0.5Fu; Shear on gross sections Fv = 0.4Fy
Allowable stresses in Joints:	bolts, rivets, etc are based on the type of load paced on them and given in in KSI; welds are based on yield strength of the base metal or the nominal tensile strength of the weld metal
Steel	an alloy (combination of materials into a base metal) ; iron and minute carbon content between 0.2% and 2.1%.
physical properties	high strength, easy to mold and shape, does not corrode easily with water/moisture, high dimensional stability due to age and environment, low weight, durability, high strength to weight ratio, flexibility and corrosive resistance. In fire with rising heat, steel lose their strength and cause failure. Encasing in fire resistive material is required. Highly recyclable and sustainable.

Beam	I-beams (many times combined with concrete) are widely used and are available in a variety of standard sizes. I-beams can be used both as beams (bending loads) and as columns (axial loads).
Standard I-beam (2)	Rolled – formed by hot rolling, cold rolling, or extrusion. rolling is a metal forming process in which metal stock is passed through a pair of rolls; Plate (welded) – formed by welding, bolting and riveting steel plates
I Beam Design	excellent for unidirectional bending in a plane parallel to the web, not well in bidirectional bending. It provides little resistance to twisting and undergo sectional warping under torsional loading.
W or I Beams Designation	depth and weight of the beam. ("W12x28″ beam is approximately 12 inches in depth and weighs approximately 28 lb/ft)
Cellular beams	the web of which is first divided/cut into custom shapes and then re-welded which results in a beam 40-60% deeper than its parent section. The finished depth, cell diameter and cell spacing are able to be adapted to specific needs. A cellular beam could be 2.5 times stronger than its parent section. Cellular Beams requires less material while providing superior strength.
Steel Bolt Connection Types	**Bearing Type:**resist shear loads on bolts through friction; **Slip Critical:** when any slippage cannot happen as it would risk the structure (e.g.: when the joints are subject to fatigue loading, the joints have oversized holes, the entire load is carried by friction); Standard round holes are 1/16" larger than the diameter of the bolt; Slotted holes are used where some adjustment is needed; The effect of reducing cross sectional area of the members or **net area** must be checked; Connection's shear failure is parallel to the load; Connection's tension failure is perpendicular to the load; Spacing of bolts and edge distance from the last bolt to the edge of the member is critical

Welding Connections	Best for moment connections; Often used with bolting as members have to be held in place until welding is finished; Single plate can be welded to a column and connected with beams; Used over bolts because gross cross section of member can be used instead of net section; Construction is more efficient with no angles/blots/washers to use
• Electrical Arc Welding Process	(most common) one electrode from power source is attached to steel member being joined while other is the welding rod; Heat generated by the arch formed by arc when welding rod is brought close to members and base metal and the end of the electrode melt into the joint and the materials fuse together; Type of weld depends on configuration of the joint, magnitude and direction of the load, cost, and erection process; Indicated on drawings by standard symbols either above or below a leader; Symbol above means the weld is on the opposite side of the leader; Symbol below means the weld is on the same side as the leader; Lap, Butt, Tee welds are most common; Plug/Slot welds are holes cut in one side of the member and the area is filled with the weld; Throat is the distance from the corner of the connection to the hypotenuse of the weld
Steel Construction Requirements	Roofs without sufficient slope for drainage must ensure stability under ponding conditions; Horizontal framing members be designed for deflection criteria and ponding requirements

Steel

Steel roof joists are manufactured with camber to compensate for deflection.
Not: Provide positive roof drainage; support a variety or roof deck systems; increase lateral stability

A balcony is hung from steel roof framing over a hotel atrium. 33% is the minimum code required increase in live load due to impact. Elevator and elevator machinery is 100% increase, Light machines, shafts or motor driven is 20% increase, reciprocating machines or power-driven units are 50% increase and floors and balconies are 33% increase in loads. All have to do with impact, or vibrations.

Not: 0 percent; 25 percent; 50 percent

ASCE 4.7.2. It states that balconies loads shall be increased 33% for impact. IBC section 1602 also mentions impact loads.

ASCE 7-02 Section 4.7 does address impact loads. The code does not specifically address a solid steel ball dropping from a certain elevation. For example: Elevator loads shall be increased by 100% for impact, and the structural supports shall be designed within the limits of deflection prescribed by Refs 4-1 and 4-2. For your example, it would seem as if it is similar to a crane load. This is found in section 4.10 of the ASCE7-02.

Wood

Wood Connection Types	Depends on the species/condition of the wood, fire retardant or not, type of load, and angel of load to the grain; Use nails and screws for light loads and timber connectors for large loads; Wood can carry a greater max load for short duration than for long durations; Connections can be adjusted given the type/duration of load; Connections are typically designed for 10 year loading duration, PLUS any of the given factors: Permanent Loading beyond 10 years = + 0.90; Snow Loading (2 month duration) = + 1.15; 7 day duration = + 1.25; Wind or earthquake = + 1.60; Impact loads = + 2.00; Partially seasoned or wet wood reduces the holding power of the connectors; The environment where the connection will be used (wet/dry/etc) will affect the connector; Any condition other than always dry or always wet will reduce the holding power; Treated wood doesn't hold connectors as well as untreated wood; If the load is other than parallel or perpendicular to the grain, the compressive stress at an angle must be calculated to determine the connection.
Nails	weakest connection, but also most common; Identified by **penny size (d),** the price for 100 nails in 15th century England...thelarger the nail, the higher cost per 100; 2d = 1", 6d = 2", 10d = 3", 20d = 4", 40d = 5", 60d = 6"; Box nails: 6d - 40d, smallest diameter; Wire nails: 6d to 60d, medium diameter; Wire spikes: 10d - 8.5" with 3/8" diameter, largest diameter;
Nail and Grains	Nails should be fastened lateral in side grain where the holding power is the greatest; The design values of shear are equal, regardless of the angle of load to grain
Screws	like nails, but best when used laterally in side grain, rather than in withdrawal from side grain; No withdrawal from end grain; Lead holes are drilled for insertion of wood screws; Size depends on species and if strew is in lateral resistance or withdrawal resistance
Lag Screws/Bolts	like screws threaded with pointed end but with head like a bolt; Lead holes and screwing fastener into wood with wrench; Diameters (measured at the non-threaded shank): 1/4" to 1 1/4"; Lengths: 1" – 12"; Design values for lateral loading and withdrawal resistance depends on species, angle of load, diameter of lag, thickness of side member, length of screw

Bolts	used for moderate to heavy loading; Design and spacing is based on thickness of main member and ratio of bolt length in main member to bold diameter number of members joined
Split Ring Connectors:	transmit loads between two pieces of wood by placement in precut grooves. Half of the ring is in each section and held together with a bolt
Shear plates	flat plates with a flange extending from the face of the plate with a hold in the middle where a bolt is placed to hold two members; Good for connections that must be disassembled; Used for two pieces of wood, or one piece of wood and a steal plate; Transfer larger loads than bolts/screws alone. Often used in trusses
Wood Material	Moisture content affects shrinkage, weight, strength and withdrawal resistance of nails; Ideally moisture content of wood should be equal to prevailing humidity to which it will be exposed when installed (though not often possible); Dry lumber max moisture content = 19%; Kiln dry lumber max moisture content = 15%; Wood shrinks perpendicular to the grain; Notched beams should be avoided. If they can't (e.g.: have to run pipes) then, Notches can't exceed 1/6" the depth and can't be located in the center third of beam; Notches at supports can't exceed 1/4" of the beam depth
Structural Lumber Grading:	Done under standards by the US Dept of Commerce, American Lumber Standards Committee and enforced by regional organizations (e.g.: Western Wood Products Association); Load carrying capacity influence by the size/number of knots/spits/defects, direction of grain, specific gravity of wood; Visually graded lumber is divided into categories based on nominal size; Same grade of lumber in a species can have different allowable stresses based on what category it's' in
Boards	1" - 1.5" thick and 2"+ wide
Dimensional Lumber	2" - 4" thick and 2"+ wide
Timbers	5" thick and 5"+ wide; Further subdivided into five categories based on size classifications
Structural light framing	nominal dimension of 2" - 4" thick and 2" - 4" wide, and divided into separate grades: Select Structural, No. 1, No. 2, and No. 3.; Select structural is the best in terms of strength (also, most expensive)
Light framing	nominal dimensions of 2" - 4" thick and 2" - 4" wide and is divided into separate grades: construction, standard, and utility
Stud	nominal dimensions of 2" - 4" thick and 2" - 6" wide.

	There's only one grade
Decking	divided into two grades, select decking and commercial decking
Structural Joists and Planks	nominal dimensions of 2" - 4" thick and 5" or greater width, typically divided into separate grades: select structural, No. 1,No. 2, and No. 3
Wood Construction Requirements	Bottom of wood joists must be at least 18" above exposed ground; Bottom of wood girders must be at least 12" above ground (unless treated or made of a species with a natural resistance to decay); End of wood girders entering masonry/concrete walls must be provided with a 1/2" air space on top/sides/end unless wood is of natural resistance to decay or treated; Foundation plates and sills must be treated or made of foundation redwood; Under floor areas (crawl spaces) must be ventilated with openings having a net area of not less than 1sf for each 150sf of under floor area and the must be place to provide cross ventilation; Wood used for construction of permanent structures located nearer than 6" to earth must be treated or wood of natural resistance to decay; All wood used as structural members must be protected from exposure to theweather and water with approved protection
Trusses	longer than 80'-0" can be cambered for the dead load deflection
National Design Specification for Wood Construction	Allowable stresses for units in structural lumber and gluelam timber; Allowable stresses for extreme fiber in bending; Tension is parallel to the grain; Horizontal shear; Compression is perpendicular and parallel to the grain
Light Wood Frame Construction:	Nail roof sheathing along ends of the sheathing of intermediate roof framing; Tie gable end walls back to the structure (one of the weakest connection points) Sheath gable end walls with wood structural panels (plywood or OSB); Use seismic/hurricane framing anchor to attach roof framing to the exterior side of the wall to prevent uplift and shear stress failure; Nail upper and lower story sheathing to common wood structural panel to provide lateral and uplift load continuity; Continuously sheath all walls with wood structural panels including around openings for windows/doors; Extend structural panel sheathing to lap the sill plate; The connection of the wall sheathing to sill plate is where uplift forces are; transferred into the plate and into the foundation through anchor bolts; Space anchor bolts about 32" – 48" o.c.

Shear Wall	2 x 4 or 2 x 6 wood cross bracing and horizontal bracing is not strong enough to resist lateral forces applied on a building's foundation; Composed of wood structural sheathing fastened to wood framing and properly connected to the foundation below and the roof above
Wood diaphragm:	Installation of wood structural panels over a roof or floor supports; Anchor bolts are one of the most cost effective ways to protect a residential building from severe structural damage by securing the mud sill to the concrete foundation; Bolts are typically placed 4'-0" to 6'-0" on center, 4" deep minimum, with an extra bolt within 9" - 12" of any joint, end plate, or step in the wall, with a minimum of two bolts per step
Seismic Absorption	Wood's flexibility allows the building better absorb and resist the forces found in both earthquakes and high winds; Wood panels are a cost effective means for providing design requirements for shear walls and diaphragms.
Box Type Structure	Light framed wood structures; Corrugation in the box sides are oriented vertically and have thus have a high vertical load carrying capacity. This is similar to orientation of studs in a light framed wood wall; Each of the wall elements in the box is rigid...it's hard to force a rectangular side of the cardboard box "out of square"; Corrugation in the top and bottom of the box run from edge to edge, and vertical loads applied to the op or bottom of the box are distributed to the sides; Only when all the edges of the box are taped together does it gain its true potential strength and ability to withstand lateral and vertical loads; force transfer from roof to wall to
Wood to foundation Joint:	Structures that are bolted to foundation are still susceptible to lateral force of an earthquake; In wood frame construction, plywood sheets should be nailed to cripple walls which create shear panels that resist forces

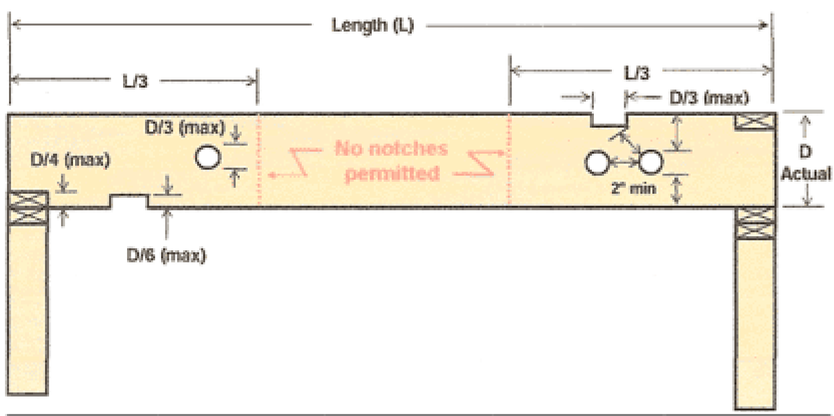
Temperature	modulus of elasticity reduces and the strength is reduced
Heat and Melting	Heat used to melt and shape a member, but once it is shaped, stiffness will still be altered
Charpy V-Notch Test:	A ductility test with a V notch cut on top of the piece. The specimen will be under the stree, the material is brittle if the time to go through the notch is fast and ductile if the notch is slow progression.
St. Venant's Principle for Direct Stress:	The stresses and strains in a body at points that are sufficiently remote from points of application of load depends only on the static resultant of the loads and not on the distribution of loads.
Direct Stress assumptions for this principle to be satisfied:	(1) The thing being loaded must be perfectly straight (2) Load must be applied axially (ie: the center of gravity at the cross section) (3) Cross section of the thing being loaded must be constant (4) Cross section under investigation has to be some distance away from the support/loaded ends (5) Loaded member must be made of a single material (6) Material must be homogenous (and strong, no soft spots!) (7) Load must be statically loaded (8) Elastic range stresses (don't go past yield stress!) (9)Loading must be pure tension, compression, or shear (no secondary effects)
Structural design Analysis Steps:	(1) Determine the loads (compute) (2) calculate the stresses (analyze) (3) Dimension and proportion the members and detail the connections such that the stresses are within the limits for the structural materials (design)
Finding Equilibrium	Objects that are at rest are at static equilibrium and use Three equations of static equilibrium (Horizontal Translational Equilibrium Equation: Sum of all forces parallel to the x axis and y axis = $\Sigma Fx = \Sigma Fy = 0$, Moment/Rotational Equilibrium Equation $\Sigma Mz = 0$

Solving A Direct Stress Problem:	Determine which equation to use f Allowable= P/A, then the cross section of the area of the form, then Figure out the stress, f = P/A. Ask question: Is it safe? What's the allowable stress we can use? Check the following:Structural Steel Allowable Tension 22,000 psi, Concrete usable, compression in bearing 900 psi, Structural Lumber (doug fir) compression parallel to grain 1,150 psi
Solving a Direct Shear Problem:	Determine which equation to use f Allowable = P/A: Determine the area of the bolts A = (# of bots) x (πr^2) then Find allowable stress Pallowable = A x F allowable

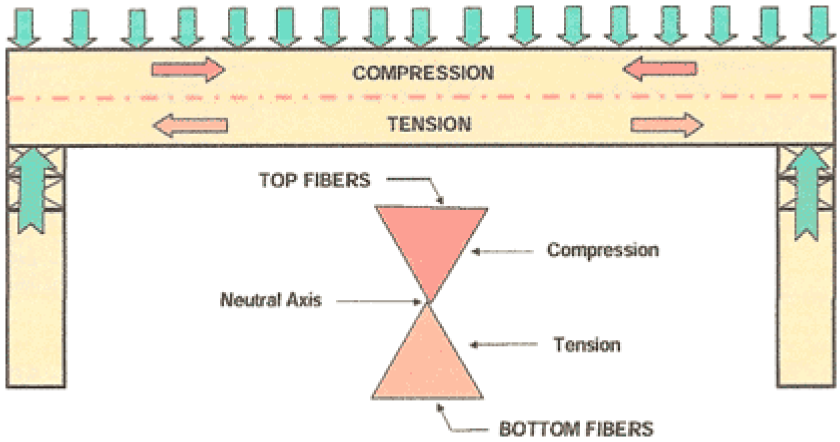
Wood:

In a renovation of an existing residential building, in which piping of conduit needs to be run through a 2 x 12 [50 x 300 mm] (actual) wood floor joist, 2.0 in [50 mm] is the minimum dimension required by the IBC [NBC] from the top or bottom of the joist to the bored hole.
Not: 1.0 in [25 mm]; 1.5 in [38 mm]; 2.5 in [63 mm]

- Notches in floor joists may occur in the top or bottom of the member but may not be located in the middle third of the span.
- A notch may not exceed one-sixth of the depth of the joist except at the very end where it may be one-fourth of the joist depth.
- The length of joist notches cannot exceed one-third of the depth of the member.
- Holes bored in joists must not be larger than one-third the depth of the joists.
- Holes cannot be located within two inches of the top or bottom edge of the member, or to any other hole located in the member.
- Holes cannot be located within 2" of any notch.



Joist Size	Max Hole	Max Notch Depth	Max End Notch	Max Notch Length
2x4	NONE	NONE	NONE	NONE
2x6	1 1/2	7/8	1 3/8	1 1/2
2x8	2 3/8	1 1/4	1 7/8	2 3/8
2x10	3	1 1/2	2 3/8	3
2x12	3 3/4	1 7/8	2 7/8	3 3/4



Gypsum shaft wall is generally the most economical material for the hoist-way wall of an elevator in a wood frame, two-story apartment building.
Not: Reinforced concrete; Pre-fabricated concrete; Concrete blocks

Timber

An 18th century farmhouse on the National Historic Register with exposed timber framing is to be restored and opened for tours. Limit the number of visitors in spaces to the available live load is the most historically correct method of addressing the lack of live load capacity of the floor framing.

Not: Replace the undersized framing with new adequately sized members; Sister the existing joists and beams; Reduce the span of the floor framing.

Concrete

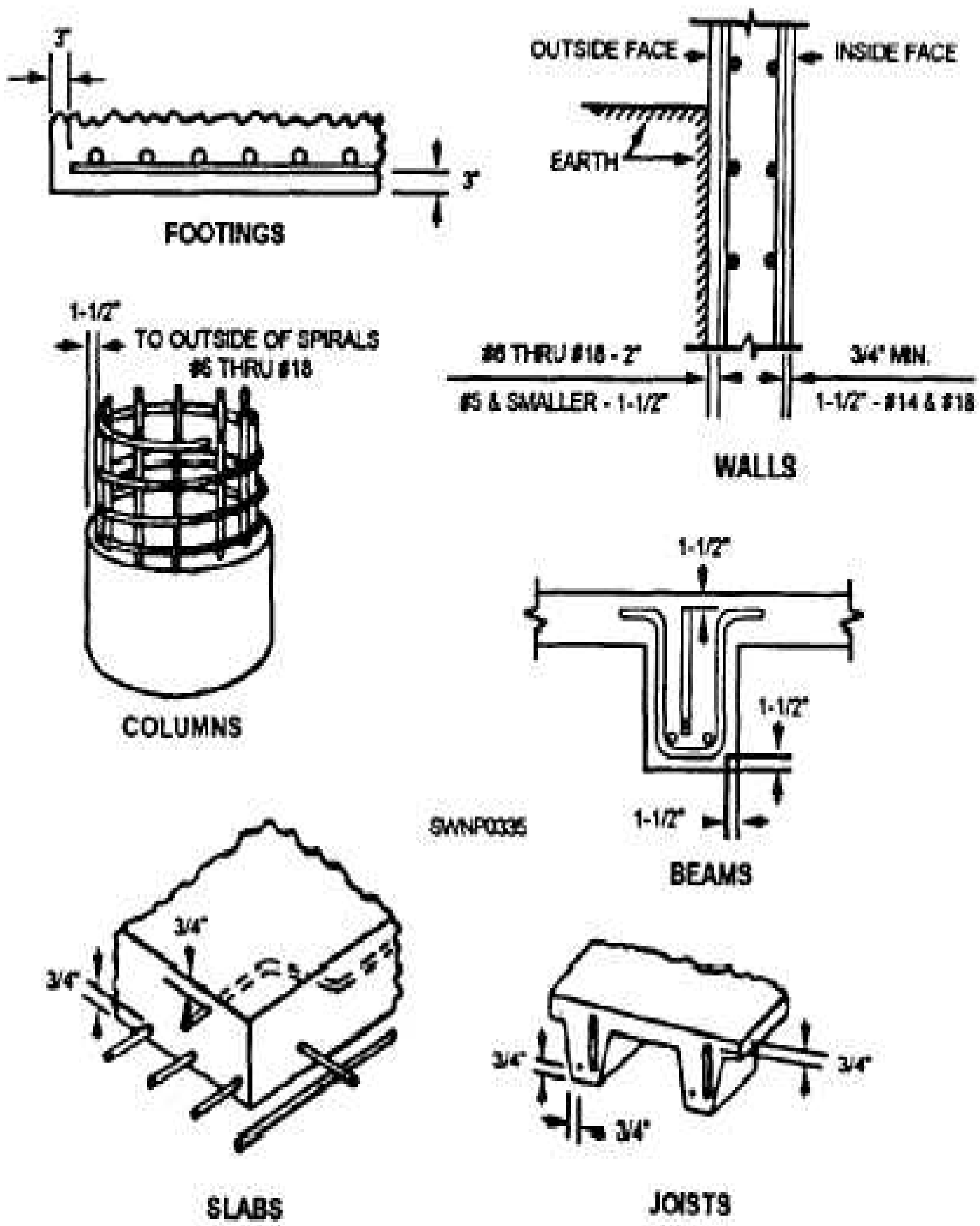
Concrete	
Concrete Construction Requirements	Construction loads cannot be supported or any shoring removed until concrete has sufficient strength to safely support its weight and loads placed on it; There are limitations on amount and placement of conduits and other pipes embedded in concrete so as to not decrease the load resisting area; Aluminum conduits cannot be embedded unless effectively coated to cover to prevent aluminum-concrete reaction or electrolytic action between steel and aluminum Pipes carrying fluids or gasses must be pressure tested prior to placement of concrete; The size and bending of reinforcement are clear to ensure that a sufficient bond is developed between the concrete and steel and that all reinforcement acts together
Water	Load developed from water is equal to the unit weight of the fluid in pounds per cubic foot multiplied by its depth; Water weighs approx 62lbf/ft3
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 a slab 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

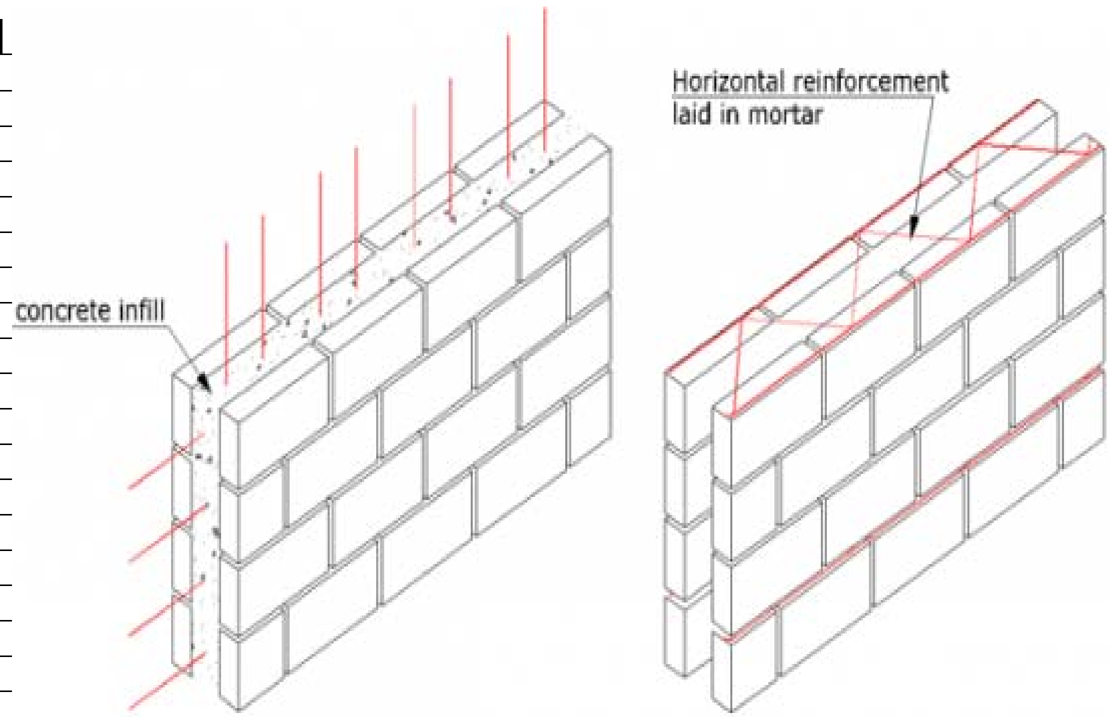
Flat plate system	Basically a Two-Way slab with no supporting beams, only columns.; Reinforced slab spans in both directions directly into columns at 25' with 6" - 12"; thickness; Typically used for light loads, short spans, when floor-floor height must be; minimized, and/or when simple under-side of 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	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 a 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
Composite Construction	Two or more materials designed to act together to resist loads (reinforced concrete construction is the most typical example)

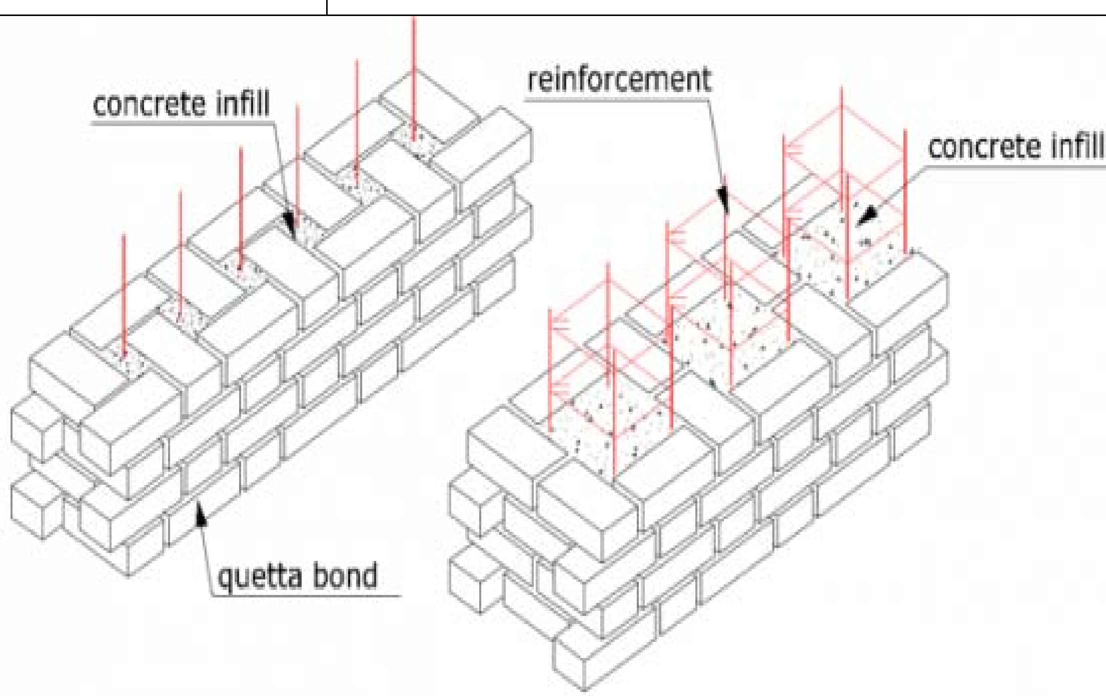
Reinforcing Steel (Rebar) Material	Used as a tensioning device in reinforced concrete/masonry structures; goal: to hold concrete in compression • Formed from carbon steel and given ridges for better anchoring into the concrete; Deformed to provide a mechanical interlocking of rebar and concrete
Types of reinforcing steel (3)	(1) **Bars:** used for standard cast in place concrete; (2) **Wire or strands:** used for pre-stressing and post tensioning, (3) **Welded wire fabric:** used for slab reinforcement
Rebar Sizes	Rebar diameter size ranges from 3/8” - 2 1/4” at 1/8” increments; rebar ID number is based on the diameter. #3 = 3/8”, #4 = 4/8”, #8 = 8/8 (or 1”), and …
Rebar grade	equal to the minimum yield strength; 60 rebar (most common) = minimum yield strength of 60 ksi; 40, 60, and 75 are typically manufactured
Spacing	Rebar should be located at a minimum distance from the exposed face of the concrete. It needs to be as close to the edge as possible to work as a tensioning device, but it still has to be protected from the site/elements
Rebar distance from face of concrete	Slabs and walls, 3/4"; Beams and Columns 1 1/2"; Exposed to weather or in contact with soil 1 1/2"; Exposed to weather or in contact w/soil (larger than No. 5 rebar) 2"; Concrete poured direction on soil 3"
Pre-tensioning Steel	stranded cables draped in forms and jacked by tension forces; Concrete is poured and allowed to cure, then cables are cut and compressive force is transferred to the concrete
Pos-tensioning Steel	hollow sleeves/conduits are placed in forms on site and steel tendons are run through it; Concrete is poured around it, and tendons are stressed with on-site hydraulic jacks after the concrete has cured
Welded Wire Fabric	pieces of w or rebar welded together to form a grid pattern and used to minimize shrinkage cracking in the surface of the concrete; Typically a square 4” x 4” up to 8” x 8”
Rebar Chairs	metal wire devices placed on a form to hold the rebar above the bottom at the required distance

Curing	Concrete hardens and gets its strength by curing though the chemical reaction between water and cement NOT THROUGH DRYING!!; Must have proper moisture/temperature condition for 7 days minimum for proper curing; Can be up to 2 weeks for critical work; If concrete cures too fast, it can loose around 30% of its strength; If concrete is too cold/freezes it can loose around 50% of its strength; Final 28 day design strength depends on the initial curing conditions; Concrete must beg placed to avoid segregation (separation of aggregates /water /sand from each other)
Concrete "dropped"	from high distances (eg: concrete pumper hose too high) or if there's excessive lateral movement; maximum drop is 5'-0"; After placement, compact concrete so that it gets into all the nooks and corners, as well as totally in contact with the rebar.
Allowable Concrete Construction	International Building Code Chapter 19 references the code requirements for reinforced concret; Concrete construction is based on the specified compressive strength f'c (psi)
Concrete Testing	Samples for strength tests must be taken for each class of concrete used; Taken once per day; Taken for each 150yd3; Taken for each 5,000 sf of surface area of slab/wall; The average of all sets of three 3 consecutive strength tests be ≥ f'c; No individual test can be 500 psi below f'c
Processes Per Fire Code:	Fire stops are required in walls at the ceiling and floor levels and at 10'-0" intervals both vertical and horizontal; Fire stops are required at interconnections between concealed vertical and horizontal spaces such as soffits and dropped ceilings; Fire stops are required in concealed spaces in stairway construction and in vertical openings between floors and the roof that could afford a passage for fire
Proportioning	to achieving a strong, durable concrete rests in the careful proportioning and mixing of the ingredients. A concrete mixture that does not have enough paste to fill all the voids between the aggregates will be difficult to place and will produce rough, honeycombed surfaces and porous concrete. A mixture with an excess of cement paste will be easy to place and will produce a smooth surface; however, the resulting concrete is likely to shrink more and be uneconomical. A properly designed concrete mixture will possess the desired workability for the fresh concrete and the

	required durability and strength for the hardened concrete.




Horizontal reinforcement
laid in mortar
concrete infill


concrete infill
reinforcement
concrete infill
quetta bond

Concrete

Portland Cement

Raw ingredients of Portland cement: iron ore, lime, alumina and silica, which are used in various proportions depending upon the type of cement being made. These are ground up and fired in a kiln to produce a clinker. After cooling, the clinker is very finery ground (to about the texture of talcum powder) and a small amount of gypsum is added to retard the initial setting time.

- **Type I** - General purpose (least expensive, the majority of concrete)
- **Type II** - Sulfate resisting, concrete in contact with high sulfate soils (gains strength faster than Type I)
- **Type III** - High early strength, which gains strength faster than Type I, enabling forms to be removed sooner
- **Type IV** - Low heat of hydration, for use in massive construction
- **Type V** - Severe sulfate resisting

Aggregates

- Fine aggregate (sand) particles which can pass through a 3/8 in sieve;
- Coarse aggregates are larger than 3/8 inch in size.
- Clean, hard, and well-graded, without natural cleavage planes(i.e. slate or shale)
- Quality of aggregates: important since 6 to 75% of the volume
- Impossible to make good concrete with poor aggregates.
- Grading of both fine and coarse aggregate is very significant because having a full range of sizes reduces the amount of cement paste needed.
- Well-graded aggregates tend to make the mix more workable as well.
- Normal concrete is made using sand and stones (~150 pcf)
- Lightweight concrete: industrial by-products: expanded slag or clay (90 to 125 pcf)
- High strengths are more difficult to achieve with weaker aggregates.
- Light Weight Concrete: savings of building self-weight, may be important when building on certain types of soil.
- Insulating concrete is made using perlite and vermiculite, it weighs only about 15 to 40 pcf and has no structural value.

3.1 Properties of Concrete

Concrete is an artificial conglomerate stone made essentially of Portland cement, water, and aggregates. When first mixed the water and cement constitute a paste which surrounds all the individual pieces of aggregate to make a plastic mixture. A chemical reaction called hydration takes place between the water and cement, and concrete normally changes from a plastic to a solid state in about 2 hours. Thereafter the concrete continues to gain strength as it cures. A typical strength-gain curve is shown in Figure 1. The industry has adopted the 28-day strength as a reference point, and specifications often refer to compression tests of cylinders of concrete which are crushed 28 days after they are made. The resulting strength is given the designation f'c

Concrete should reach its design compressive strength in 28 days
Not: 3, 7, 32

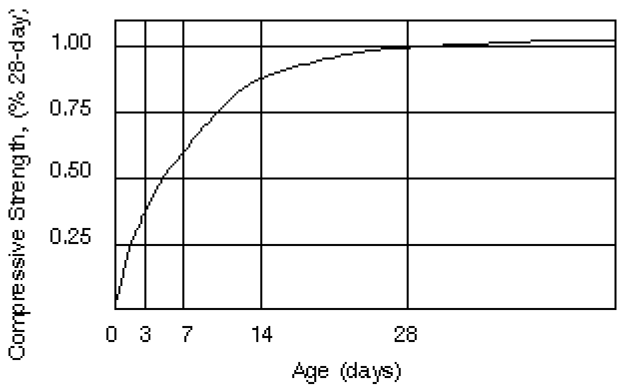


Figure 1. Typical strength-gain curve.

During the first week to 10 days of curing it is important that the concrete not be permitted to freeze or dry out because either of these, occurrences would be very detrimental to the strength development of the concrete. Theoretically, if kept in a moist environment, concrete will gain strength forever, however, in practical terms, about 90% of its strength is gained in the first 28 days.

Concrete has almost no tensile strength (usually measured to be about 10 to 15% of its compressive strength), and for this reason it is almost never used without some form of reinforcing. Its compressive strength depends upon many factors, including the quality and proportions of the ingredients and the curing environment. The single most important indicator of strength is the ratio of the water used compared to the amount of cement. Basically, the lower this ratio is, the higher the final concrete strength will be.

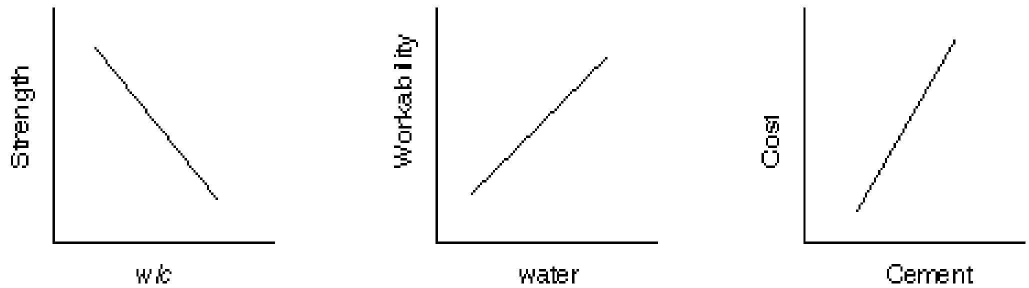


Figure 3. Mix Proportion relationships.

Since larger aggregate sizes have relatively smaller surface areas (for the cement paste to coat) and since less water means less cement, it is often said that one should use the largest practical aggregate size and the stiffest practical mix. (Most building elements are constructed with a maximum aggregate size of 3/4 to 1 in, larger sizes being prohibited by the closeness of the reinforcing bars.)

A good indication of the water content of a mix land thus the workability) can be had from a standard slump test. In this test a metal cone 12 in tall is filled with fresh concrete in a specified manner. When the cone is lifted, the mass of concrete "slumps" downward (Figure 4) and the vertical drop is referred to as the slump. Most concrete mixes have slumps in the 2- to 5-in range.

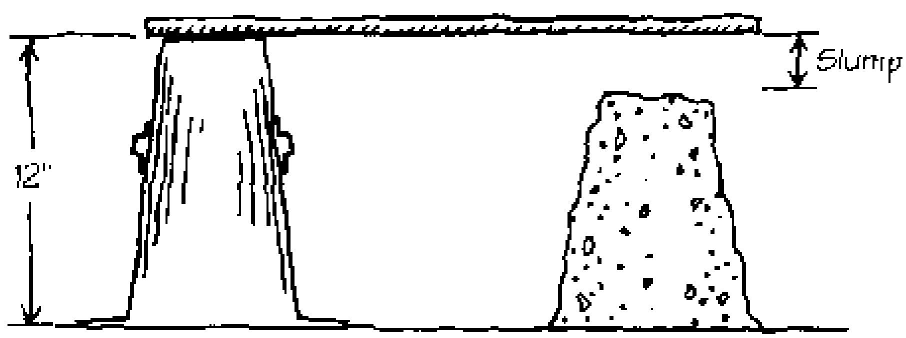


Figure 4. Slump Test..

The Basic Mix:

The physical properties of density and strength of concrete are volume proportional mixture of water, cement, and aggregate. Mix the dry ingredients and slowly add water until the concrete is workable. This mixture may need to be modified depending on the aggregate used to provide a concrete of the right workability. The mix should not be too stiff or too sloppy. It is difficult to form good test specimens if it is too stiff. If it is too sloppy, water may separate (bleed) from the mixture.

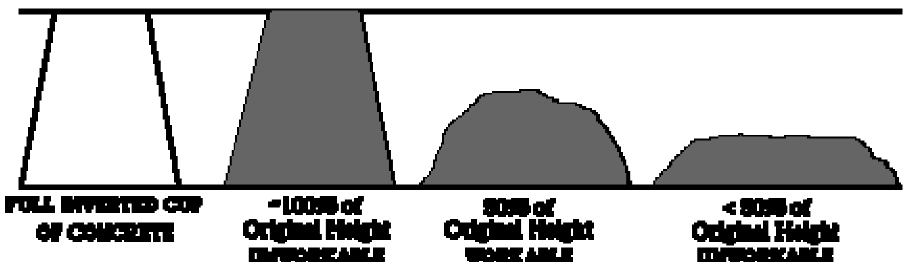
Remember that water is the key ingredient. Too much water results in weak concrete. Too little water results in a concrete that is unworkable.

Suggestions:

1. If predetermined quantities are used, the method used to make concrete is to dry blend solids and then slowly add water (with admixtures, if used).
2. It is usual to dissolve admixtures in the mix water before adding it to the concrete. Super plasticizer is an exception.
3. Forms can be made from many materials. Cylindrical forms can be plastic or paper tubes, pipe insulation, cups, etc. The concrete needs to be easily removed from the forms. Pipe insulation from a hardware store was used for lab trials. This foam-like material was easy to work with and is reusable with the addition of tape. The bottom of the forms can be taped, corked, set on glass plates, etc. Small plastic weighing trays or Dairy Queen banana split dishes can be used as forms for boats or canoes.
4. If compression tests are done, it may be of interest to spread universal indicator over the broken face and note any color changes from inside to outside. You may see a yellowish surface due to carbonation from CO_2 in the atmosphere. The inside may be blue due to calcium hydroxide.
5. To answer the proverbial question, "Is this right?" a slump test may be performed. A slump test involves filling an inverted, bottomless cone with the concrete mixture. A Styrofoam or paper cup with the bottom removed makes a good bottomless cone. Make sure to pack the concrete several times while filling the cone. Carefully remove the cone by lifting it straight upward. Place the cone beside the pile of concrete. The pile should be about 1/2 to 3/4 the height of the cone for a concrete mixture with good workability.

A slump cone is used primarily to provide an Strength and workability characteristics of concrete.

Not: Durability and finish; Air entrainment and chemical resistance; Appearance and color



6. To strengthen samples and to promote hydration, soak concrete in water (after it is set).
7. Wet sand may carry considerable water, so the amount of mix water should be reduced to compensate.
8. Air bubbles in the molds will become weak points during strength tests. They can be eliminated by:
   - i. packing the concrete.
   - ii. Tapping the sides of the mold while filling the mold.
   - iii. "rodding" the concrete inside the mold with a thin spatula.
9. Special chemicals called "water reducing agents" are used to improve workability at low water to cement ratios and thus produce higher strengths. Most ready-mix companies use these chemicals, which are known commercially as super plasticizers. They will probably be willing to give you some at no charge.

A bag contains 94 lb. (40kg) of cement.

The ingredients of concrete can be proportioned by weight or volume. The goal is to provide the desired strength and workability at minimum expense. Sometimes there are special requirements such as abrasion resistance, durability in harsh climates, or water impermeability, but these properties are usually related to strength. Sometimes concretes of higher strength are specified even though a lower f'c value would have met all structural requirements.

A low water-to-cement ratio is needed to achieve strong concrete. It would seem therefore that by merely keeping the cement content high one could use enough water for good workability and still have a low w/c ratio.

The most important factor affecting the strength of concrete is the water-to-cement ratio

Not: weather conditions during curing; volume of the mixture;

$$E = 57{,}000\sqrt{f'_c}$$

E values thus computed have proven to be acceptable amount of vibration of the mix

CONCRETE:

TYPICAL CONCRETE COMPRESSIVE STRENGTHS		
CONCRETE	MINIMUM 28 DAY COMPRESSIVE STRENGTH	SLUMP AT PLACEMENT
UNLESS NOTED OTHERWISE, ALL CONCRETE SHALL BE	3,000 PSI	4 1/2" MAXIMUM
CONCRETE OVER STEEL DECK	3,000 PSI	4" MAXIMUM
SLABS ON GRADE	3,500 PSI	4" MAXIMUM
FOOTINGS AND STEM WALLS	3,000 PSI	4" MAXIMUM

All footings are 3000 PSI. Now refer back to the Typical Reinforcing Bar Splice Detail. Now the grade of rebar needs to be found. Referring back to S-01 the following is found.

Creep In Concrete

When concrete is held under sustained stress, the strain will continue to increase with time. Creep defines this time-dependent phenomenon.
Not: Shrinkage; Temperature expansion; Contraction

Concrete creep is defined as: deformation of structure under sustained load. Basically, long term pressure or stress on concrete can make it change shape. This deformation usually occurs in the direction the force is being applied. Like a concrete column getting more compressed, or a beam bending.

Creep does not necessarily cause concrete to fail or break apart. Creep is factored in when concrete structures are designed.

Factors Affecting Creep

1. Aggregate
2. Mix Proportions
3. Age of concrete

1. Influence of Aggregate

Aggregate undergoes very little creep. It is really the paste which is responsible for the creep. However, the aggregate influences the creep of concrete through a restraining effect on the magnitude of creep. The paste which is creeping under load is restrained by aggregate which do not creep. The stronger the aggregate the more is the restraining effect and hence the less is the magnitude of creep. The modulus of elasticity of aggregate is one of the important factors influencing creep.

It can be easily imagined that the higher the modulus of elasticity the less is the creep. Light weight aggregate shows substantially higher creep than normal weight aggregate.

2. Influence of Mix Proportions:

The amount of paste content and its quality is one of the most important factors influencing creep. A poorer paste structure undergoes higher creep. Therefore, it can be said that creep increases with increase in water/cement ratio. In other words, it can also be said that creep is inversely proportional to the strength of concrete. Broadly speaking, all other factors which are affecting the water/cement ratio are also affecting the creep.

3. Influence of Age:

Age at which a concrete member is loaded will have a predominant effect on the magnitude of creep. This can be easily understood from the fact that the quality of gel improves with time. Such gel creeps less, whereas a young gel under load being not so stronger creeps more. What is said above is not a very accurate statement because of the fact that the moisture content of the concrete being different at different age also influences the magnitude of creep.

Effects of Creep on Concrete and Reinforced Concrete

- In reinforced concrete beams, creep increases the deflection with time and may be a critical consideration in design.
- In eccentrically loaded columns, creep increases the deflection and can load to buckling.
- In case of statically indeterminate structures and column and beam junctions creep may relieve the stress concentration induced by shrinkage, temperatures changes or movement of support. Creep property of concrete will be useful in all concrete structures to reduce the internal stresses due to non-uniform load or restrained shrinkage.
- In mass concrete structures such as dams, on account of differential temperature conditions at the interior and surface, creep is harmful and by itself may be a cause of cracking in the interior of dams. Therefore, all precautions and steps must be taken to see that increase in temperature does not take place in the interior of mass concrete structure.
- Loss of prestress due to creep of concrete in prestressed concrete structure.

Design thin shell

Since the 1960's, thin-shell concrete roof structures have seldom been utilized in the United States and Canada primarily because formwork is prohibitively expensive.
Not: Building codes often make it difficult to obtain approval for their use; design fees are substantially greater than for more conventional structures; materials (concrete and steel) are too costly

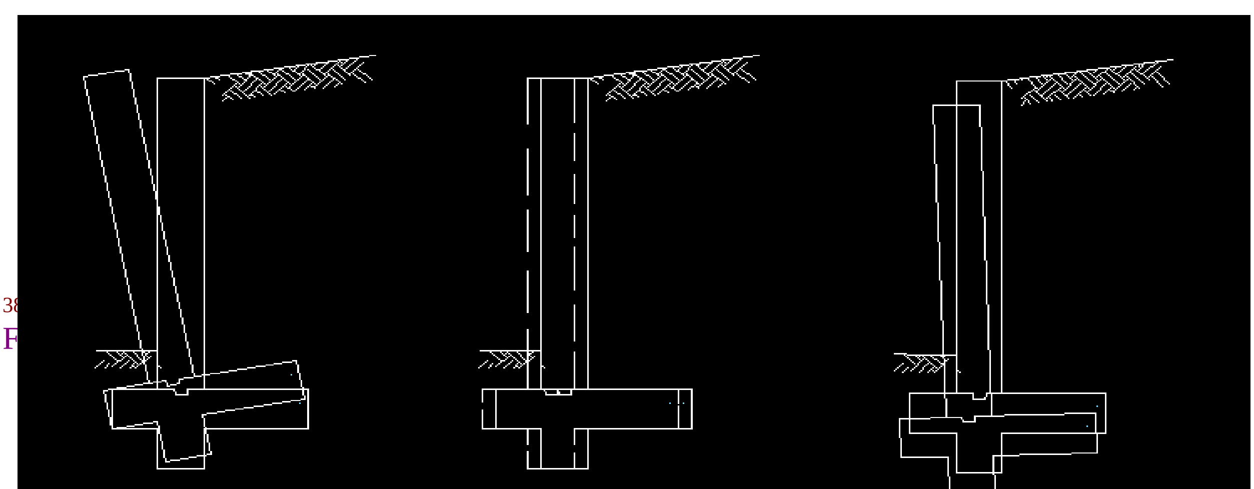
Foundation Types

Area of Footing =	total wall or column load + weight of footing + any soil on top of footing / allowable soil bearing pressure
Earth Pressure on a wall (P) =	30 lb/ft3 x height of wall
Shallow Footing	Foundation transfers building loads to the earth very near the surface, within 1′-10′. Shallow foundations includes: spread footing foundations, slab-on-grade foundations, and rubble trench foundations.
Spread Footing:	Most economical…$ method. Delivers load directly to soil over a large area,. Strips or pads of concrete which transfer the loads from walls and columns to the soil. Common in residential construction. Relatively simple system considered a shallow foundation system,
Continous Footings	**The most frequently used footing type at the exterior wall for load-bearing wall support systems is continuous wall footings.** Not: mat footings; pile footings; isolated pad footings
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.

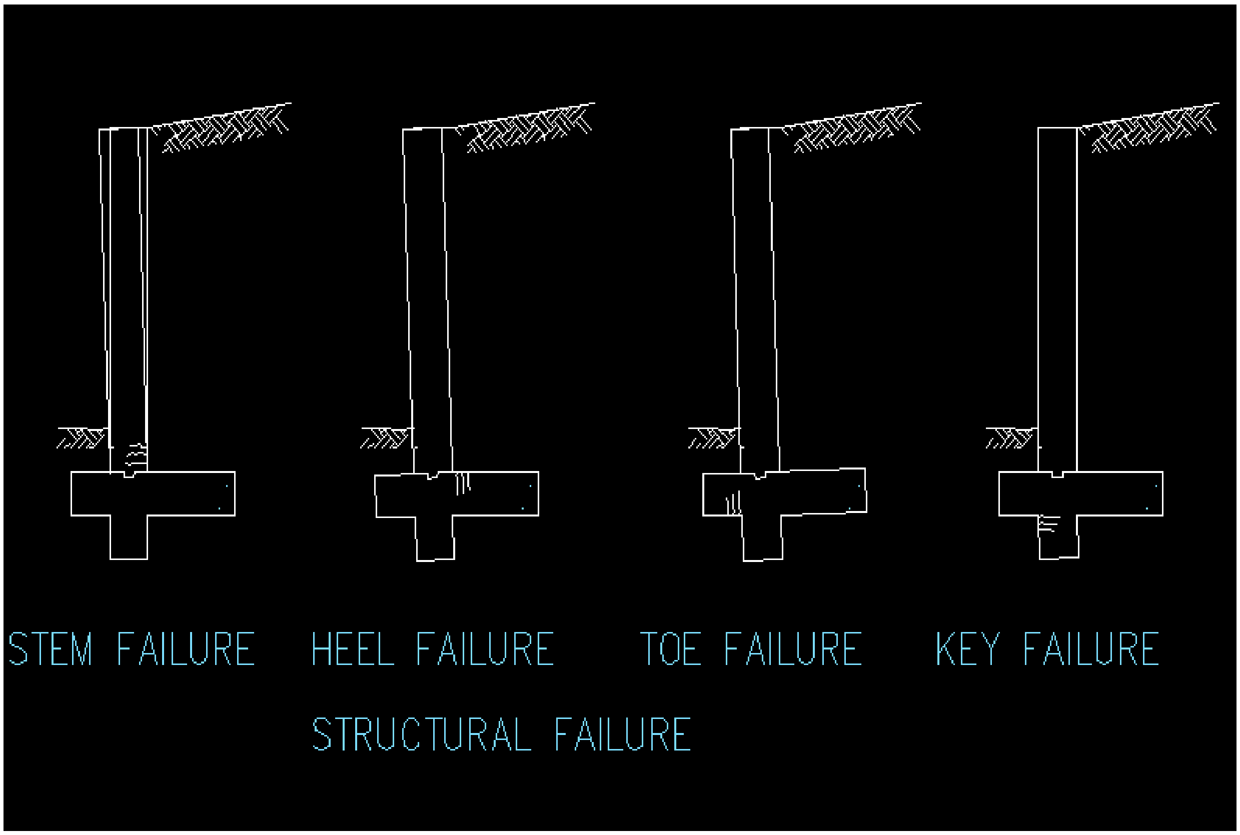
	• They're basically really, really deep spread footings
Friction Pile:	Driven into softer soil. Friction transmits the load between pile and soil Bearing capacity is limited by whichever is weaker: strength of the pile or soil_
Driven Piles	Prefabricated piles that are driven into the ground by a pile driver. The act of driving the pile causes increased friction, caused by the compression of soil around the pile
Pile Cap	Concrete block into which the heads of the piles are embedded
Drilled Piles	Also known as caissons and CIDH piles. A cavity is bored to the designed depth then a reinforcing cage is introduced, concrete is poured in the bore.
Drilled pier	The drilled pier (caisson) shown above is belled in order **to increase the bearing area**;Not: prevent water infiltration; prevent caving; increase frictional resistance
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
Liquifaction	A loss of soil shear strength resulting in the movement of the surficial soil layers of a building site in a direction parallel to the ground surface under earthquake conditions is most likely caused by liquefiable soils. Not: a low bearing capacity; a gently sloping site;Not: a low bearing capacity; a gently sloping site;
Area of Footing	Area of the footing = load/safe bearing capacity. If the soil bearing capacity is 3000 psf [143 500 N/m2] and the applied load is 48,000 lbs [212 kN], 16 sf [1.5 m2] is the area for the footing.
Slab on Grade –	Concrete slab is poured into a mold (consisting of trenches and wood forms) that is created on site. There is no cavity between the existing earth and concrete. This type of construction is more typically found in warmer climate with out the issues of frost heave

Rubble Trench	Type of foundation that uses loose stone or rubble to minimize the use of concrete and improve drainage. Consisting of a rubble trench and layer which the concrete slab is then poured over.
Deep	Driven, Drilled Foundations
Base Isolation Systems	Designed to deal with seismic forces. It is a collection of structural elements which decouples a superstructure from its substructure in an event of an earthquake. Its goal is to dampen the extreme forces with decoupling isolation units. Some examples are spring-damper systems (similar to an automotive suspension) and sliding units.

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 conterforts 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



Stability failure	(1) Overturning.; (2) Sliding; (3) Bearing capacity.
Structural failure	Bending or shear failure of: stem; heel; toe; key.
retaining wall in slope	rotational stability failure
Stability analysis cantilever retaining wall:	(1) Check factor of safety against overturning; (2) Check soil bearing pressure (3) Check factor of safety against sliding.



Design of concrete cantilever retaining wall

Common failure of retaining wall:

Stability failure
1. Overturning.
2. Sliding.
3. Bearing capacity.

Structural failure

4. Bending or shear failure of stem.
5. Bending or shear failure of heel.
6. Bending or shear failure of toe.
7. Bending or shear failure of key.

All items above should be considered in designing a retaining wall.
There is also a rotational stability failure that is not normally checked except when a retaining wall is located on a slope.

Design procedure for cantilever retaining wall:

Stability analysis
1. Check factor of safety against overturning.
2. Check soil bearing pressure.
3. Check factor of safety against sliding.

Factor of Safety

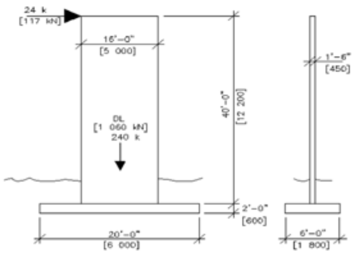
Foundatation Analysis by Bowels uncertainties and assigns a factor of safety

1. Magnitude of damages (loss of life and property damage) 2. Relative cost of increasing or decreasing the factor of safety 3. Relative change in probability of failure by changing the factor of safety 4. Reliability of soil data 5. Construction tolerances 6. Changes in soil properties due to construction operations 7. Accuracy (or approximations used) in developing design/ analysis methods

Failure Mode	Foundation Type	F.S.
Shear	Earthwork for Dams, Fills, etc.	1.2 - 1.6
Shear	Retaining Walls	1.5 - 2.0
Shear	Sheetpiling, Cofferdams	1.2 - 1.6
Shear	Braced Excavations (Temporary)	1.2 - 1.5
Shear	Spread Footings	2.0 - 3.0
Shear	Mat Footings	1.7 - 2.5
Shear	Uplift for Footings	1.7 - 2.5
Seepage	Uplift, heaving	1.5 - 2.5
Seepage	Piping	3.- 5.
Overturning	retaining walls with granular backfill	1.5
Overturning	retaining walls with cohesive backfill	2
sliding	retaining walls sliding with active earth pressures	1.5
sliding	retaining walls sliding with passive earth pressures	2

4.2 is the factor of safety against overturning for the concrete shear wall shown if resisted only by gravity forces. Assume the weight of concrete equals 150 lb/ft 3 [23.5 kN/m3], and the dead load equals 240 kips [1060 kN]. Ignore the weight of the soil over the footing.

Not: 1.5; 2.0; 3.7



Rebar Earth cover

TYPICAL CLEAR CONCRETE COVERAGES		
CONCRETE CAST AGAINST AND PERMANENTLY EXPOSED TO EARTH		3"
FORMED CONCRETE EXPOSED TO EARTH OR WEATHER	#6 AND LARGER	2"
	#5 AND SMALLER	1 1/2"
FORMED CONCRETE NOT EXPOSED TO WEATHER OR IN CONTACT WITH GROUND :		
SLABS, WALLS, OR JOISTS	#14 AND LARGER	1 1/2"
	#11 AND SMALLER	3/4"
BEAMS, COLUMNS (TO PRIMARY REINFORCEMENT, TIES, OR STIRRUPS)		1 1/2"
ALL OTHERS PER LATEST EDITION OF ACI 318.		

OR

MAINTAIN THE FOLLOWING CONCRETE COVERAGE'S FOR CONCRETE REINFORCING:

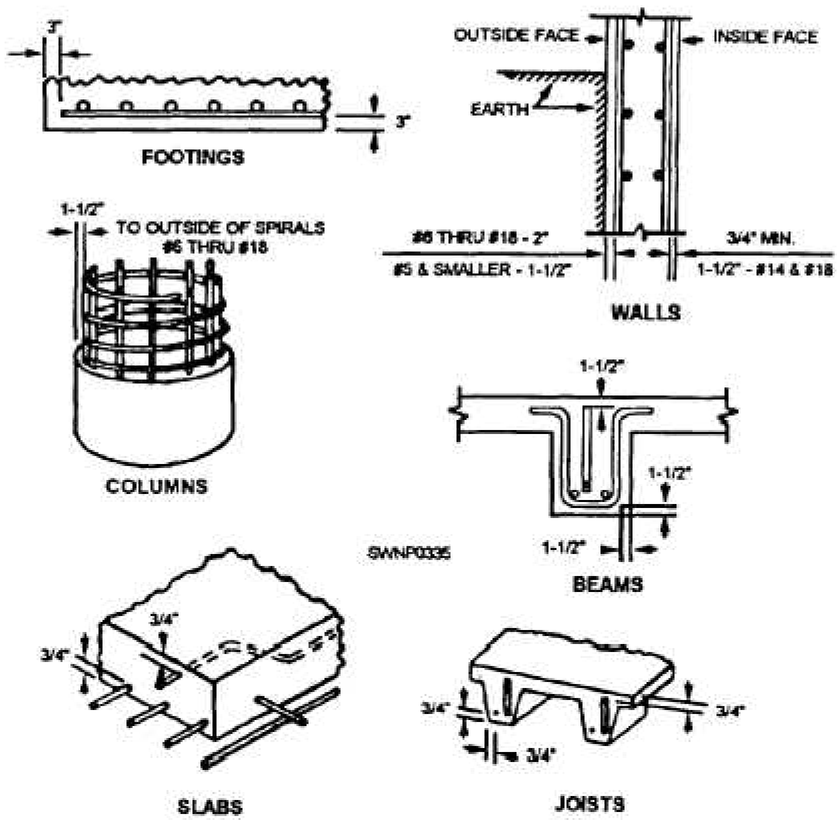
UNFORMED SURFACES IN CONTACT WITH EARTH.	3"
FORMED SURFACES IN CONTACT WITH EARTH.	2"
FORMED SURFACES EXPOSED TO OUTSIDE WEATHER.	1 1/2"
SLABS AND WALLS NOT EXPOSED TO WEATHER.	0 3/4"
CLEAR DISTANCE BETWEEN BARS.	2"

Condition 1: The top condition vertical component of the dowel is essentially a formed surface Exposed to outside weather requiring 1 1/2" of concrete coverage.
Condition 2: The bottom condition of the vertical component of the dowel is an unformed surface in contact with the earth so it requiring 3" of concrete coverage.
Condition 3: The horizontal end component of the dowel is a formed surface in contact with the earth requiring 2" of concrete coverage.

Cast in Place

Cast-in-place concrete beams and columns with No. 11 [35M] rebar or smaller reinforcing bars that are not exposed to weather or in contact with the ground should have a minimum coverage of concrete over the bars of 1 1/2 in [37 mm].

Not: 3/4 in [19 mm]; 1 in [25 mm]; 1/2 in [12 mm]



Slabs

Slab Types

Slab on Grade (SOG)
Slab on Metal Deck (SOMD)
Suspended Slabs (SS)

Reinforcing
Rebar [All]
Mesh [All]
Fiber Mesh [more typical SOG]
PT Cable [SS]
Forming

One Way Slab
A one-way slab is used typically in Parking types of buildings.

Not: Museum; Library; Warehouse

Masonry	ystem 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 a 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
Composite Construction	Two or more materials designed to act together to resist loads (reinforced concrete construction is the most typical example)
Reinforcing Steel (Rebar) Material	Used as a tensioning device in reinforced concrete/masonry structures; goal: to hold concrete in compression • Formed from carbon steel and given ridges for better anchoring into the concrete; Deformed to provide a mechanical interlocking of rebar and concrete
Types of reinforcing steel (3)	(1) **Bars:** used for standard cast in place concrete; (2) **Wire or strands:** used for pre-stressing and post tensioning, (3) **Welded wire fabric:** used for slab reinforcement
Rebar Sizes	Rebar diameter size ranges from 3/8" - 2 1/4" at 1/8" increments; rebar ID number is based on the diameter. #3 = 3/8", #4 = 4/8", #8 = 8/8 (or 1"), and …

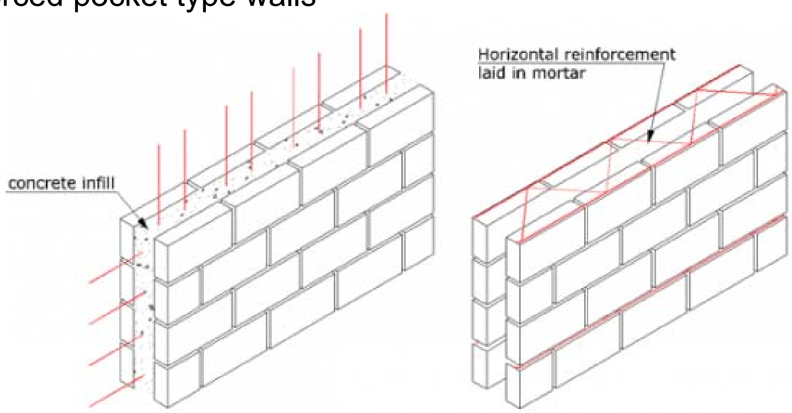
Concrete Masonry Unit

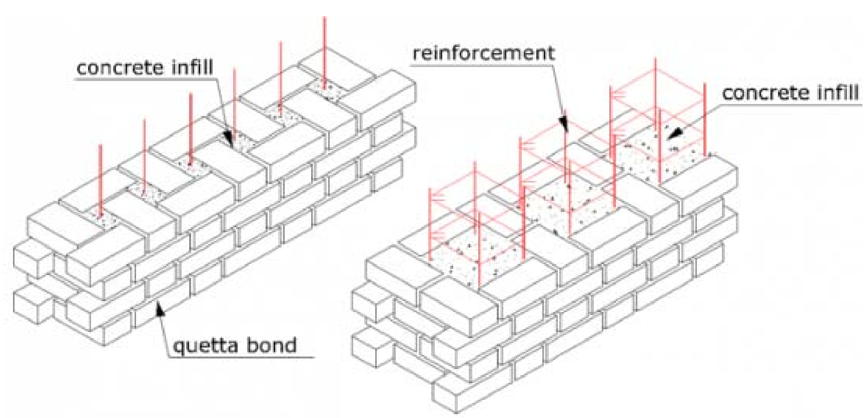
Each unit laid in and bound by mortar: brick, stone, concrete block, and tile.

It provide great compressive strength

- **Tensile Strength**- it is weak in tensile strength (twisting or stretching) unless reinforced
- **Reinforcement**- A construction system where steel reinforcement is embedded in the mortar joints of masonry or placed in holes and after filled with concrete or grout is called Reinforced masonry. Typical reinforced masonry can be classified into three types:

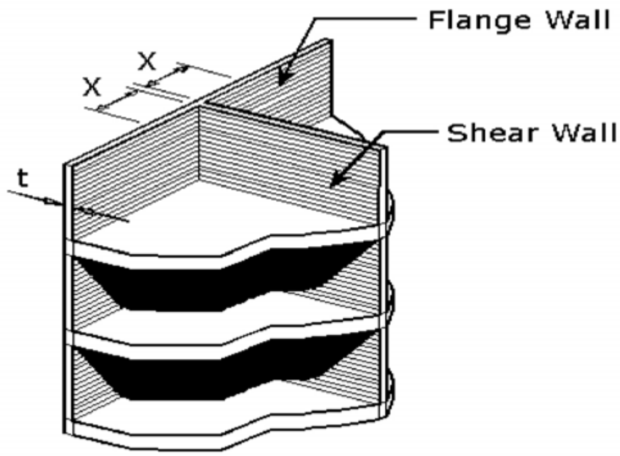
1. Reinforced hollow unit masonry
2. Reinforced grouted cavity masonry
3. Reinforced pocket type walls





A primary cause of failure of concrete masonry walls during hurricanes is a lack of vertical reinforcement. Not: Poorly filled mortar joints; improper base and sill flashing; an inadequate number of wall anchors

In the CMU stem-flanged shear wall arrangement shown, the minimum dimension X recommended to achieve shear transfer is 6t.
Not: 3t, 9t, 12t

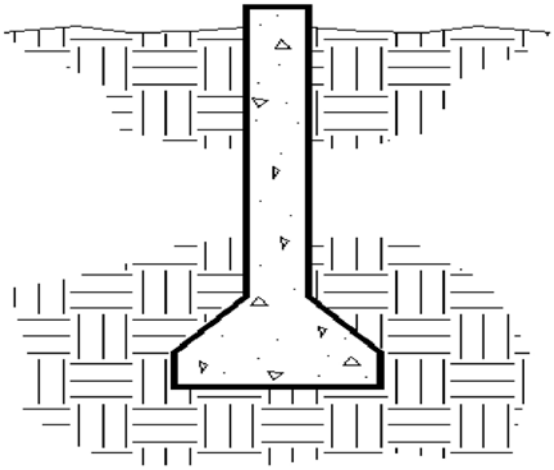


According to model codes; Connection of masonry web shear walls to masonry flange walls must be accomplished using Running bond, Bond beams, and Metal plate strap anchors.
Not: Stacked bond; Steel dowels, High-strength mortar

Footings

The drilled pier (caisson) shown above is belled in order to increase the bearing area

Not: prevent water infiltration; prevent caving; increase frictional resistance



The most frequently used footing type at the exterior wall for load-bearing wall support systems is continuous wall footings.

Not: mat footings; pile footings; isolated pad footings

Soil

Bearing Capacity	The capacity of soil to support the loads applied to the ground. *Ultimate bearing capacity* is the theoretical maximum pressure which can be supported without failure; *allowable bearing capacity* is the ultimate bearing capacity divided by a factor of safety
Testing	Soil Analysis is performed by drilling boring, bringing up sample of soil at various depths. Load test can also be performed at the site.
Soil Types	In descending order of bearing capacity: Rock; gravel and sand; slit and clay; and organic soils.
Settlement/Consolidation	When constant stress is applied to a soil that causes the soil particles to pack together more tightly, thereby reducing its volume.
Differential Settlement	When one part of a foundation settles more than another part.
Climate Influences- Frost Heave	Results from ice forming beneath the surface of soil during freezing conditions. The ice grows in the direction of heat loss (vertically toward the surface) starting at the freezing boundary, frost line, in the soil. The foundation is set below the frost line to counteract frost heave
Expansive Soil	Changes in soil moisture will influence soil volume. Clay soil are especially sensitive to moisture. Piles can be set below the seasonal soil change.
Groundwater	Foundations below the groundwater line with have to be design to counteract hydrostatic pressure

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.	

Soil

A loss of soil shear strength resulting in the movement of the surficial soil layers of a building site in a direction parallel to the ground surface under earthquake conditions is most likely caused by liquefiable soils.
Not: a low bearing capacity; a gently sloping site;

If the soil bearing capacity is 3000 psf [143 500 N/m2] and the applied load is 48,000 lbs [212 kN], 16 sf [1.5 m2] is the area for the footing.

48/3= 16 sqft or 4x4 footing

Ground Motion: Seismic Systems	
Earthquakes	are initiated when (due to slowly accumulated pressure) the ground slips along a fault plane on/near a plate boundary. Earth's crust is divided into several major plates
Waves of vibration	in the earth create ground motion on the earth
Epicenter	occurs on surface directly above the focus point or fault rupture.
Surface faulting	is the crack/split on the surface that is the layperson's vision of earthquakes
Earthquake Design:	against the vibrations caused by fault slippage and try to ensure that building are not built over fault zones. Earthquakes also trigger failure in the form of landslides, liquefaction, and subsidence
Soil/Earthquake impact:	Avoiding sites with a potential for liquefaction, landslides or subsidence requirements the best design approach; Ground shaking triggers subsidence/liquefaction in soils that are unconsolidated/saturated with water; Shaken sandy, water saturated soils cause the bearing capacity to reduce as it; liquefies and flows both laterally and vertically; Well built structures are vulnerable if site conditions/foundation design are ignored
cause of earthquake damage	ground shaking: Affects the building in three ways: internal forces, period/resonance, and torsion; Shaking causes damage by internally generated internal forces that come from the vibration of the building's mass
Mass and Earthquake	Increase in mass (or the weight of the building) will result in an increase in the force for a given execration (lightweight construction preferred)
Failure of vertical elements:	like columns or walls can occur by buckling, when mass pushed down due to gravity experts its force on a member bent or moved out of plumb
Period:	All objects have a natural/fundamental period...the rate at which they will vibrate if they are given a horizontal push; Natural period for a building varies from 0.05 to 2 seconds; Stiffness of construction materials and geometric proportions affect the period; Height is the most important consideration when dealing with period; Natural ground period is 0.4 seconds to 1.5 second; It's possible the motion the ground transmits to the building will be at its natural period; avoid amplification in building vibration not to coincide building period with the ground

Not good periods:	stiff building with short period isn't appropriate on a soft site with a long period. Earthquake shaking tends to be greater on soft ground than on hard ground. Earthquakes are more sever in areas of soft ground
Response spectrum:	shows the accelerations that may be expected at varying periods
Base isolation:	is based on shifting the building period towards the long period of the spectrum where the response is reduced
Close to Fault:	Locations closer to the fault from where the energy is release will experience higher frequency/shorter period ground motion. The farther the building is from the earthquake touch may be subjected to considerable long-period motion
The center of mass, or center of gravity	of an object is the point at which it could be exactly balance without any rotation resulting. Uniformly distributed mass results in the coincidence of a plan's geometric center with the center of mass. If the mass within a floor is uniformly distributed, then the resultant force of the horizontal acceleration of all its particles of mass is exerted through the floor's center. If the resultant of the resistance (walls or frames) pushes back through this point, balance remains
Torsion (very undesirable)	is a twisting action on a building.
Resist and Dissipate seismic energy:	Three basic characteristics of buildings help resist and dissipate the effects of seismically induced motion: damping, ductility, and straight/stiffness
Damping affects:	the dynamic behavior of the building and modifies its response to ground motion. When damped, buildings are inefficient in their vibration and when set in motion, return to their starting position quickly.
Ductility	the property of certain materials, typically steel, to fail only after considerable inelastic (permanent) deformation occurs; Good ductility requires special detailing of joints
Strength and stiffness	two of the most important characteristic of any structure. Analysis of forces is not precise and deliberately errs on the conservative side.
Stiffness (1/Deflection)	Deflection is a measure of stiffness…In the sizing of floor joists, deflection rather than strength governs because no one wants a bouncy floor...even though it's safe. In the design of a floor system, the joists might tolerate a certain deflectionbut the ceiling finish cannot.
Strength	Resisting a given load without exceeding a safe stress in the material is astrength problem

Relative rigidities:	of members are a concern of seismic analyst. As soon as a rigid horizontal element or diaphragm is tied to vertical resisting elements, it will force those elements to deflect the same amount

Site Issues	
	Seismic design isn't limited to the actually project site, but the to a broad environmental analysis of regional and community vulnerability.
	Factors that impact site vulnerability include proximate to active earthly faults, susceptibility of the site to ground shaking, the potential for ground failure (subsidence, spreading, liquefaction landslides) adjacent structures and land uses.
	If a structure is built over an active fault trace is should be designed to accommodate displacement or fault offset. In many areas development is limited/prohibited within defined zones adjacent to active faults Geology of a region plays a significant role in determining the potential for shaking and ground failure damage
Location of site	Understanding the regional and local geology can tell the designer a great deal about the relative risk of an individual site
Non Structural Damage	Damage to lifeline systems (water, sewer, power, transport, communication) can isolate a structure and cease its ability to operate, even if the structure is ok
Client	Selects site and unaware of risks and vulnerability
Site analysis	include an assessment of the environment beyond the property line and include adjacent structures and site conditions that could "spill over" onto the site

Non Structural Components: (limited attention by designers)	systems and components that are part of a building that don't like in the primary load bearing path of the building
Access floors	
Appendages and ornamentation	
Cabinets	Storage cabinets and laboratory equipment; Tall shelving need longitudinal bracing and attachment to the floor;
Cantilever elements:	Parapets; Chimneys
Ceilings	Suspended; Attached to rigid sub-frame; Suspended ceilings are braced by wires or rigid members no more than 144 square feet;
Exterior nonstructural wall elements and connections	Light wall elements (metal insulated panels); Heavy wall elements (precast concrete); Body of panel connections; Fasteners of the connecting systems; Heavy partitions like CMU should be separated from surrounding structure to avoid local stiffing and to avoid transmitting racking forces to the wall; Heavy parapets should be braced back to the roof structure;
General electrical	Distributed systems (bus ducts, conduit, cable trays); Equipment Emergency power equipment needs a positive restraint; Elevator components; Escalator components
General mechanical	Boilers and furnaces; Pressure vessels freestanding and on skirts; Stacks; Large cantilevered chimneys
HVAC/Plumbing system equipment	Vibration isolated; Non Vibration isolated; Mounted in-line with ductwork; Gas water heaters need restraint to prevent it from toppling over and breaking the gas connection; Sheet metal ductwork should be anchored and hung with threaded rods
Interior nonstructural walls and partitions	Metal studs that terminate at a lay-in ceiling should e braced independently (kickers) to the building structure
Lighting fixtures	Surface mounted to structure; Suspended from structure; Supported by suspended ceiling grid, surface mounted, or hung from suspended ceiling; Lighting fixtures must be supported independently, so if the lay-in ceiling falls, the light won't;

Manufacturing and process machinery	General; Conveyors (non personnel); Vibration isolated equipment is fitted with “snubbers” that limit lateral motion to prevent the equipment toppling off the isolators and suffering damage
Other flexible components	
Other rigid components	
Penthouse (separate from main building structure)	
Piping system	High deformability elements and attachments; Limited deformability elements and attachments; Low deformability elements and attachments
Signs and billboards	
Trussed towers (freestanding or guyed)	
Veneer	Limited deformability elements; Low deformability elements

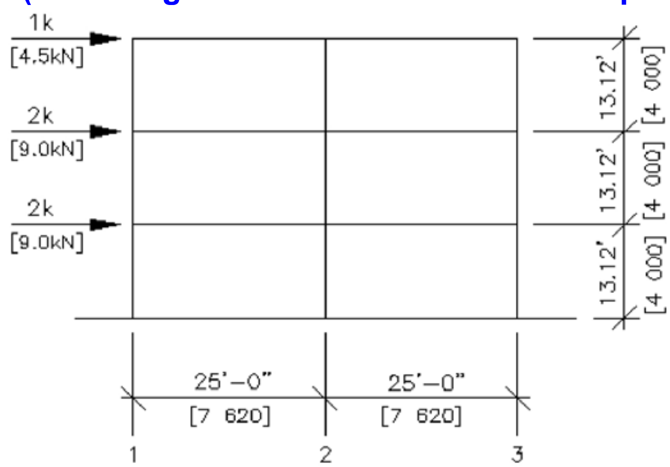
Seismic forces

33. The earthquake regulations of model codes are intended to provide resistance to Ground shaking.
Not: Earth slides; Ground rupture in fault zones; Settlement

34. A structure will have a better chance of surviving an earthquake if The structure has redundancy .
Not: Principal members change section abruptly; The load-bearing members are not equally loaded; All columns and walls are discontinuous.

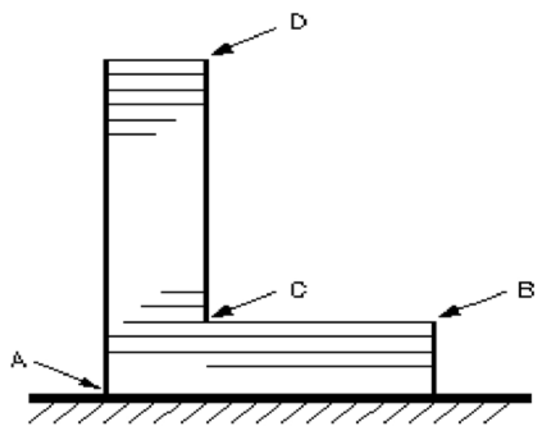
19. A building with a symmetrical square plan would be most appropriate for a high-rise building in a high-risk seismic zone.
Not: A building on stilts; A building with an L-shaped plan; A building with a symmetrical T-shaped plan

For the rigid frame structure shown, the approximate horizontal shear at the base of column 2 (assuming all column stiffnesses are equal) is 2.5 K.



Seismic Forces are: 1k+2K+3K = 5 K
They react with three columns: column 1,2, and 3. The tributary forces on 2 carry more than the other two 1 and 3. If building is uniform weight, the weight ratio for 2 is twice the 1 and 3, therefore, Column2: 5/2= 2.5 k shear force.

37. In the elevation of a multi-storied building subject to earthquake forces shown above, at at position C is stress concentration most likely to be a problem.



Shear walls, Braced frames, and Moment-resisting frames are primary structural system that is employed to resist lateral loads.
Not: Hinged frames

All of the following are criteria for base isolation systems:

- **The system must allow lateral movement.**
- **The system must control the movement between ground and structure.**
- **Energy must be dissipated in the isolators.**

Not: The system must amplify ground accelerations.

An eccentrically braced frame (EBF) utilized to resist lateral seismic forces in a building is a frame in which diagonal members are connected to a beam a short distance from the column joint
Not: Frame in which members are subjected primarily to axial forces; frame in which members and joints are capable of resisting forces by flexure as well as along the axis of the member; braced frame whose plan location results in torsion

Base isolation in an office building is most effective for four story building heights, assuming that the areas per floor are the same
Not: One-story; Twenty-story; Forty-story

38. A building form that is ideal for resistance to earthquake forces would be characterized by Symmetrical in plan and Heavier at the base than at the top
Not: Symmetrical about a reentrant corner; Asymmetrical in plan; Long linear plan; Asymmetrical in elevation

Column

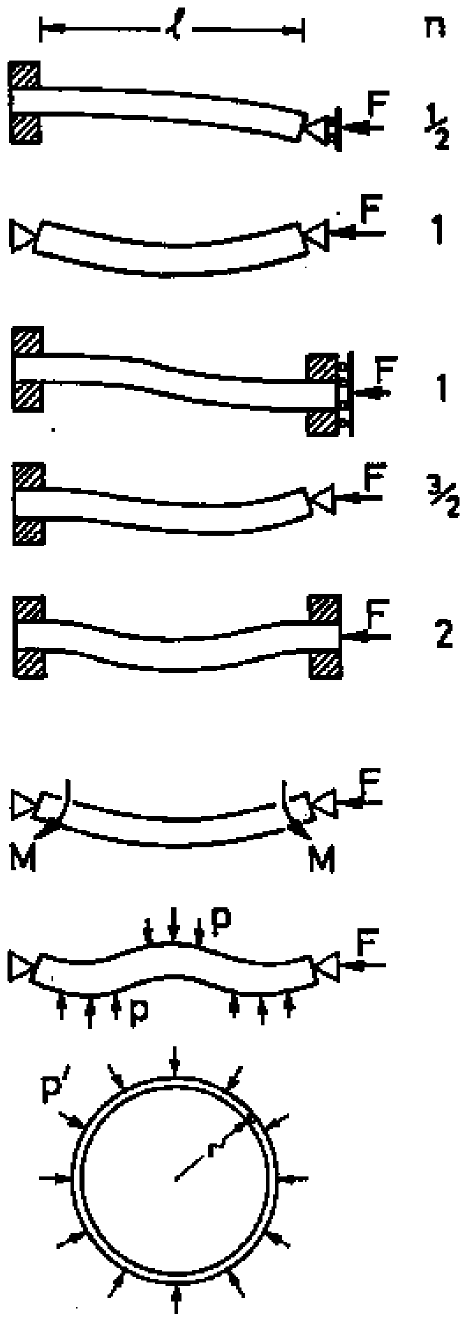
Column: Buckling of Columns, Panels and Shafts

If sufficiently slender, an elastic column, loaded in compression, fails by elastic buckling at a critical load, F_{crit}. This load is determined by the end constraints, of which four extreme cases are illustrated on Fig. A4: an end may be constrained in a position and direction; it may be free to rotate but not translate (or 'sway'); it may sway without rotation; and it may both sway and rotate. Pairs of these constraints applied to the ends of column lead to the five cases shown. Each is characterized by a value of the constant n which is equal to the number of half-wavelengths of the buckled shape.

The addition of the bending moment M reduces the buckling load by the amount shown in the second box. A negative value of F_{crit} means that a tensile force is necessary to prevent buckling.

An elastic foundation is one that exerts a lateral restoring pressure, p, proportional to the deflection (p = ky where k is the foundation stiffness per unit depth and y the local lateral deflection). Its effect is to increase F_{crit}, by the amount shown in the third box.

A thin-walled elastic tube will buckle inwards under an external pressure p', given in the last box. Here I refers to the second moment of area of a section of the tube wall cut parallel to the tube axis.



$$F_{crit} = \frac{n^2\pi^2 EI}{\ell^2} \quad \text{or} \quad \frac{F_{crit}}{A} = \frac{n^2\pi^2 E}{(\ell/r)^2}$$

F = force (N)

M = moment (Nm)

E = Young's Modulus (N/m^2)

ℓ = Length (m)

A = Section area (m^2)

I = See Fig. A1

r = Gyration rad $\left(\frac{I}{A}\right)^{\frac{1}{2}}$ (m)

k = Foundation stiffness (N/m^2)

n = Half-wavelengths in buckled shape

p′ = pressure (N/m^2)

$$F_{crit} = \frac{\pi^2 EI}{\ell^2} - \frac{M^2}{4EI}$$

$$F_{crit} = \frac{n^2\pi^2 EI}{\ell^2} + \frac{k\ell^2}{n^2}$$

$$P'_{crit} = \frac{3EI}{(r')^3}$$

Figure A2 Buckling of Columns

Buckling of a column can be reduced by (a) Increasing the size of the member, (b) Bracing the column (c) Changing the type of end restraints; (D) Reducing the length of the column

Not: Reducing the radius of gyration, Rotating the column

26. Buckling of a column can be reduced by: A. Increasing the size of the member; C. Bracing the column; D. Changing the type of end restraints; E. Reducing the length of the column.
Not: Rotating the column

28. The recommended deflection criteria due to wind loading on a brick veneer wall utilizing a metal stud back-up system is L/600.
Not: L/360; L/400; L/720

Building Code requirements for Masonry Structures ACI 530-05 limits the deflection of beams and lintels to l/600 (.3in.) to prevent cracking. The deflection of the brick veneer with stud backup isn't specified. But the commentary from ACI 530 says "The Brick Industry Association has held that an appropriate deflection limit should be in the range of stud span length divided by 600 to 720."

Another way to look at the question is that L/360 is a max deflection for wood member carrying live load.

L/400 is recommended for formwork.

L/720 is recommended for soft stone tile/marble.

Basically you want less deflection for more delicate connections/materials.

Deflection Limit State

In the absence of more specific criteria, criteria for structures with brittle finishes (as found in code documents for years) is frequently used. This simplistic criteria puts a limit of the span divided by 360 on the incremental deflection due to live (or transient) load only and a limit of the span divided by 240 on deflection under total load. These limit states are mathematic expressed as:

$$\Delta_{LL} \leq L/360$$

$$\Delta_{TL} \leq L/240$$

These limits were originally developed for members with "brittle" finishes, such as plaster. Plaster is not commonly used as a finishing material anymore. The goal of the limits was to minimize the possibility of damage to the finish and provide reasonable comfort for the building occupants. The criteria has persisted in practice.

Other criteria has been used that more explicitly addresses the use of the beam under consideration. For example, the Timber Construction Manual [ref. 12], page 66 suggests the values given in Table 8.4.2.1 and 8.4.2.2. Other references give different, but similar, criteria.

Table 8.4.2.1
AITC Recommended Deflection Limits
Used with Permission

Use Classification	Applied Load Only	Applied Load + Dead Load
Roof Beams		
- Industrial	L/180	L/120
- Commercial and institutional		
- Without plaster ceiling	L/240	L/180
- With plaster ceiling	L/360	L/240
Floor Beams		
- Ordinary usage[a]	L/360	L/240
Highway bridge stringers	L/200 to L/300	
Railway bridge stringers	L/300 to L/400	

[a]Ordinary usage classification for floors is intended for construction in which walking comfort and minimized plaster cracking are the main considerations. These recommended deflection limits may not eliminate all objections to vibrations such as in long spans approaching the maximum limits or for some office and institutional applications where increased floor stiffness is desired. For these usages, the deflections limits of table 8.4.2.2 have been found to provide additional stiffness.

Table 8.4.2.2
AITC Deflection Limits for Uses Where Increased Floor Stiffness is Desired
Used with Permission

Use Classification	Applied Load Only	Applied Load + Dead Load[a]
Floor Beams		
- Commercial, Office & Institutional		
- Floor Joists, spans to 26 ft[b]		
- LL ≤ 60 psf	L/480	L/360
- 60 psf < LL < 80 psf	L/480	L/360
- LL ≥ 80 psf	L/420	L/300
- Girders, spans to 36 ft[b]		
- LL ≤ 60 psf	L/480	L/360
- 60 psf < LL < 80 psf	L/420	L/300
- LL ≥ 80 psf	L/360	L/240

[a]The AITC includes a modifier on DL depending on whether or not the timber is seasoned.
[b]For girder spans greater than 36 ft and joist spans greater than 26 ft, special design considerations may be required such as more restrictive deflection limits and vibration considerations that include the total mass of the floor.

Live Load Reduction

IBC Sections 1607.9 (floors) and 1607.11 (roofs) allow live loads set forth in IBC Table 1607.1 to be reduced. Live loads are permitted to be reduced because, for the most part, the likelihood that the entirety of a given floor or roof area will be fully loaded with the design live loads is low. There are many rules set forth in the code for when, and by how much, live loads may be reduced. See the table below to clearly understand these rules and why they are necessary.

Rule	Reduction of Floor Live Loads		Reduction of Roof Live Loads	Reason
	Section 1607.9.1 Based on Influence Area	Section 1607.9.2 (ALTERNATE) Based on Tributary Area	Section 1607.11.2 Based on Tributary Area	
1	(KLL)(AT) needs to be greater than 400 square feet.	Tributary area A needs to be greater than 150 square feet.	For flat roofs, AT needs to be greater than 200 square feet.	A minimum area is necessary before it can be assumed that an entire area will not be fully loaded with the design live loads.
2	Reduction cannot exceed 50 percent for elements that support loads of a single floor.	Reduction cannot exceed 40 percent or 23.1 (1 + D/L0) percent for horizontal members.	20 psf of roof live load may not be reduced to less than 12 psf.	This ensures that a horizontal structural member, such as a beam or a slab, will be designed for a minimum live load.
3	Reduction cannot be more than 60 percent for elements that support loads of two or more floors. for vertical members.	Reduction cannot exceed 60 percent or 23.1 (1 + D/L0) percent	20 psf of roof live load may not be reduced to less than 12 psf.	This ensures that a vertical structural member, such as a column or wall, will be designed for a minimum live load.
4	AT for one-way slabs, for use in reduction calculation, cannot exceed the slab span times a width of 1.5 times the slab span.	Tributary area A for one-way slabs, for use in reduction calculation, cannot exceed the slab span times 0.5 times the slab span.	No rule	This takes into account the lower redundancy of (possibility of load redistribution in) one-way slabs compared to two-way slabs.
5	Live loads greater than 100 psf cannot be reduced, except that live loads for members supporting two or more floors may be reduced by as much as 20 percent (plus one more exception).			In storage-type applications with heavier live loads, several adjacent floor panels may be fully loaded.
6	Live loads in passenger vehicle garages cannot be reduced, except that live loads for members supporting two or more floors may be reduced by as much as 20 percent.			Passenger vehicle garage decks often are fully loaded.
7	Live loads of 100 psf, or on areas where fixed seats are located, cannot be reduced in Group A occupancies.	Live loads cannot be reduced in Group A occupancies.	Live loads of 100 psf or more on areas of roofs classified as Group A occupancies shall not be reduced.	Because of large concentrations of people in Group A occupancies, it is likely that the entire area under consideration will be fully loaded.

There are changes in the live load reduction provisions between the 2006 IBC and the 2009 IBC, the most significant of which can be summarized as follows:

Table 1607.9.1 Live load element factor, K_{LL} — the live load reduction provisions are revised to align with similar provisions in ASCE 7-05 Section 4.8. “One-way slabs” is added to IBC Table 1607.9.1 to make it consistent with Table 4-2 of ASCE 7-05. In the 2006 IBC, Section 1607.9.1.4 prohibited live load reduction on one-way slabs, except for certain heavy live load scenarios. The 2009 IBC permits the reduction of live loads on one-way slabs using Equation 16-24 with a K_{LL} value of 1. However, new 2009 IBC Section 1607.9.1.1 imposes a restriction on the value of the tributary area, A_T, of a one-way slab that can be used in Equation 16-24. The restriction is the same as that found in ASCE 7-05 Section 4.8.5.

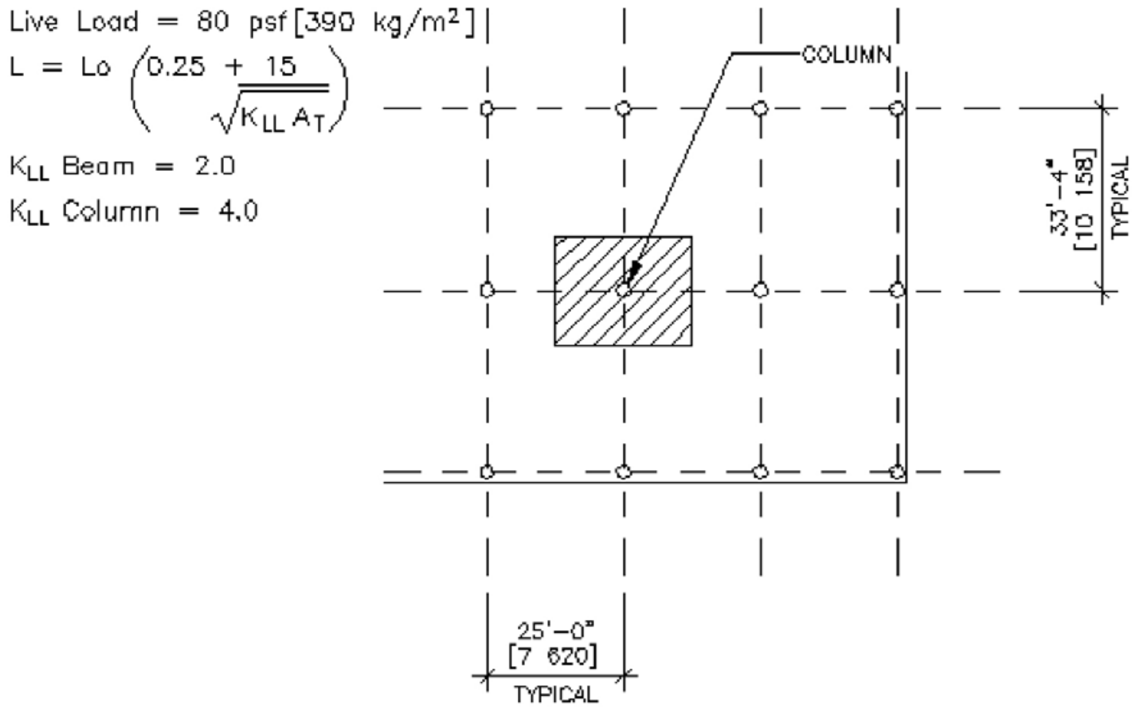
Section 1607.9.1.4 Group A Occupancies — 2009 IBC Section 1607.9.1.4 now refers to Group A occupancies instead of assembly occupancies, as was done in 2006 IBC Section 1607.9.1.3, in order to clearly define the scope of the provision.

Because there are public assembly uses with occupant loads less than 50 and categorized as Group B that do not warrant the prohibition, specifying Group A occupancy unambiguously applies the provision only where it is applicable. The scope of this provision now is restricted even further by applying it to live loads of 100 pounds per square foot (psf) only, instead of the 2006 IBC requirement of 100 psf *or less*. The only exception to this is an area where fixed seats are located. Even though the live load for fixed seats in an assembly area is 60 psf (Item 4 in Table 1607.1), it was judged that the areas with fixed seats also warrant this prohibition.

Section 1607.9.2 Alternate floor live load reductions — a new exception is added to make the alternate floor live load reduction applicable to live loads exceeding 100 psf where the usage is not storage and a registered design professional approves such a reduction through a rational approach. This revision makes Section 1607.9.2 consistent with Section 1607.9.1.2 (2006 IBC Section 1607.9.1.1).

Section 1607.11.2.1 Flat, pitched, and curved roofs — awnings and canopies other than those of fabric construction supported by a lightweight rigid skeleton structure are now specifically included within the scope of live load reduction provision of this section. The language in Item 29 in Table 1607.1 implies that reduction is permitted for these kinds of roofs, but no clear indication was given in the 2006 IBC regarding how to carry out the reduction. It has always been the intent of the code to apply the provisions of Section 1607.11.2.1 to the above mentioned roof category. However, since “awnings and canopies” are distinctly separate from “ordinary flat, pitched, and curved roofs” in Item 29 of Table 1607.1, this intent was not automatically conveyed. This oversight now is fixed.

A change in the language also clearly specifies that greenhouses are just one example of the type of structures that use special scaffolding for maintenance and repair purposes. Thus, the requirement of using a minimum live load of 12 psf is not specific to greenhouses, but to all such structures.



Area= (25*33'4") *80= 66,6667 lb

When considering permitted live load reductions for the column shown above, 67 kips [30 390 kg] the live load for the floor supported by the column.

Not applicable: L= 80 (0.25 +15/sqrt(4.0*25*33.3))= 80(0.25+0.259)= 33.33 kips.
Possibly the problem is for public assembly.
Not applicable when:

(a) In Public assemblies (any?) Live load for assembly is 100 psf, non-reducible. Due to higher probability of people congregated in one area, think about exiting after a concert

(b) Where the Lo is < or = 100psf (any application?) Live load 100 psf or less is reducible. So, a 101 psf live load is non-reducible.

(c) Ballast mentions something about Parking garages .... when? Live load reduction is not allowed for horizontal members. 20% reduction allowed for columns.Typical parking stall is 9'-0" x 18'-0" times 40 psf (code required live load for garages) equals 6,480 lbs. Some hummers weigh more than this. In older codes the live load was 50 psf.

(d) any member supporting more than 150 SF Members supporting more than 150 sf CAN have their live load reduced. Members with area less than 150 psf are not allowed a live load reduction.

Wind forces in structural design are based on probability as a result of historical analysis/
Not: Water pressures; Dead loads; Soil pressures

Recommended deflection criteria due to wind loading on a brick veneer wall utilizing a metal stud
back-up system is L/600
Not: L/360; L/400; L/720http://www.wbdg.org/resources/seismic_design.php - top#top

Loads

Shear force:	acts parallel to area resisting force
Moment	The statical moment of an area with respect to an axis: the area multiplied by the perpendicular distance from the centroid of the area to the axis.
centroid	the center of gravity of the area
No Torsion:	If a load acts through something's center of gravity, then it has no tendency to rotate, but will translate in the direction of the applied force
Ultimate strength	Steel 58,000 - 80,000 psi; Concrete 3,000 - 6,000 psi (higher strengths possible); Wood 2,000 - 8,000 psi
structures:	connect two points (eg: bridge), withstand natural forces (eg: dam), span and enclose space (eg: building), Structure is a 3-D art form, like sculpture, but it exists with a purpose, Most structural failures are during construction
Purpose of structural design:	Resolution of the conflict between the vertical direction of most load forces and the horizontal dynamics of mankind (eg: gravity and the way we work); All structures will be destroyed eventually; Many structural failures are caused by improper load assumptions; Most concerning types of stress in building design and construction are tension, compression and shear
Forces (or Loads) on Architectural Structures:	
External (applied) loads	cause primary stresses.

Vertical forces:	Dead loads and Live Loads, Static and Dynamic, Concentrated versus Distributed, Vertical loads (gravity), People (which are both static and dynamic), Moveable equipment, Vehicles, Rain, Snow, Drifting Snow, Ponding, Buoyancy, Construction Materials (bricks, stockpile, materials, etc)
Dead loads	permanently fixed in a structure, and easier to predict
Live loads	move around on their own, or can be moved, and cause vibration, hard to predict and require a higher safety precaution
Deformation:	Dynamic: the load changes with respect to time, often suddenly (eg: earthquakes, wind), Static: the load moves with building accumulation, slowly. (walking in a classroom is static, siting in a chair is dynamic)
Horizontal forces or LATERAL FORCES:	Wind: hurricanes, tornados (no warning or unpredicted); Ice: Expansion force (as it freezes), footings below frost lines; Earthquakes- ground rupture (in the fault zone), ground failure (sliding, settlement, liquefaction), tsunami (seismic sea waves, called a "seich" on inland bodies of water), ground shaking (vibration, repetitive dynamic motion), People: pushing on a window, balcony, etc. , Vehicles: impact loads (collisions), sudden starts and stops, Machinery: generators, oscillating equipment, vibration of equipment, Earth or Water: pressure on below grade structure, Transportation and Erection: (in transport to site and put in place), Lighting: powerful, Blast: explosions
Internal Forces	secondary stresses (> primary stresses) is the result of system or material characteristics, Movements (if resisted) are elastic (temporary) or inelastic (permanent) strains, Shrinkage: some takes place early (eg: concrete), Humidity Changes (eg: wood), Thermal Changes (eg: steel, metal, thin shell), Fabrication Errors (eg: incomplete concrete pour), Prestressing (they're all the same)

Soil:

Soil: Mixture of rock particles, minerals, decayed organic materials (humus), water and air. Soils are different due to variation in composition.

Soil: layer covers regolith layer or loose rocks then the earth crust. Soil has three layers or horizons:

- Horizon A: Top layer: tiny rocks, humus, dark color, spongy, holds more water
- Horizon B: High iron and clay, minerals through rain travel to this
- Horizon C: Slate/Shale from bedrock- Crushed rocks and some minerals leached through rain

Soil of the World: Forest, prairie, Desert, Polar, Mountain, Grassland, Tropical

Forest:
Soil in Forest are not fertile
Very Acidic: Leaves such as pine needle, twigs
Heavy Rain leaches minerals into lower layers (Horizon B)
Top soil is thin
Trees have deep roots for food

Prairie:
prairie soils are fertile
Less rain therefore less leaching
Top soil is deep
High Humus
Without plant covering the soil becomes dry and wind blows away
When no top soil nothing grows

Desert:
Very Fertile
less humus
sparse of top soil with high minerals
irrigation: Crops grow
After two years of irrigation, top soi is too salty to grow

Polar:
Horizon B only.
Perma frost (Permanently frozen)
Tudra areas
Soil is black
water logged
no evaporation or drainage
short seasons
Plants are small
little to decay to make humus

Mountain
Depends on the side of the mountain
Rainy side-
    Lots of Humus
    Top soils to support trees and shrubs
Little grows on the other side
In tropical zone: More top soil if further away from equator

Grassland:
High calcium- Whitish color
Not enough rain to leach
Humus rich and deep
grow wheat and rye
Fertile for grazing

Tropical:
Variety of animals and plants
Fragile soil: Rainfall leaches all minerals
Only Aluminum oxides (Al_2O_3) and clay to remain
Rusty red color
No accumulation of top soil due to use of humus from dead plants and animals
If no trees, all surfaces would be clay and after the rain, the surface becomes clay rock

Types of Soil

Clay: Fine grained, firm cohesive is introduced by decomposition + hydration of rocks. Clay is plastic (wet) & hard (dry), impervious (relative), swells when absorbing water, shrinks when dry, very unstable & predictable for support of buildings maybe used for foundation & needs engineers.
Clay is smaller than sand or silt. Clay is cohesive.

Silt: Fine grained, sedimentary, <.002" or less
Silt plus water makes mud, soft, sticky, plastic

Sand: Loose granular, .002" to 1/4", not plastic, & not cohesive
"course- grained solid"= sand +gravel=
base foundation relative + excellent drainage =
relatively permeable
quick Sand= sand + moving water, unstable, "sink hole"

Gravel: Larger soil particles with most void has higher permeability than clay, sand, silt. 1/4" to 3 1/2"; greater than 3 1/2"= cobblestone, greater than cobblestone= boulder

Hard pan: Mixture of Gravel, clay, sand foundation phase

Decomposed rock: Disintegrated rock mass that were solid

Boulders: Rock detached from bedrock

Shale/ slate bedrock: Fine textured soft rock (sheets); Solid material/ earth's crust.

Humus**:** Well decomposed, more or less stable, organic matter in soil, dead plants, animals

Mulch: Conserve moisture and temperature, prevent surface compaction, reduce runoff, and erosion. Improve soil structure and control weed

Muck: combination of soil, water, higher mineral content than peat. The level of decomposed is high and original plant part cannot be identified.

Peat: peat (turf) is an accumulation of partially decayed vegetation matter or histosol. Peat forms in wetland bogs, moors, muskegs, pocosins, mires, and peat swamp forests.

Compost: Used as organic fertilizer; mixed nitrogen and soil. Compost is to permit organic material to become crumbly and to reduce carbon- nitrogen ratio of the material

Mortar: Cement + water+ sand+ Lime; less stiff than concrete and handle with trowel

Concrete/grout: Cement + water+ sand+ Gravel;

Grout: Quite fluid poured in bricks

Compare large amount of loose silt site and organic soil for cost:

Organic soil (peat) is elastic, weak, little cohesion and organic will cost more. It must be removed and replace.
Loose silt can be compacted.

Land has loose fill, sloped, and large area: Site usefulness:

Identify the potentials, level the site and make recreational. Do not deny based on soils.

Bulb tee foundation: Underpinning as a temporary support. Usually in gypsum concrete construction. In bridges, they are permanent.

Building built to next existing building with shallower foundation: Both footings must be at same length. Temporary support: major shoring to take place.

Expansive soil:

Locate the footings in soils below the zone of seasonal moisture change
Extend concrete piers below the zone of seasonal moisture change
Design foundation for soil bearing pressure greater than the swell pressure of the expansive soil
Expansive soil is silty, clayey expands wet
High upward pressure
Oversize the footings will not help- More area for the upward pressure.

Exceeding the load bearing capacity of soil:

Settlement can occur and uneven movement and cracks occur
Structure fails
Mat or raft foundation is good for poor soil
Not enough for poor soil with insufficient soil capacity- Even for mat
Overhanging to a pile is also not sufficient
Piles must transfer to deep bedrock is the only response

Boring and tests:

Soil test - No guessing- Liability

Test pits: Simple excavation, visual excavation of soil condition, soil layer in open pit (access to soil). Do not go below water table

Wash borings: >100', use 2" or 4" diameter + water jet to soften soil to find bed rock (mistake => boulder is not bedrock)

Soil load: Use loading platform, incremental load applied, pressure continues till settlement becomes regular loadings, test= (2) contemplated load tests

Core boring: More cost, more reliable, penetrates thru, diamond blade cut thru rocks, 5"sample taken out for tests. # of bores, locations, Geotechnical Engineer to analyze for city

Dry samples: Drive pipes with special sampling and tip, 5" samples/lifted/stored/test every 5" each, # of bore, location, plus depth

Properties >>>>>>>>>> Foundations >>>>>>>>>>>>Soil bearings

Specific gravity: Density/density of water used to determine void ratio

Grain size: For granular soil) to determine permeability, frost action, compaction, shear strength

Grain shape: To estimate shear strength

Liquid/ plastic limit: (In cohesive soil) to determine compressibility & compaction values

Water content: (Cohesive soil)

Void ratio: To determine compressibility

Slump test: To measure the consistency of a mix. Concrete, mortar and grout stiff to loose.

Unconfined compression: (Cohesive soil) to estimate shear strength

Percolation test: On site sewage disposal for property "not" evaporation test, soil alkalinity, or soil density

Soil exploration & testing: Intrinsic character of soil. "Not" bearing capacity, depth or water table or bedrock

Proctor test: Optimum moisture content and density of soil.

Test boring: Highly accurate data for specific site.

Compacted fill: If soil is soft. Remove and replace with compacted soil. Fill or imported soil. Compact every 6" layer (sheep foot roller). Compacted fill needed for buildings, walkways and pavements.

Sub surface investigation reports includes

- -Field results
- -Laboratory results
- -Foundation type recommendation

"Not"

- -Soil sieve analysis: This is an inner component data only important to lab. analyst

Number of test boring when uniform sub surface. More spaced boring; When building foot print is more complex & square feet is high number of test boring increases

"Not" affected: Encountering firm strata; Regardless of strata, boring extends to 20' min. unless rock is encountered

Geotechnical Engineer: Provides soil characteristics plus bearing capacity of soil

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.	

Testing Concrete:		
Slump Test:	measures the workability of fresh concrete/ the consistency of the concrete in that specific batch and done on the jobsite • Concrete is poured in a cone mold that is 12" tall with 8" diameter at the bottom and 4" diameter at the top is made • The mold is removed and the concrete is allowed to slump naturally, due to the effects of gravity • The amount the sample "slumps" is measured. (Good = 1" and Bad = 6") • If it slumps too much, then there's too much water in the mix, if it doesn't slump very much, then it will be difficult to work with • It's a simple test, but that means there's a wide variability in the manner in which it's performed.	
Cylinder Test:	Measures the compressive strength in PSI of concrete and done in a lab	
	• Results are compared to the concrete design values and tested at 7 day intervals	
Core Cylinder Test:	Like a cylinder test, but the portion of the concrete is already in place. A core is drilled and taken to a lab (expensive!!!)	
Kelly Ball Test:	a half-spherical steel ball is dropped onto a slab of concrete to measure its consistency	
	• The amount it penetrates into the concrete is measured and compared to the half values of the slump test (a 1" penetration of the kelly ball = 2" of slump)	
Impact Hammer Test:	a spring loaded plunger is snapped against a concrete surface and the rebound is measured	

Footings

Piles are best for low bearing capacity (a boat) transmit load to deeper more firm soil. Structure with heavy loads on dense earth: Structural steel pile

-Jetted pile= rarely used
-Wood pile= light for moderate loads
-Boat footing, mat foundation= low bearing capacity

Pile with “driven to refusal”:

Pile driven to a point where additional blows will result in no significant penetration. Pile does not need for bedrock

Wood piles: Where untreated wood piles permitted:

If they are below the longest ground water level.
If untreated wood is constantly wet.
They are in no danger of deterioration.
Wet and dry causes mold and decay.
They are not subject the allowable unit stresses.

Piles: When upper soils have insufficient bearing capacity, then piles transfer loads to firmer soil.

Load on footings= Reduction of soil's void volume, "not" shrinkage, differential settlement, reduce bearing capacity

Ratio of load to bearing capacities are high: best to use mat foundation

area is very high p/a= low match bad bearing capacity (bath tub)

6 story building with 25 ft of loose fill: Great beams and piles extending the loose fill.

Spread footings: Good soil at shallow depth. On re-compacted soil is not economical. Loose leaf with 5 ft depth will not satisfy

Mat foundation: Large whole building mat is only for fair to poor soil. Loose fill is not known to be used with mat foundation.

Foundations: Conventional: Concrete and cost less

Piles: Costly, wider range of materials. Timber, steel, concrete, very slow construction process

Frost:

Frost line level: Foundation design in northern climate is 5ft down dye to frost line level.

"Not" earthquake, against snow drift, rest on undisturbed soil

Frost action: Freezing then thawing---> heave of ground stress to building --> serious damage

Soil frost depth varies frost line= Soil does not freeze below frost line

Frozen footings: Place concrete footings below freeze line. Three to five feet below grade. Below frost penetration

If soil in parking lot rise in winter: Frost and heaving of sub soil - Ice expands

Footing excavation is frozen:

Excavate frozen ground
Never place concrete on frozen ground, when thaw, it shrink and cracks
Hating and thawing: Not practical, not reliable

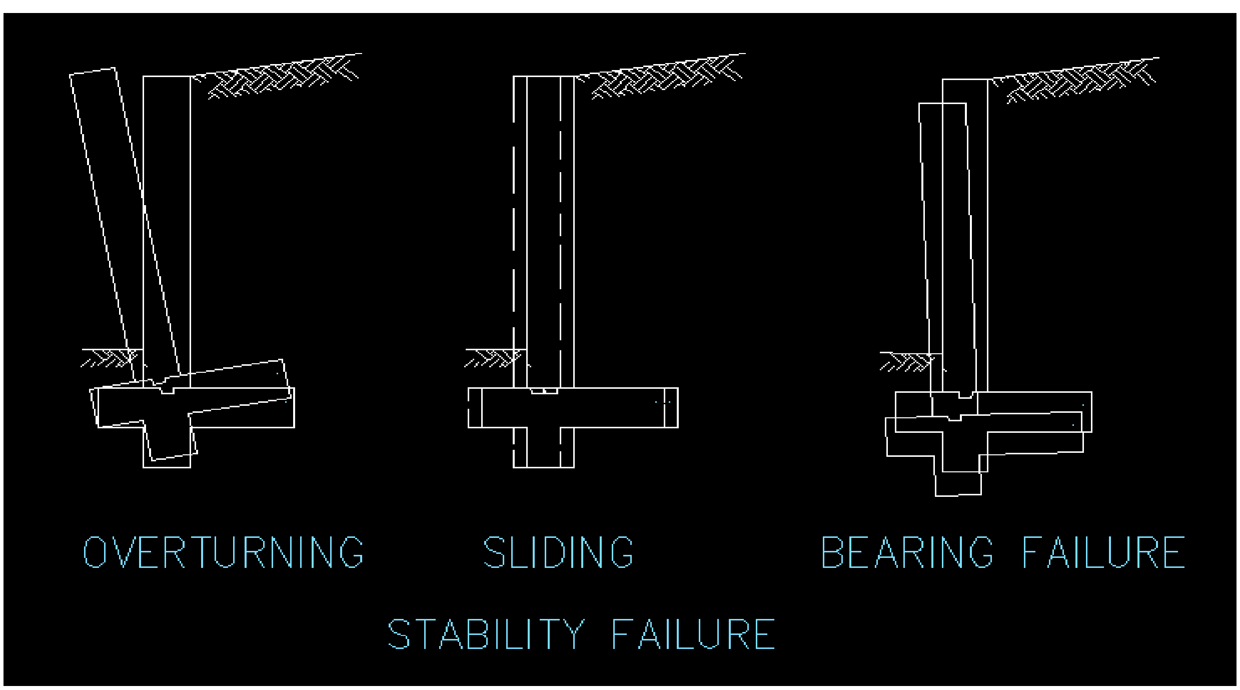
Frost line in North Dakota: 6 ft

Foundation Types	
Area of Footing =	total wall or column load + weight of footing + any soil on top of footing / allowable soil bearing pressure
Earth Pressure on a wall (P) =	30 lb/ft3 x height of wall
Shallow Footing	Foundation transfers building loads to the earth very near the surface, within 1′-10′. Shallow foundations includes: spread footing foundations, slab-on-grade foundations, and rubble trench foundations.
Spread Footing:	Most economical…$ method. Delivers load directly to soil over a large area,. Strips or pads of concrete which transfer the loads from walls and columns to the soil. Common in residential construction. Relatively simple system considered a shallow foundation system,
Continous Footings	The most frequently used footing type at the exterior wall for load-bearing wall support systems is continuous wall footings. Not: mat footings; pile footings; isolated pad footings
Wall Footings	Most common method. Under a continuous foundation wall that supports a bearing wall
Column Footing:	one footing supports one column
	when 2+ columns are too close to each other or a property
Combined Footing:	line for separate footings, one footing is poured for them all
Strap/Cantilever Footing:	like a combined footing, but columns are far apart
	Very expensive…$$$ method.
Mat Foundations:	Typically it’s only used when the strata is weak, It acts as one continuous foundation.
	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.
Pile Foundations:	• They’re basically really, really deep spread footings

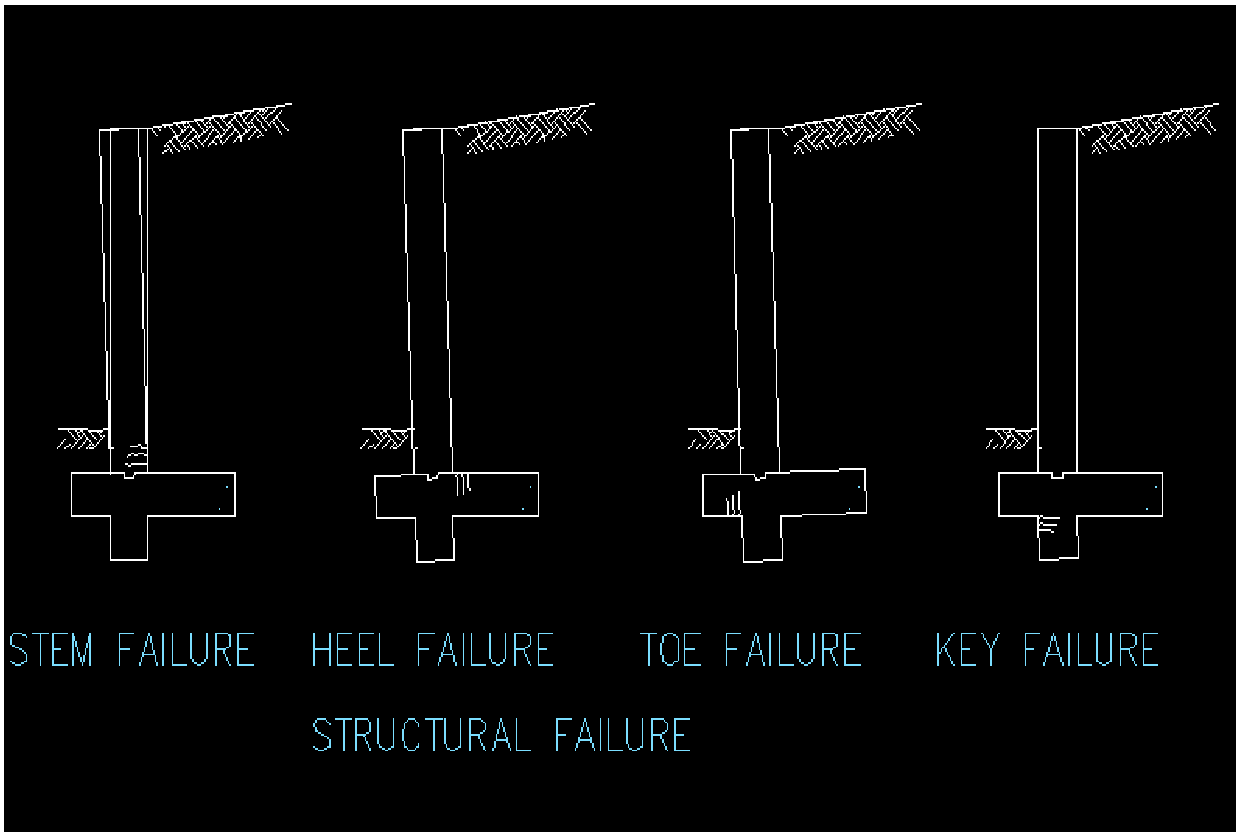
Friction Pile:	Driven into softer soil. Friction transmits the load between pile and soil Bearing capacity is limited by whichever is weaker: strength of the pile or soil_
Driven Piles	Prefabricated piles that are driven into the ground by a pile driver. The act of driving the pile causes increased friction, caused by the compression of soil around the pile
Pile Cap	Concrete block into which the heads of the piles are embedded
Drilled Piles	Also known as caissons and CIDH piles. A cavity is bored to the designed depth then a reinforcing cage is introduced, concrete is poured in the bore.
Drilled pier	The drilled pier (caisson) shown above is belled in order **to increase the bearing area**;Not: prevent water infiltration; prevent caving; increase frictional resistance
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
Liquifaction	A loss of soil shear strength resulting in the movement of the surficial soil layers of a building site in a direction parallel to the ground surface under earthquake conditions is most likely caused by liquefiable soils. Not: a low bearing capacity; a gently sloping site;Not: a low bearing capacity; a gently sloping site;
Area of Footing	Area of the footing = load/safe bearing capacity. If the soil bearing capacity is 3000 psf [143 500 N/m2] and the applied load is 48,000 lbs [212 kN], 16 sf [1.5 m2] is the area for the footing.
Slab on Grade –	Concrete slab is poured into a mold (consisting of trenches and wood forms) that is created on site. There is no cavity between the existing earth and concrete. This type of construction is more typically found in warmer climate with out the issues of frost heave
Rubble Trench	Type of foundation that uses loose stone or rubble to minimize the use of concrete and improve drainage. Consisting of a rubble trench and layer which the concrete slab is then poured over.
Deep	Driven, Drilled Foundations

Base Isolation Systems	Designed to deal with seismic forces. It is a collection of structural elements which decouples a superstructure from its substructure in an event of an earthquake. Its goal is to dampen the extreme forces with decoupling isolation units. Some examples are spring-damper systems (similar to an automotive suspension) and sliding units.

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 conterforts 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



Stability failure	(1) Overturning.; (2) Sliding; (3) Bearing capacity.
Structural failure	Bending or shear failure of: stem; heel; toe; key.
retaining wall in slope	rotational stability failure
Stability analysis cantilever retaining wall:	(1) Check factor of safety against overturning; (2) Check soil bearing pressure (3) Check factor of safety against sliding.



Footings:	designed to balance load capacity of the soil and the load required (dictated by the weight of the structure).
Bearing Capacity	The capacity of soil to support the loads applied to the ground. *Ultimate bearing capacity* is the theoretical maximum pressure which can be supported without failure; *allowable bearing capacity* is the ultimate bearing capacity divided by a factor of safety
Testing	Soil Analysis is performed by drilling boring, bringing up sample of soil at various depths. Load test can also be performed at the site.
Soil Types	In descending order of bearing capacity: Rock; gravel and sand; slit and clay; and organic soils.
Settlement/Consolidation	When constant stress is applied to a soil that causes the soil particles to pack together more tightly, thereby reducing its volume.
Differential Settlement	When one part of a foundation settles more than another part.
Climate Influences- Frost Heave	Results from ice forming beneath the surface of soil during freezing conditions. The ice grows in the direction of heat loss (vertically toward the surface) starting at the freezing boundary, frost line, in the soil. The foundation is set below the frost line to counteract frost heave
Expansive Soil	Changes in soil moisture will influence soil volume. Clay soil are especially sensitive to moisture. Piles can be set below the seasonal soil change.
Groundwater	Foundations below the groundwater line with have to be design to counteract hydrostatic pressure

Drainage:

- Begins with grading all water on top surface away from building & out to right- away
- Gutters, flumes, berm, gentle wrap of paved surfaces direct water to drains, catch basins & penetration soil works

Pipe (trench) perforated outside next to foundation footing
-To reduce hydrostatic pressure on water.
"Not"
-Maintain uniform or increase hydrostatic pressure
-Decrease vapor pressure in basement room

Drainage: Connecting on site drainage to existing city drainage

Wastewater collection: Always flows by gravity, pipes at constant slope, mains are below street level (one to two pipes). Grades to transport solids is ½% to 2%, and diameters are up to 4 ft and 20 ft long

Surface water management: Natural or mechanical site drainage systems

Green codes: Minimum volume of water to ground water

Runoff: Amount water- What does not seep into ground beyond saturation. Seepage is function o f porosity, slope, vegetation

5 year storm: Residential
25- 50 year storm: Shopping center

Drainage systems**:** Culvert, guiters, "sheet flows", pipes

"Check dams": To reduce speed at high slopes

Final/ finished ground surface: + positive drainage; Free of un-drained depressions. No water stagnation

To control or avoid erosion: Use channels, pipes, hard surface, lower grade, finally connect to underground pipes
Below traffic & surge pressures (-3 to -4ft in colder area).
Deep excavation may be cost prohibitive.
Destructive wears must be prevented.

Simpler the better: Minimum pipe length, access, slopes, …, filters

Green Code: Swales, surface drainage, native grasses used as green codes
Sub surface drains are function of permeability, depth of drain, size of drain, slope of drain, spacing of joints, perforated PVC/clay

Vapor extraction: Site contamination leads to ground water contamination: Clean up to remediate unsaturated zone: Vapor extraction "not" in situ incineration, bio degradation, photolysis

Extraction/treatment: Ground water remediation projects: Extraction/ treatment
"Not" with in situ aeration, biological barriers/filters, gas chromatography

Water detention areas: Used for control surface water run off,
Not: To create swimming & recreation
To create aesthetically pleasing vistas
To act as reservoir during drought

Permeable water aquifer
Aquifer: Underground permeable material through which water flows

Permeability: A measure of ease with a particular fluid flows through voids. "Not" compressibility, osmosis, or cohesion

Hydrostatic pressure: Fluid force exerting pressure on building.
"Not" dynamic, water, or wedge

If 5 yr storm is not adequate: Go for 10 year storm (100 year too costly), or use growth vegetation area for absorb or swales

To reduce complex drainage system:
Create thick ground cover of plant materials to absorb and slow down
Drainage to collect, conduct, and dispose rain
Paving does not absorb
Best is to greater absorption and percolation- Reduce erosion
Earth berm only diverts flow

Probability of poor drainage:
Flat site, high water table, no storm drain system

Septic tank: Soil must be pervious (permeable). Slope= 1 inch in 24 ft 1 inch/24 ft (not ¼"/ft- too fast). 100 ft from any body of water.

Rain water: Keep natural runoff and runoff after construction the same. Removal of vegetation decreases transpiration, impervious surfaces reduce infiltration.

Slopes

Sheet flows: Land 1 to 1 ½ % slope, adjacent to building: 2%

Drainage ditches: 2 to 10%

Grass slopes: Maximum 25%; turf: <25% for mowing; 25% max. grassland

Un-mowed (planted banks) lawns: Maximum 50% (ivy)
[>50%: Avoid erosion]

Flat: 4% or less- Considered
level <4% ; 4% intensive activity
Moderate: 4--> 10% slope effect to climb/ descend
easy grade 4%to 10%; 4-10% informal
Steep: 10-50 % steep/ unusable
step grade> 10%; >10% limited
>10% is costly & more complications,
split level = very usual
Grassy recreational <3%; 5%< erosion
Un-retained earth cuts: 50% to 100% depending on soil
Walk next to buildings max= 4%
Minimum slope of land 0.5%,
5% slopes of parking
2% away from building
Streets 10% max
Storm drains: 0.3% to 1%
Short ramp 15%
Pedestrians 10%
Parking stalls must have slopes of .5 to 10% max if slope is 25 ft in 100 ft run (25%) the area must be regarded as steep.
Vehicular slope limit is 15%.
Vehicular parking lot ramp: 12% at 32'. Rise @ 8 ft long transitions.
If the slope is greater than 10%, then slope of transitions is to be ½ slope of central portion. 12%/2= 6% and 6% of 8 ft= 5.76 " rise.
Pipes are sloped for self- cleansing (0.3% minimum)
Drainage ditch = 10% max

Legal surveying

Benchmark: Reference point of project

Public land of 1785: Created townships and sections

Easement on private property: Across created.
Not: Daylight, setbacks, landscaping

Land use restriction by authority having jurisdictions: Setbacks, height/area limits/zoning

Not: Covenants (Local restriction- Specific)
Not: Accessibility regulations: (No restriction) must do

Distance & compress bearings: Metes & bonds, "not" chaning- 66', datum elevation, or benchmark

Restrictive covenants on behalf of property owner, not any Engineers, Architects

Right-a-way: A right belonging to a party to pass over land of another.
“Not” : Purchase of land, taking property, picketing/strike

Street

Roadways smallest to largest

Local access streets: Low intensity fronting houses & often in forms of loops or cul de sac

Collector streets: Transition from local access to arterial intersections. Intersections: Controlled by traffic signals, local streets with stop signs

Arterial streets: Continuous vehicular channels that connect with expressway through ramps generally two to three lanes

Expressways: Large movement between urban center and accesses are limited

Legal constraint on a proposed land:

Deed restrictions: zoning ordinances; easements. "Not" environmental impact statements (EIS). Only +/- impact on potential for the site

Practical & effective dry crawl space?

Provide tight & continuous ground cover using polyethylene film @ least 4 mil thick (vapor barrier floor & sub floor okay but not help)

Non confirming but legal existed prior to enactment of land use is grand fathered, not: -easement -dedicated -aggrieved
Deed restrictions: Legal restrictions imposed on land by private parties on buyers to maintain integrity of property

Zoning ordinances include: limited population density; segregated permitted uses, restricted lot coverage, not include: diminished fire danger.

Spot elevation: Proposed finished elevation of single point. Elevation of key structures such as building corners, manholes, and catch basins.

Seismic or resistivity survey: Limited but reliable but enough for foundation.

Zoning ordinances include: Provide building interiors with natural light and ventilation, inhibit fire spread from building to buildings, eventual widening of the streets, preserve setbacks

Topography

Find elevation on topography: The elevation on the two Contours are 60 and 55 ft the interval is 16 ft. What is the elevation 4 ft away from contour 55

60-55 = 5 ft elevation difference in 16 ft
4 ft is 25% of the distance (4/16)
5 (4/16) = 1.25 ft + 55 ft = 56.25 ft elevation

Slope: (Contour 1- contour 2)/ change in interval= V/H= G = 245-230/5 = 3:1
Topography: Land layout and Site Slope are critical in evaluating site worth and applicability. Cut and fill costs are not cheap.

Topography critical for routing storm water (natural slope)
not water, electric/ gas

Contour lines: Spaced @ given horizontal intervals show elevation of location_ terrain. Continuous elevation lines with equal elevation lines. Dashed lines are existing or natural topography. Solid lines: New modified contour lines. Lines never split and are always same elevations.

Contour lines: In building design: To minimize grading, buildings are designed in parallel to match hill side contour lines.

Contour lines: 5% grade, interval is 1 ft, G = V/H= 5/100= 1 ft/h= > H= 20 ft.

Highly irregular contour lines: Most appropriate for cluster type residential development. Concentrated grouping of residential space in open areas through clusters. Cluster was to condense large number of units. Lengths of street reduced, high roads, and moderate slopes.

Uniform slope: When spacing between contours is equal
Valley: When contours elevation increase outward
Ridge: Increase outward
Steep: When contour lines are close together

Topographic map includes: Property line, easements, and utilities, location of streams, roads, and buildings- Not shown: Soil conditions

Slope of land: Required for sanitary and sewer/storm. Slope is not required for gas, water, or electric

Arial photograph: Terrain conditions, nothing to do with sub-terrain

Parking

Site parking calculation: 50000 sqft, building 10000 sqft, parking: Building (3:1) ratio, 400 sqft per car: Number of parking slots

Building: Parking
10K: ? 1:3--> parking (3X 10K)---> 30K
30000/400= 75 parking

New rental center factor: Accessibility to market area traffic

FAR (Floor to Area Ratio): 30% in 12000 sqft lot. Therefore (0.3*12000)=) 3600 sqft allotted. If four story building, 900 sqft per floor, and 2700 sqft will be above grade.

60 degrees parking= Easy to use, not efficient
90 degree parking= Most efficient
Parking ANSi standard for handicap: 8 ft stall plus 5 ft sides 3 ft curb for access

Parking lot large: Do not do: Dead level paved areas causes ponding of water and dead end aisles creates congestions

Entrance versus exiting parking lot: Slow exit even stop to yield. Entrance faster speed of advancement road

Parking layout

Correct: traffic aisles arranged to serve buildings they serve
> Angled parking requires one way traffic
> Circulation of traffic in parking is continuous
> Slow (not rapid) traffic towards 90 degrees perpendicular parking layout

Area for parking cars: Good/car therefore 300 cars
300*400 cars= 120,000
For retail: 3000 to 4000 sqft parking per 1000 retail space

To reduce vehicle usage: Central city area:
Incentives for car pool, monthly rate parking fee,
-No parking (or united parking) with tax system earmarked for public transportation

Area for parking lot: 325 cars park @90 degrees parking.
325 cars x 400 square feet for = 130,000/ 43560 =2.98 acre

Road/carcirculations: Curviilinear is similar to natural environmental. Others "not" grid, radial, linear

Fastest volume of traffic- Free express way (no stops/lights). Not: Access, distributor, collector, arterial, highway, interchange

Land use and development use: Street system. Not: Topographic, climate (factors) or utility system

Shopping centers to be located @ intersection of arterial/collections

Street design criteria: Curb radii min.= 12'; traffic lanes (12ft); Intersections to be @ right angle; Avoid Compound curves; Parking lanes to be included

Street design criteria:

Light street: 4" roll-curb

Heavy traffic: 6" curb & gutter; 9'0" shoulder on each side of street and concrete paving. Asphalt is best choice. Vehicle width for lanes 11 to 12 ft

Power lines installed above: Are cheaper

Pedestrians circulations: Only safety matters
Non-ambulatory disabilities: Physical layout

2 Wheelchairs pass = 60" in diameter (clear 180 degree turn).
Walkway not interrupted by cracks or edge ½" or more in height.
Walkways not greater than 5% gradient.
Ramp minimum 36" side

Road Position: Gradient is 5%: 5:100
150 ft away elevation 142.5' on hill
5% of 150 ft= 7.5 ft
142.50 +7.5 = 150 ft <<<<<<<<<<<←--

Parking 361 cars minimum Accessible requirements

Over 150 - 249	5 + two cars per 100
250- 349	7
350- 449	9

Parking: 2 accessible cars stall: 8'+5'+8' = 21 ft

Landscapes:

Trees: Used for screen wind, increase ventilation

Vegetation: Capture moisture, reduce fog, increase sunlight reaching ground

Plats: Aesthetic value, screen or disguise as required, trees absorb sound

Planted area: Cooler during hot days, less heat loss during night

Deciduous tree: Looses leaves in winter

Coniferous tree: Has leaves throughout the year

Handicap

Handicap design: Path less that 1: 20; ramp< 1:12; <30 ft. max.

Handicap pathway surface: Asphalt surface is the best: smooth, no transition Bad: Tanbark, brick, flag stone are rough on wheel chair

Handicap slope maximum: Ramp 1:12 and flatter the better ramp anything steeper than 1:20 is a ramp.
Ramps other than those are used by non-handicap is limited 1:8

City planning

City planning: Mixture of central business district & presidential

-A viable community asset

"Not "prohibited due to land cost; all substandard units converted to commercial; future units to be low income & elderly

- Best orientation towards sea view: The maximum number of units facing the ocean

Site preparation

-Clear all object
-Demolish her plan
-All utilities to be dealt with
-Undisturbed plants to be protected
-Batter boards offset from building or excavations
-Top 6 inches of soil Removed

Catchment area: Market area or trade area, tributary area from which a facility derives its user population; depending on type & size of shopping center, the catchment area fluctuates with size on basis of traveling & convenience in reaching facility type & size of shopping center is primacy determined by its catchment basis

To reduce cost: Compact low cost housing development main cost: Grading, road construction, utility

Configuration of conventional suburban shopping mall

Axial: Anchor tenants very similar to linear but anchors create main axis for design

Precinctual organizational pattern:

Graduak accumulation of self-contained building complexes.

Each serving distinct activity & interrelated with neighbors. It allows growth in any direction. Flexible/compact
Street

Site issues- Bearing capacity, sub- surface, water shrinkage, seismic, stable earth

Life cycle

Life cycle components under Architect's control:
-Includes construction (15%), Operating, maintenance, & replacement, renovation … are in Architects control
-Not in control taxes & financing
- Financing cost can be reduced for fast track construction
- Higher quality materials reduce long term costs

Climate

Temperature climate:

Best configuration for a temperature climate

-Short wall facing west

-Overhang on long side on south

-Primary heat gain on roof

- Stagger horizontal or vertical

-Stacked high rise

City Planning: City (Northern, CA) or Minnesota best climate design

-Town structure closely dense, larger buildings grouped sheltering wind, but utilize sun/ solar

"Not" design loosely/free layout

-Dense but with shades

-Town character to be loosed/scattered

City planning - Thermal environment: Character of existing & new structures affects thermal environment: Shadow pattern.
"Not": Mechanical system, texture, foot prints

Climatic characteristics: Temperature, humidity, wind velocity

Solstice: Winter December 21^{st}-Longest night, Summer June 21^{st}- Longest day

In hot arid climate:
Thick walls-Thermal mass: Materials with high heat storage value used in arid lands. (Arizona, New Mexico)

Wide overhangs

High ceilings are good designs

Southwest desert buildings:

Most significant: Recognize the climate and other problems of the area.

Deeply recessed openings are best shading for glazing in any directions.

Shaded glass is more important than insulated glass.

Radiation is more value than conduction.

Roof area is not that critical when compared to recessed glazing.

Vertical louvers (especially south) diminish solar radiation

Solar radiation:

South wall get maximum winter radiation.

Roof and east / west walls receive maximum radiation in summer

Cold climates vapor barriers in attic: Minimize moisture migration.
Not: Serve secondary water proofing, support insulation, protection from insects

Roof overhang built in northern hemisphere seasonal adjustment for solar radiation: South facing overhang

Most important factor in residential units: Recieve sun part of winter day
Not: -West facing @ a premium
-Bedrooms away from harsh wind
-Mask units from breezes

Innovative technologies - Cost effective:
Site driven technologies: Wind turbines, photovoltaic, small scale hydroelectric. They are also relatively cost effective.
Fuel cell technologies and groundwater aquifer for cooling and heating depending on climate/environment.

Solar energy is limited in building on north side of high rises. High rises cause shadow on their northerly buildings

Solar: Sun chart shows**:** A) Path of sun by means of attitude & azimuth (21st day month). Sunrise to Sunset
B) Amount of sunshine based
C) Cloudiness not in chart
D) Heating degree days in not in chart

Solar site depends on slope & latitude. All earth @ same latitude gets same sun regardless longitude

Building Orientations: External influences: Climate, noise, views & solar. Foundation is not related.

Town 1 @ base of mountain & town 2 @ 3000' above town 1
Town 2 is always cooler

Rural versus urban climate - Planted rural area**:**
Stabilize microclimate hard surfaces swing temperature fast plants absorbs & store heat. Plats increase transpiration & increase rainfall. Plants purify air

Geothermal: Needs mechanical for design & Architect to implement. Landscape (& structural) not involved. Outside beneath earth

Best use of overhang:

Sun @ low angle is fully captured

Ideal orientation and fenestration based on climate:

Latitude
Adjacent reflective surfaces
Interior room functions
Building heights
Avoid tree screens of sunlight

HVAC is an external to building issue - Secondary concern

Wind

Air movement - Degree of comfort @75 F degrees, 30 R.M., 100 FPM = Quite pleasant.

Less than 50 FPM = Not noticeable.

> 25 F PM: Drafty & annoying

Wind: Open plaza windward side of high rise:

Shelter Hotel, relocate the entrance, placing walls, trees are not very effective

Wind: Two building, smooth surface and one is steps or jagged

-Smooth surface building creates more turbulence, "not" wind acts same way regardless

-Turbulence is more on stepped building energy is dissipated

-Turbulence is a minimum concern in high rise & street

Wind and pressure: When velocity doubles, the pressure quadruples.

$$P = c\,V^2$$

Aerodynamic Pressure:	the interaction between the wind and the building
Basic Wind Speed:	the wind speed with a 50 year average recurrence interval measured at 33'-0" above grade in Exposure C (flat, open terrain) It is a peak gust speed
Building drift:	the distance a building moves in wind
	CONTENT AREA: WIND FORCES
Down Slope Wind:	wind that flows down the slope of a mountain
Downburst:	An area of significantly rain-cooled air that, after reaching ground level, spreads out in all directions producing strong winds. Associated with thunderstorms
Exposure:	classification for the characteristics of the ground roughness and surface irregularities in the vicinity of a building
Hurricane:	spiraling wind systems that converge with increasing speed towards the storm's center (eye)
Main Wind Force Resisting System (MWFRS)	**:** a structural assembly that provides for the overall stability of the building and receives wind loads from more than one surface (eg: shear walls, diaphragms, rigid frames, space structures)
Northeaster:	cold, violent storm that occurs along NE coast and last for days
Special Wind Regions:	mountainous areas in the continental US
Straight Line Wind	**:** most common wind type, blows in a straight line
Thunderstorm:	rapidly forming storm that produces high wind speed
Tornado:	rotating column of air that extends from base of thunderstorm to the ground

Leed or sustainable design

Sustainable design: Economics, aesthetics, environments, mechanical systems

Natural step: Organized 1996, preservation of ecosphere & bio sphere (-5 within each to +5 miles above surface of earth).

Natural step principles

-Zone of earth that supports human life is highly fragile eco system last 100 years has affected the earth "wrong" biosphere affecting human is relatively stable & resistant 5 mile in/ out

--Vast majority of technological building environment is inefficient. innovation has improved, but not there

-Toxic substance affect large areas beyond time & space are above "great lakes" is toxic with DDT many years after it has been banned, jet streams bring toxicity elements & pesticides in other continents

-Recycling is only beginning: More buildings to be recyclable & biodegradable

LEED: Cost of design for Engineers & Architects increase

Vandalism: Impact is to use impact resistance materials

In housing projects

-Exterior paths & entrance doors are visible

-Surveillance, well lighted, avoid cursed paths

-Durable & vandal & tamper proof of elements

Planning phasing sustainable projects:

-Use native landscaping- functional, aesthetic..

-Sun orientation (neighbors...) topographic relief

-Scale of other buildings

-Location of project with respect to public transportation

Elements in sustainable design:

-Solar shading devices

-Urban heat island effect

-Fenestration & glazing

Sustainable goals: Use less, recycle, do not deplete natural resources, do not buy from long distance, least amount of demolition, keep existing

LEED indoor air quality: Sick building syndrome: Poor indoor Air Quality based on indoor tobacco smoking, inadequate ventilation, off gassing of fabrics and coatings

Leed substitution by Architects: Architectural supervision: Product substitution to insure original design standards are met

Leed: Requires Architect, Wetland Engineer, Energy Engineer Commissioners, Landscape Architect, Energy Model Engineers

Site selection

Site selection (Every Building): Sun orientation, topographic relief, scaleof adjacent buildings, location of trees and plants, landscaping, avoid erosion surfaces, and area prone to fire.

Next to flood lines 1 ft above and 100 ft away

Be next to public transportation

Flood Plain: Very limited construction: Agricultural or recreation, build only above flood plain, 100 year storm.

Notify Architect: When unknown object are uncovered during construction

CSI Specifications: Security steel gate is In section 10 for Specialties not doors, or metals, or equipments.

Site Preparation: Site clearing, Removal top soil, rough grading, then finish grading.

Ground Motion: Seismic Systems	
Earthquakes	are initiated when (due to slowly accumulated pressure) the ground slips along a fault plane on/near a plate boundary. Earth's crust is divided into several major plates
Waves of vibration	in the earth create ground motion on the earth
Epicenter	occurs on surface directly above the focus point or fault rupture.
Surface faulting	is the crack/split on the surface that is the layperson's vision of earthquakes
Earthquake Design:	against the vibrations caused by fault slippage and try to ensure that building are not built over fault zones. Earthquakes also trigger failure in the form of landslides, liquefaction, and subsidence
Soil/Earthquake impact:	Avoiding sites with a potential for liquefaction, landslides or subsidence requirements the best design approach; Ground shaking triggers subsidence/liquefaction in soils that are unconsolidated/saturated with water; Shaken sandy, water saturated soils cause the bearing capacity to reduce as it; liquefies and flows both laterally and vertically; Well built structures are vulnerable if site conditions/foundation design are ignored
cause of earthquake damage	ground shaking: Affects the building in three ways: internal forces, period/resonance, and torsion; Shaking causes damage by internally generated internal forces that come from the vibration of the building's mass
Mass and Earthquake	Increase in mass (or the weight of the building) will result in an increase in the force for a given execration (lightweight construction preferred)
Failure of vertical elements:	like columns or walls can occur by buckling, when mass pushed down due to gravity experts its force on a member bent or moved out of plumb
Period:	All objects have a natural/fundamental period...the rate at which they will vibrate if they are given a horizontal push; Natural period for a building varies from 0.05 to 2 seconds; Stiffness of construction materials and geometric proportions affect the period; Height is the most important consideration when dealing with period; Natural ground period is 0.4 seconds to 1.5 second; It's possible the motion the ground transmits to the building will be at its natural period; avoid amplification in building vibration not to coincide building period with the ground

Not good periods:	stiff building with short period isn't appropriate on a soft site with a long period. Earthquake shaking tends to be greater on soft ground than on hard ground. Earthquakes are more sever in areas of soft ground
Response spectrum:	shows the accelerations that may be expected at varying periods
Base isolation:	is based on shifting the building period towards the long period of the spectrum where the response is reduced
Close to Fault:	Locations closer to the fault from where the energy is release will experience higher frequency/shorter period ground motion. The farther the building is from the earthquake touch may be subjected to considerable long-period motion
The center of mass, or center of gravity	of an object is the point at which it could be exactly balance without any rotation resulting. Uniformly distributed mass results in the coincidence of a plan's geometric center with the center of mass. If the mass within a floor is uniformly distributed, then the resultant force of the horizontal acceleration of all its particles of mass is exerted through the floor's center. If the resultant of the resistance (walls or frames) pushes back through this point, balance remains
Torsion (very undesirable)	is a twisting action on a building.
Resist and Dissipate seismic energy:	Three basic characteristics of buildings help resist and dissipate the effects of seismically induced motion: damping, ductility, and straight/stiffness
Damping affects:	the dynamic behavior of the building and modifies its response to ground motion. When damped, buildings are inefficient in their vibration and when set in motion, return to their starting position quickly.
Ductility	the property of certain materials, typically steel, to fail only after considerable inelastic (permanent) deformation occurs; Good ductility requires special detailing of joints
Strength and stiffness	two of the most important characteristic of any structure. Analysis of forces is not precise and deliberately errs on the conservative side.
Stiffness (1/Deflection)	Deflection is a measure of stiffness…In the sizing of floor joists, deflection rather than strength governs because no one wants a bouncy floor...even though it's safe. In the design of a floor system, the joists might tolerate a certain deflectionbut the ceiling finish cannot.
Strength	Resisting a given load without exceeding a safe stress in the material is astrength problem
Relative rigidities:	of members are a concern of seismic analyst. As soon as a rigid horizontal element or diaphragm is tied to vertical resisting elements, it will force those elements to deflect the same amount

Environmental

Environmental impact considered site analysis: Reflection, air movement, and sun & shadow patterns. “Not” archeological finds

Development potential of parcel: Verify these issues: wetland/ endangered species/ hazardous waste. Not: acid rain has nothing be controlled.

After “sight” what other senses is important: hearing. “Not”: Touch, smell, taste
To remove noise: best way increase distance to receiver

Architectural Registration Examination

Site Planning Design

USC School of Architecture

"Dr. Saum K. Nour, Ph.D."
PE Civil, PE Electrical, PE Mechanical,
CPD, CIPE, CFPE, **LEED AP, AIA**

snour@Absoluteco.com

3839 Birch, Newport Beach, Ca 92660.
949 852 8700. 949 852 1918 fax

Covering the Nation

Soil damage

Water table:

- When soil is saturated, the line above is water table
- Parallels earth surface
- Varies with seasonal fluctuations
- Precipitation, on ground surface
- In practice: water table to be below foundation to avoid damage [hydro static/ capillary action]
- Water to be drained away "from building"
- Drainage tiles: 6" below lowest floor slab
- Open joists to be covered with wire mesh then coarse gravel or stone back fill
- Slab on grade with no hydrostatic pressure is on gravel fill (6"-8"), water not drawn by capillary
- Sealant are used in all connections

Water table:

Boundary between aeration (zone) & saturation zone

Increased moisture content in bearing soils effects:
Chance in volume and reduction in bearing capacity
“not” increase in cohesion, or decrease in compatibility

Sudden loss of shearing resistance in cohesion less soil

Liquefaction

“Not” plasticity, collapsing soil, or expansive soil

Unstable differential settlement: building failures due to unstable subsoil that causes differential settlement of foundation:

Based on large beds of clay contained in gravel

“not” stratified rocks, small boulders in gravel, or deep layer of dry sand and gravel

Erosion: Removal of vegetarian from site causes erosion
"not" pollution, disorientation, defoliation

To reduce potential vertical movement due to expansive clay:

- Over excavate below footing grade & fill with compacted gravel,
- Extend footings & foundations to a depth of consistent ground moisure
- Drain surface water away from foundation
- Control roof water run off

“Not”: Water proof foundation to reduce filtration plant trees near building to stabilize ground

Settlement: As wp (weight) of buildings increase, soil under footing compresses, reduce void volume then bldg settles. Even bedrock has to be verified slight even settlement is okay.. Differential settlement creates cracks/ failures continuous survey of site as construction occurs is required settlement continuous with time due to void, moisture, movements

Earth movement: Great with easy subsoil, clay swells (wet) & shrinks moisture content @ surface with clay creates each movements @ 5' earth movement is great. Serious issues if footings are different. Adjacent excavations affect clay moisture content this causes settlement or slippage @ sub surface clay slope surface + raw or moisture moves earth mass evidence: Structure with tilt or rows or sloping power poles

Cubic yard: Units measuring cuts & soils is volume "not" square yard (area), acres (area_, tonnage (weight)

Balancing cut & fill is for site grading
“not” Sediment control, land reclamation, footing excavation

Soil:

Soil: Mixture of rock particles, minerals, decayed organic materials (humus), water and air. Soils are different due to variation in composition.

Soil: layer covers regolith layer or loose rocks then the earth crust. Soil has three layers or horizons:

- Horizon A: Top layer: tiny rocks, humus, dark color, spongy, holds more water
- Horizon B: High iron and clay, minerals through rain travel to this
- Horizon C: Slate/Shale from bedrock- Crushed rocks and some minerals leached through rain

Soil of the World: Forest, prairie, Desert, Polar, Mountain, Grassland, Tropical

Forest:
Soil in Forest are not fertile
Very Acidic: Leaves such as pine needle, twigs
Heavy Rain leaches minerals into lower layers (Horizon B)
Top soil is thin
Trees have deep roots for food

Prairie:
prairie soils are fertile
Less rain therefore less leaching
Top soil is deep
High Humus
Without plant covering the soil becomes dry and wind blows away
When no top soil nothing grows

Desert:
Very Fertile
less humus
sparse of top soil with high minerals
irrigation: Crops grow
After two years of irrigation, top soi is too salty to grow

Polar:
Horizon B only.
Perma frost (Permanently frozen)
Tudra areas
Soil is black
water logged
no evaporation or drainage
short seasons
Plants are small
little to decay to make humus

Mountain
Depends on the side of the mountain
Rainy side-
    Lots of Humus
    Top soils to support trees and shrubs
Little grows on the other side
In tropical zone: More top soil if further away from equator

Grassland:
High calcium- Whitish color
Not enough rain to leach
Humus rich and deep
grow wheat and rye
Fertile for grazing

Tropical:
Variety of animals and plants
Fragile soil: Rainfall leaches all minerals
Only Aluminum oxides (Al2O3) and clay to remain
Rusty red color
No accumulation of top soil due to use of humus from dead plants and animals
If no trees, all surfaces would be clay and after the rain, the surface becomes clay rock

Types of Soil

Clay: Fine grained, firm cohesive is introduced by decomposition + hydration of rocks. Clay is plastic (wet) & hard (dry), impervious (relative), swells when absorbing water, shrinks when dry, very unstable & predictable for support of buildings maybe used for foundation & needs engineers.
Clay is smaller than sand or silt. Clay is cohesive.

Silt: Fine grained, sedimentary, <.002" or less
Silt plus water makes mud, soft, sticky, plastic

Sand: Loose granular, .002" to 1/4", not plastic, & not cohesive
"course- grained solid"= sand +gravel=
base foundation relative + excellent drainage =
relatively permeable
quick Sand= sand + moving water, unstable, "sink hole"

Gravel: Larger soil particles with most void has higher permeability than clay, sand, silt. 1/4" to 3 1/2"; greater than 3 1/2"= cobblestone, greater than cobblestone= boulder

Hard pan: Mixture of Gravel, clay, sand   foundation phase

Decomposed rock: Disintegrated rock mass that were solid

Boulders: Rock detached from bedrock

Shale/ slate bedrock: Fine textured soft rock (sheets); Solid material/ earth's crust.

Humus**:** Well decomposed, more or less stable, organic matter in soil, dead plants, animals

Mulch: Conserve moisture and temperature, prevent surface compaction, reduce runoff, and erosion. Improve soil structure and control weed

Muck: combination of soil, water, higher mineral content than peat. The level of decomposed is high and original plant part cannot be identified.

Peat: peat (turf) is an accumulation of partially decayed vegetation matter or histosol. Peat forms in wetland bogs, moors, muskegs, pocosins, mires, and peat swamp forests.

Compost: Used as organic fertilizer; mixed nitrogen and soil. Compost is to permit organic material to become crumbly and to reduce carbon- nitrogen ratio of the material

Mortar: Cement + water+ sand+ Lime; less stiff than concrete and handle with trowel

Concrete/grout: Cement + water+ sand+ Gravel;

Grout: Quite fluid poured in bricks

Compare large amount of loose silt site and organic soil for cost:

Organic soil (peat) is elastic, weak, little cohesion and organic will cost more. It must be removed and replace.

Loose silt can be compacted.

Land has loose fill, sloped, and large area: Site usefulness:

Identify the potentials, level the site and make recreational. Do not deny based on soils.

Bulb tee foundation: Underpinning as a temporary support. Usually in gypsum concrete construction. In bridges, they are permanent.

Building built to next existing building with shallower foundation: Both footings must be at same length. Temporary support: major shoring to take place.

Expansive soil:

Locate the footings in soils below the zone of seasonal moisture change
Extend concrete piers below the zone of seasonal moisture change
Design foundation for soil bearing pressure greater than the swell pressure of the expansive soil
Expansive soil is silty, clayey expands wet
High upward pressure
Oversize the footings will not help- More area for the upward pressure.

Exceeding the load bearing capacity of soil:

Settlement can occur and uneven movement and cracks occur
Structure fails
Mat or raft foundation is good for poor soil
Not enough for poor soil with insufficient soil capacity- Even for mat
Overhanging to a pile is also not sufficient
Piles must transfer to deep bedrock is the only response

Boring and tests:

Soil test - No guessing- Liability

Test pits: Simple excavation, visual excavation of soil condition, soil layer in open pit (access to soil). Do not go below water table

Wash borings: >100', use 2" or 4" diameter + water jet to soften soil to find bed rock (mistake => boulder is not bedrock)

Soil load: Use loading platform, incremental load applied, pressure continues till settlement becomes regular loadings, test= (2) contemplated load tests

Core boring: More cost, more reliable, penetrates thru, diamond blade cut thru rocks, 5"sample taken out for tests. # of bores, locations, Geotechnical Engineer to analyze for city

Dry samples: Drive pipes with special sampling and tip, 5" samples/lifted/stored/test every 5" each, # of bore, location, plus depth

Properties >>>>>>>>>> Foundations >>>>>>>>>>>>Soil bearings

Specific gravity: Density/density of water used to determine void ratio

Grain size: For granular soil) to determine permeability, frost action, compaction, shear strength

Grain shape: To estimate shear strength

Liquid/ plastic limit: (In cohesive soil) to determine compressibility & compaction values

Water content: (Cohesive soil)

Void ratio: To determine compressibility

Slump test: To measure the consistency of a mix. Concrete, mortar and grout stiff to loose.

Unconfined compression: (Cohesive soil) to estimate shear strength

Percolation test: On site sewage disposal for property "not" evaporation test, soil alkalinity, or soil density

Soil exploration & testing: Intrinsic character of soil. "Not" bearing capacity, depth or water table or bedrock

Proctor test: Optimum moisture content and density of soil.

Test boring: Highly accurate data for specific site.

Compacted fill: If soil is soft. Remove and replace with compacted soil. Fill or imported soil. Compact every 6” layer (sheep foot roller). Compacted fill needed for buildings, walkways and pavements.

Sub surface investigation reports includes

- -Field results
- -Laboratory results
- -Foundation type recommendation

"Not”

- -Soil sieve analysis: This is an inner component data only important to lab. analyst

Number of test boring when uniform sub surface. More spaced boring; When building foot print is more complex & square feet is high number of test boring increases

“Not” affected: Encountering firm strata; Regardless of strata, boring extends to 20' min. unless rock is encountered

Geotechnical Engineer: Provides soil characteristics plus bearing capacity of soil

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.	

Footings

Piles are best for low bearing capacity (a boat) transmit load to deeper more firm soil. Structure with heavy loads on dense earth: Structural steel pile

- -Jetted pile= rarely used
- -Wood pile= light for moderate loads
- -Boat footing, mat foundation= low bearing capacity

Pile with "driven to refusal":

Pile driven to a point where additional blows will result in no significant penetration. Pile does not need for bedrock

Wood piles: Where untreated wood piles permitted:

If they are below the longest ground water level.
If untreated wood is constantly wet.
They are in no danger of deterioration.
Wet and dry causes mold and decay.
They are not subject the allowable unit stresses.

Piles: When upper soils have insufficient bearing capacity, then piles transfer loads to firmer soil.

Load on footings= Reduction of soil's void volume, "not" shrinkage, differential settlement, reduce bearing capacity

Ratio of load to bearing capacities are high: best to use mat foundation
area is very high p/a= low match bad bearing capacity (bath tub)

6 story building with 25 ft of loose fill: Great beams and piles extending the loose fill.

Spread footings: Good soil at shallow depth. On re-compacted soil is not economical. Loose leaf with 5 ft depth will not satisfy

Mat foundation: Large whole building mat is only for fair to poor soil. Loose fill is not known to be used with mat foundation.

Foundations: Conventional: Concrete and cost less
Piles: Costly, wider range of materials. Timber, steel, concrete, very slow construction process

Frost:

Frost line level: Foundation design in northern climate is 5ft down dye to frost line level.

"Not" earthquake, against snow drift, rest on undisturbed soil

Frost action: Freezing then thawing---> heave of ground stress to building --> serious damage

Soil frost depth varies frost line= Soil does not freeze below frost line

Frozen footings: Place concrete footings below freeze line. Three to five feet below grade. Below frost penetration

If soil in parking lot rise in winter: Frost and heaving of sub soil - Ice expands

Footing excavation is frozen:

Excavate frozen ground
Never place concrete on frozen ground, when thaw, it shrink and cracks
Hating and thawing: Not practical, not reliable

Frost line in North Dakota: 6 ft

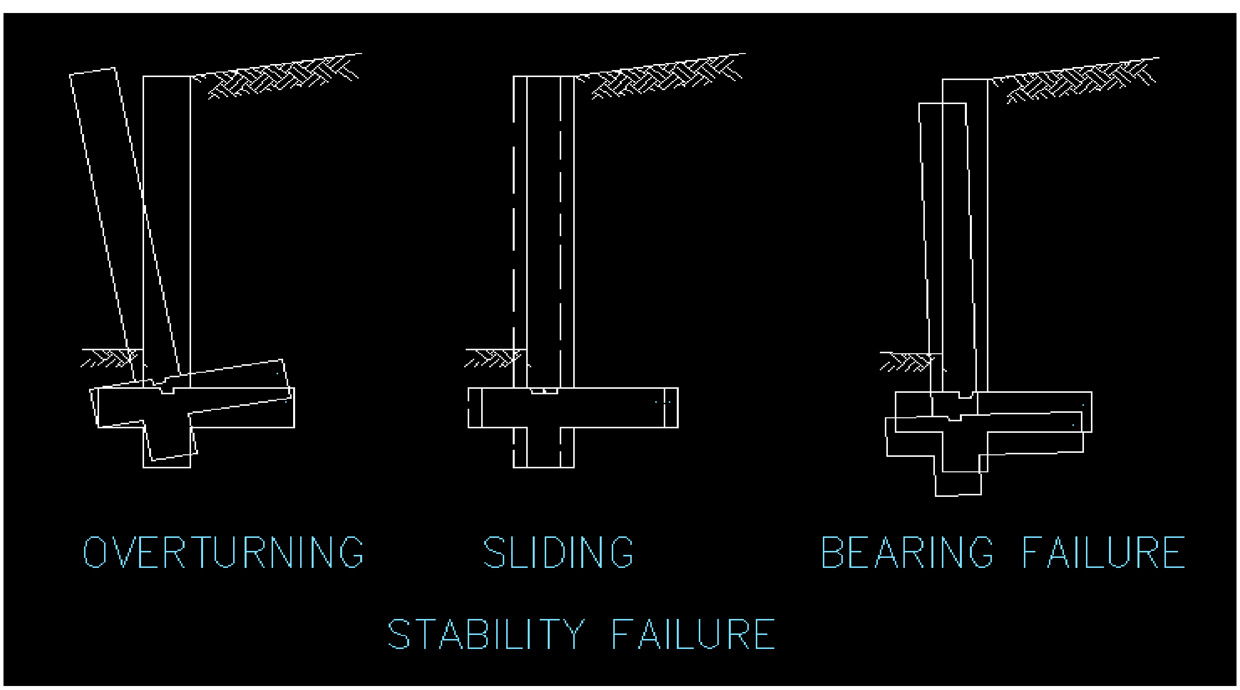
Foundation Types	
Area of Footing =	total wall or column load + weight of footing + any soil on top of footing / allowable soil bearing pressure
Earth Pressure on a wall (P) =	30 lb/ft3 x height of wall
Shallow Footing	Foundation transfers building loads to the earth very near the surface, within 1′-10′. Shallow foundations includes: spread footing foundations, slab-on-grade foundations, and rubble trench foundations.
Spread Footing:	Most economical…$ method. Delivers load directly to soil over a large area,. Strips or pads of concrete which transfer the loads from walls and columns to the soil. Common in residential construction. Relatively simple system considered a shallow foundation system,
Continous Footings	The most frequently used footing type at the exterior wall for load-bearing wall support systems is continuous wall footings. Not: mat footings; pile footings; isolated pad footings
Wall Footings	Most common method. Under a continuous foundation wall that supports a bearing wall
Column Footing:	one footing supports one column
	when 2+ columns are too close to each other or a property
Combined Footing:	line for separate footings, one footing is poured for them all
Strap/Cantilever Footing:	like a combined footing, but columns are far apart
	Very expensive…$$$ method.
Mat Foundations:	Typically it's only used when the strata is weak, It acts as one continuous foundation.
	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.
Pile Foundations:	• 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_
Driven Piles	Prefabricated piles that are driven into the ground by a pile driver. The act of driving the pile causes increased friction, caused by the compression of soil around the pile
Pile Cap	Concrete block into which the heads of the piles are embedded
Drilled Piles	Also known as caissons and CIDH piles. A cavity is bored to the designed depth then a reinforcing cage is introduced, concrete is poured in the bore.
Drilled pier	The drilled pier (caisson) shown above is belled in order **to increase the bearing area**;Not: prevent water infiltration; prevent caving; increase frictional resistance
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
Liquifaction	A loss of soil shear strength resulting in the movement of the surficial soil layers of a building site in a direction parallel to the ground surface under earthquake conditions is most likely caused by liquefiable soils. Not: a low bearing capacity; a gently sloping site;Not: a low bearing capacity; a gently sloping site;
Area of Footing	Area of the footing = load/safe bearing capacity. If the soil bearing capacity is 3000 psf [143 500 N/m2] and the applied load is 48,000 lbs [212 kN], 16 sf [1.5 m2] is the area for the footing.
Slab on Grade –	Concrete slab is poured into a mold (consisting of trenches and wood forms) that is created on site. There is no cavity between the existing earth and concrete. This type of construction is more typically found in warmer climate with out the issues of frost heave
Rubble Trench	Type of foundation that uses loose stone or rubble to minimize the use of concrete and improve drainage. Consisting of a rubble trench and layer which the concrete slab is then poured over.
Deep	Driven, Drilled Foundations

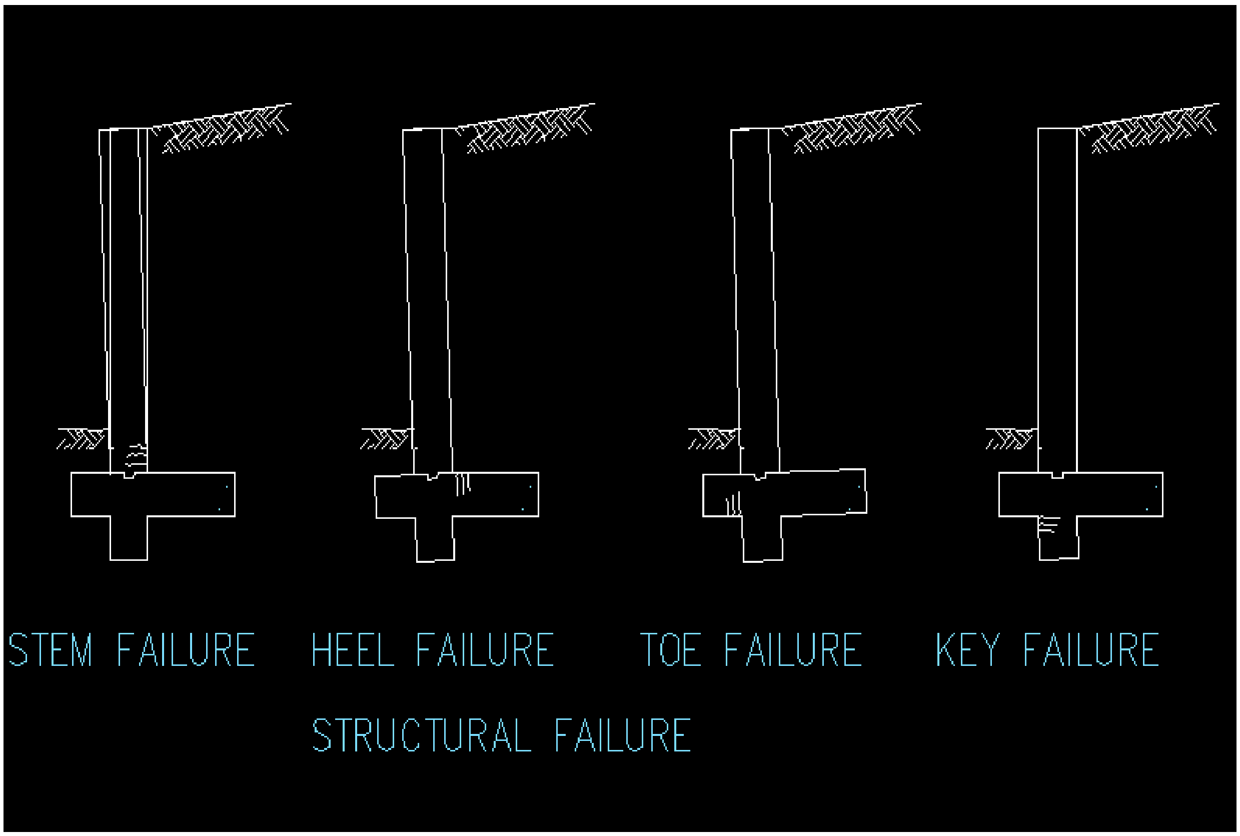
Base Isolation Systems	Designed to deal with seismic forces. It is a collection of structural elements which decouples a superstructure from its substructure in an event of an earthquake. Its goal is to dampen the extreme forces with decoupling isolation units. Some examples are spring-damper systems (similar to an automotive suspension) and sliding units.

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 conterforts 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



Stability failure	(1) Overturning.; (2) Sliding; (3) Bearing capacity.
Structural failure	Bending or shear failure of: stem; heel; toe; key.
retaining wall in slope	rotational stability failure
Stability analysis cantilever retaining wall:	(1) Check factor of safety against overturning; (2) Check soil bearing pressure (3) Check factor of safety against sliding.



Footings:	designed to balance load capacity of the soil and the load required (dictated by the weight of the structure).
Bearing Capacity	The capacity of soil to support the loads applied to the ground. *Ultimate bearing capacity* is the theoretical maximum pressure which can be supported without failure; *allowable bearing capacity* is the ultimate bearing capacity divided by a factor of safety
Testing	Soil Analysis is performed by drilling boring, bringing up sample of soil at various depths. Load test can also be performed at the site.
Soil Types	In descending order of bearing capacity: Rock; gravel and sand; slit and clay; and organic soils.
Settlement/Consolidation	When constant stress is applied to a soil that causes the soil particles to pack together more tightly, thereby reducing its volume.
Differential Settlement	When one part of a foundation settles more than another part.
Climate Influences- Frost Heave	Results from ice forming beneath the surface of soil during freezing conditions. The ice grows in the direction of heat loss (vertically toward the surface) starting at the freezing boundary, frost line, in the soil. The foundation is set below the frost line to counteract frost heave
Expansive Soil	Changes in soil moisture will influence soil volume. Clay soil are especially sensitive to moisture. Piles can be set below the seasonal soil change.
Groundwater	Foundations below the groundwater line with have to be design to counteract hydrostatic pressure

Drainage:

- Begins with grading all water on top surface away from building & out to right- away
- Gutters, flumes, berm, gentle wrap of paved surfaces direct water to drains, catch basins & penetration soil works

Pipe (trench) perforated outside next to foundation footing

-To reduce hydrostatic pressure on water.
"Not"
-Maintain uniform or increase hydrostatic pressure
-Decrease vapor pressure in basement room

Drainage: Connecting on site drainage to existing city drainage

Wastewater collection: Always flows by gravity, pipes at constant slope, mains are below street level (one to two pipes). Grades to transport solids is ½% to 2%, and diameters are up to 4 ft and 20 ft long

Surface water management: Natural or mechanical site drainage systems

Green codes: Minimum volume of water to ground water

Runoff: Amount water- What does not seep into ground beyond saturation. Seepage is function o f porosity, slope, vegetation

5 year storm: Residential
25- 50 year storm: Shopping center

Drainage systems**:** Culvert, guiters, "sheet flows", pipes

"Check dams": To reduce speed at high slopes

Final/ finished ground surface: + positive drainage; Free of un-drained depressions. No water stagnation

To control or avoid erosion: Use channels, pipes, hard surface, lower grade, finally connect to underground pipes
Below traffic & surge pressures (-3 to -4ft in colder area).
Deep excavation may be cost prohibitive.
Destructive wears must be prevented.

Simpler the better: Minimum pipe length, access, slopes, …, filters

Green Code: Swales, surface drainage, native grasses used as green codes
Sub surface drains are function of permeability, depth of drain, size of drain, slope of drain, spacing of joints, perforated PVC/clay

Vapor extraction: Site contamination leads to ground water contamination: Clean up to remediate unsaturated zone: Vapor extraction "not" in situ incineration, bio degradation, photolysis

Extraction/treatment: Ground water remediation projects: Extraction/ treatment
"Not" with in situ aeration, biological barriers/filters, gas chromatography

Water detention areas: Used for control surface water run off,
Not: To create swimming & recreation
To create aesthetically pleasing vistas
To act as reservoir during drought

Permeable water aquifer
Aquifer: Underground permeable material through which water flows

Permeability: A measure of ease with a particular fluid flows through voids. "Not" compressibility, osmosis, or cohesion

Hydrostatic pressure: Fluid force exerting pressure on building.
"Not" dynamic, water, or wedge

If 5 yr storm is not adequate: Go for 10 year storm (100 year too costly), or use growth vegetation area for absorb or swales

To reduce complex drainage system:
Create thick ground cover of plant materials to absorb and slow down
Drainage to collect, conduct, and dispose rain
Paving does not absorb
Best is to greater absorption and percolation- Reduce erosion
Earth berm only diverts flow

Probability of poor drainage:
Flat site, high water table, no storm drain system

Septic tank: Soil must be pervious (permeable). Slope= 1 inch in 24 ft 1 inch/24 ft (not ¼"/ft- too fast). 100 ft from any body of water.

Rain water: Keep natural runoff and runoff after construction the same. Removal of vegetation decreases transpiration, impervious surfaces reduce infiltration.

Slopes

Sheet flows: Land 1 to 1 ½ % slope, adjacent to building: 2%

Drainage ditches: 2 to 10%

Grass slopes: Maximum 25%; turf: <25% for mowing; 25% max. grassland

Un-mowed (planted banks) lawns: Maximum 50% (ivy)
[>50%: Avoid erosion]

Flat: 4% or less- Considered
level <4% ; 4% intensive activity
Moderate: 4--> 10% slope effect to climb/ descend
easy grade 4%to 10%; 4-10% informal
Steep: 10-50 % steep/ unusable
step grade> 10%; >10% limited
>10% is costly & more complications,
split level = very usual
Grassy recreational <3%; 5%< erosion
Un-retained earth cuts: 50% to 100% depending on soil
Walk next to buildings max= 4%
Minimum slope of land 0.5%,
5% slopes of parking
2% away from building
Streets 10% max
Storm drains: 0.3% to 1%
Short ramp 15%
Pedestrians 10%
Parking stalls must have slopes of .5 to 10% max if slope is 25 ft in 100 ft run (25%) the area must be regarded as steep.
Vehicular slope limit is 15%.
Vehicular parking lot ramp: 12% at 32'. Rise @ 8 ft long transitions.
If the slope is greater than 10%, then slope of transitions is to be ½ slope of central portion. 12%/2= 6% and 6% of 8 ft= 5.76 " rise.
Pipes are sloped for self- cleansing (0.3% minimum)
Drainage ditch = 10% max

Legal surveying

Benchmark: Reference point of project

Public land of 1785: Created townships and sections

Easement on private property: Across created.
Not: Daylight, setbacks, landscaping

Land use restriction by authority having jurisdictions: Setbacks, height/area limits/zoning

Not: Covenants (Local restriction- Specific)
Not: Accessibility regulations: (No restriction) must do

Distance & compress bearings: Metes & bonds, "not" chaning- 66', datum elevation, or benchmark

Restrictive covenants on behalf of property owner, not any Engineers, Architects

Right-a-way: A right belonging to a party to pass over land of another.
“Not” : Purchase of land, taking property, picketing/strike

Street

Roadways smallest to largest

Local access streets: Low intensity fronting houses & often in forms of loops or cul de sac

Collector streets: Transition from local access to arterial intersections.
Intersections: Controlled by traffic signals, local streets with stop signs

Arterial streets: Continuous vehicular channels that connect with expressway through ramps generally two to three lanes

Expressways: Large movement between urban center and accesses are limited

Legal constraint on a proposed land:

Deed restrictions: zoning ordinances; easements. "Not" environmental impact statements (EIS). Only +/- impact on potential for the site

Practical & effective dry crawl space?

Provide tight & continuous ground cover using polyethylene film @ least 4 mil thick (vapor barrier floor & sub floor okay but not help)

Non confirming but legal existed prior to enactment of land use is grand fathered, not: -easement -dedicated -aggrieved
Deed restrictions: Legal restrictions imposed on land by private parties on buyers to maintain integrity of property

Zoning ordinances include: limited population density; segregated permitted uses, restricted lot coverage, not include: diminished fire danger.

Spot elevation: Proposed finished elevation of single point. Elevation of key structures such as building corners, manholes, and catch basins.

Seismic or resistivity survey: Limited but reliable but enough for foundation.

Zoning ordinances include: Provide building interiors with natural light and ventilation, inhibit fire spread from building to buildings, eventual widening of the streets, preserve setbacks

Topography

Find elevation on topography: The elevation on the two Contours are 60 and 55 ft the interval is 16 ft. What is the elevation 4 ft away from contour 55

60-55 = 5 ft elevation difference in 16 ft
4 ft is 25% of the distance (4/16)
5 (4/16) = 1.25 ft + 55 ft = 56.25 ft elevation

Slope: (Contour 1- contour 2)/ change in interval= V/H= G = 245-230/5 = 3:1
Topography: Land layout and Site Slope are critical in evaluating site worth and applicability. Cut and fill costs are not cheap.

Topography critical for routing storm water (natural slope)
not water, electric/ gas

Contour lines: Spaced @ given horizontal intervals show elevation of location_ terrain. Continuous elevation lines with equal elevation lines. Dashed lines are existing or natural topography. Solid lines: New modified contour lines. Lines never split and are always same elevations.

Contour lines: In building design: To minimize grading, buildings are designed in parallel to match hill side contour lines.

Contour lines: 5% grade, interval is 1 ft, G = V/H= 5/100= 1 ft/h= > H= 20 ft.

Highly irregular contour lines: Most appropriate for cluster type residential development. Concentrated grouping of residential space in open areas through clusters. Cluster was to condense large number of units. Lengths of street reduced, high roads, and moderate slopes.

Uniform slope: When spacing between contours is equal
Valley: When contours elevation increase outward
Ridge: Increase outward
Steep: When contour lines are close together

Topographic map includes: Property line, easements, and utilities, location of streams, roads, and buildings- Not shown: Soil conditions

Slope of land: Required for sanitary and sewer/storm. Slope is not required for gas, water, or electric

Arial photograph: Terrain conditions, nothing to do with sub-terrain

Parking

Site parking calculation: 50000 sqft, building 10000 sqft, parking: Building (3:1) ratio, 400 sqft per car: Number of parking slots

Building: Parking
10K: ? 1:3--> parking (3X 10K)---> 30K
30000/400= 75 parking

New rental center factor: Accessibility to market area traffic

FAR (Floor to Area Ratio): 30% in 12000 sqft lot. Therefore (0.3*12000)=) 3600 sqft allotted. If four story building, 900 sqft per floor, and 2700 sqft will be above grade.

60 degrees parking= Easy to use, not efficient
90 degree parking= Most efficient
Parking ANSi standard for handicap: 8 ft stall plus 5 ft sides 3 ft curb for access

Parking lot large: Do not do: Dead level paved areas causes ponding of water and dead end aisles creates congestions

Entrance versus exiting parking lot: Slow exit even stop to yield. Entrance faster speed of advancement road

Parking layout

Correct: traffic aisles arranged to serve buildings they serve
> Angled parking requires one way traffic
> Circulation of traffic in parking is continuous
> Slow (not rapid) traffic towards 90 degrees perpendicular parking layout

Area for parking cars: Good/car therefore 300 cars
300*400 cars= 120,000
For retail: 3000 to 4000 sqft parking per 1000 retail space

To reduce vehicle usage: Central city area:
Incentives for car pool, monthly rate parking fee,
-No parking (or united parking) with tax system earmarked for public transportation

Area for parking lot: 325 cars park @90 degrees parking.
325 cars x 400 square feet for = 130,000/ 43560 =2.98 acre

Road/carcirculations: Curviilinear is similar to natural environmental. Others "not" grid, radial, linear

Fastest volume of traffic- Free express way (no stops/lights). Not: Access, distributor, collector, arterial, highway, interchange

Land use and development use: Street system. Not: Topographic, climate (factors) or utility system

Shopping centers to be located @ intersection of arterial/collections

Street design criteria: Curb radii min.= 12'; traffic lanes (12ft); Intersections to be @ right angle; Avoid Compound curves; Parking lanes to be included

Street design criteria:

Light street: 4” roll-curb

Heavy traffic: 6” curb & gutter; 9’0” shoulder on each side of street and concrete paving. Asphalt is best choice. Vehicle width for lanes 11 to 12 ft

Power lines installed above: Are cheaper

Pedestrians circulations: Only safety matters

Non-ambulatory disabilities: Physical layout

2 Wheelchairs pass = 60” in diameter (clear 180 degree turn).

Walkway not interrupted by cracks or edge ½” or more in height.

Walkways not greater than 5% gradient.

Ramp minimum 36” side

Road Position: Gradient is 5%: 5:100

150 ft away elevation 142.5’ on hill

5% of 150 ft= 7.5 ft

142.50 +7.5 = 150 ft <<<<<<<<<<<←--

Parking 361 cars minimum Accessible requirements

Over 150 - 249	5 + two cars per 100
250- 349	7
350- 449	9

Parking: 2 accessible cars stall: 8’+5’+8’ = 21 ft

Landscapes:

Trees: Used for screen wind, increase ventilation

Vegetation: Capture moisture, reduce fog, increase sunlight reaching ground

Plats: Aesthetic value, screen or disguise as required, trees absorb sound

Planted area: Cooler during hot days, less heat loss during night

Deciduous tree: Looses leaves in winter

Coniferous tree: Has leaves throughout the year

Handicap

Handicap design: Path less that 1: 20; ramp< 1:12; <30 ft. max.

Handicap pathway surface: Asphalt surface is the best: smooth, no transition Bad: Tanbark, brick, flag stone are rough on wheel chair

Handicap slope maximum: Ramp 1:12 and flatter the better ramp anything steeper than 1:20 is a ramp.
Ramps other than those are used by non-handicap is limited 1:8

City planning

City planning: Mixture of central business district & presidential

-A viable community asset

"Not "prohibited due to land cost; all substandard units converted to commercial; future units to be low income & elderly

- Best orientation towards sea view: The maximum number of units facing the ocean

Site preparation

-Clear all object

-Demolish her plan

-All utilities to be dealt with

-Undisturbed plants to be protected

-Batter boards offset from building or excavations

-Top 6 inches of soil Removed

Catchment area: Market area or trade area, tributary area from which a facility derives its user population; depending on type & size of shopping center, the catchment area fluctuates with size on basis of traveling & convenience in reaching facility type & size of shopping center is primacy determined by its catchment basis

To reduce cost: Compact low cost housing development main cost: Grading, road construction, utility

Configuration of conventional suburban shopping mall

Axial: Anchor tenants very similar to linear but anchors create main axis for design

Precinctual organizational pattern:

Graduak accumulation of self-contained building complexes.

Each serving distinct activity & interrelated with neighbors. It allows growth in any direction. Flexible/compact

Street

Site issues- Bearing capacity, sub- surface, water shrinkage, seismic, stable earth

Life cycle

Life cycle components under Architect's control:
-Includes construction (15%), Operating, maintenance, & replacement, renovation … are in Architects control
-Not in control taxes & financing
- Financing cost can be reduced for fast track construction
- Higher quality materials reduce long term costs

Climate

Temperature climate:

Best configuration for a temperature climate

-Short wall facing west
-Overhang on long side on south
-Primary heat gain on roof
- Stagger horizontal or vertical
-Stacked high rise

City Planning: City (Northern, CA) or Minnesota best climate design

-Town structure closely dense, larger buildings grouped sheltering wind, but utilize sun/ solar

"Not" design loosely/free layout
-Dense but with shades
-Town character to be loosed/scattered

City planning - Thermal environment: Character of existing & new structures affects thermal environment: Shadow pattern.
"Not": Mechanical system, texture, foot prints

Climatic characteristics: Temperature, humidity, wind velocity

Solstice: Winter December 21st-Longest night, Summer June 21st- Longest day

In hot arid climate:
Thick walls-Thermal mass: Materials with high heat storage value used in arid lands. (Arizona, New Mexico)

Wide overhangs
High ceilings are good designs

Southwest desert buildings:

Most significant: Recognize the climate and other problems of the area.
Deeply recessed openings are best shading for glazing in any directions.
Shaded glass is more important than insulated glass.
Radiation is more value than conduction.
Roof area is not that critical when compared to recessed glazing.
Vertical louvers (especially south) diminish solar radiation

Solar radiation:

South wall get maximum winter radiation.
Roof and east / west walls receive maximum radiation in summer

Cold climates vapor barriers in attic: Minimize moisture migration.
Not: Serve secondary water proofing, support insulation, protection from insects

Roof overhang built in northern hemisphere seasonal adjustment for solar radiation: South facing overhang

Most important factor in residential units: Recieve sun part of winter day
Not: -West facing @ a premium
-Bedrooms away from harsh wind
-Mask units from breezes

Innovative technologies - Cost effective:
Site driven technologies: Wind turbines, photovoltaic, small scale hydroelectric. They are also relatively cost effective.
Fuel cell technologies and groundwater aquifer for cooling and heating depending on climate/environment.

Solar energy is limited in building on north side of high rises. High rises cause shadow on their northerly buildings

Solar: Sun chart shows**:** A) Path of sun by means of attitude & azimuth (21st day month). Sunrise to Sunset
B) Amount of sunshine based
C) Cloudiness not in chart
D) Heating degree days in not in chart

Solar site depends on slope & latitude. All earth @ same latitude gets same sun regardless longitude

Building Orientations: External influences: Climate, noise, views & solar. Foundation is not related.

Town 1 @ base of mountain & town 2 @ 3000' above town 1
Town 2 is always cooler

Rural versus urban climate - Planted rural area**:**
Stabilize microclimate hard surfaces swing temperature fast plants absorbs & store heat. Plats increase transpiration & increase rainfall. Plants purify air

Geothermal: Needs mechanical for design & Architect to implement. Landscape (& structural) not involved. Outside beneath earth

Best use of overhang:

Sun @ low angle is fully captured

Ideal orientation and fenestration based on climate:

Latitude
Adjacent reflective surfaces
Interior room functions
Building heights
Avoid tree screens of sunlight

HVAC is an external to building issue - Secondary concern

Wind

Air movement - Degree of comfort @75 F degrees, 30 R.M., 100 FPM = Quite pleasant.

Less than 50 FPM = Not noticeable.

> 25 F PM: Drafty & annoying

Wind: Open plaza windward side of high rise:

Shelter Hotel, relocate the entrance, placing walls, trees are not very effective

Wind: Two building, smooth surface and one is steps or jagged

-Smooth surface building creates more turbulence, "not" wind acts same way regardless
-Turbulence is more on stepped building energy is dissipated
-Turbulence is a minimum concern in high rise & street

Wind and pressure: When velocity doubles, the pressure quadruples.

$$P = c\,V^2$$

Aerodynamic Pressure:	the interaction between the wind and the building
Basic Wind Speed:	the wind speed with a 50 year average recurrence interval measured at 33'-0" above grade in Exposure C (flat, open terrain) It is a peak gust speed
Building drift:	the distance a building moves in wind
	CONTENT AREA: WIND FORCES
Down Slope Wind:	wind that flows down the slope of a mountain
Downburst:	An area of significantly rain-cooled air that, after reaching ground level, spreads out in all directions producing strong winds. Associated with thunderstorms
Exposure:	classification for the characteristics of the ground roughness and surface irregularities in the vicinity of a building
Hurricane:	spiraling wind systems that converge with increasing speed towards the storm's center (eye)
Main Wind Force Resisting System (MWFRS)	**:** a structural assembly that provides for the overall stability of the building and receives wind loads from more than one surface (eg: shear walls, diaphragms, rigid frames, space structures)
Northeaster:	cold, violent storm that occurs along NE coast and last for days
Special Wind Regions:	mountainous areas in the continental US
Straight Line Wind	**:** most common wind type, blows in a straight line
Thunderstorm:	rapidly forming storm that produces high wind speed
Tornado:	rotating column of air that extends from base of thunderstorm to the ground

Leed or sustainable design

Sustainable design: Economics, aesthetics, environments, mechanical systems

Natural step: Organized 1996, preservation of ecosphere & bio sphere (-5 within each to +5 miles above surface of earth).

Natural step principles

-Zone of earth that supports human life is highly fragile eco system last 100 years has affected the earth "wrong" biosphere affecting human is relatively stable & resistant 5 mile in/ out

--Vast majority of technological building environment is inefficient. innovation has improved, but not there

-Toxic substance affect large areas beyond time & space are above "great lakes" is toxic with DDT many years after it has been banned, jet streams bring toxicity elements & pesticides in other continents

-Recycling is only beginning: More buildings to be recyclable & biodegradable

LEED: Cost of design for Engineers & Architects increase

Vandalism: Impact is to use impact resistance materials

In housing projects

-Exterior paths & entrance doors are visible

-Surveillance, well lighted, avoid cursed paths

-Durable & vandal & tamper proof of elements

Planning phasing sustainable projects:

-Use native landscaping- functional, aesthetic..

-Sun orientation (neighbors...) topographic relief

-Scale of other buildings

-Location of project with respect to public transportation

Elements in sustainable design:

-Solar shading devices

-Urban heat island effect

-Fenestration & glazing

Sustainable goals: Use less, recycle, do not deplete natural resources, do not buy from long distance, least amount of demolition, keep existing

LEED indoor air quality: Sick building syndrome: Poor indoor Air Quality based on indoor tobacco smoking, inadequate ventilation, off gassing of fabrics and coatings

Leed substitution by Architects: Architectural supervision: Product substitution to insure original design standards are met

Leed: Requires Architect, Wetland Engineer, Energy Engineer Commissioners, Landscape Architect, Energy Model Engineers

Site selection

Site selection (Every Building): Sun orientation, topographic relief, scaleof adjacent buildings, location of trees and plants, landscaping, avoid erosion surfaces, and area prone to fire.

Next to flood lines 1 ft above and 100 ft away
Be next to public transportation

Flood Plain: Very limited construction: Agricultural or recreation, build only above flood plain, 100 year storm.

Notify Architect: When unknown object are uncovered during construction

CSI Specifications: Security steel gate is In section 10 for Specialties not doors, or metals, or equipments.

Site Preparation: Site clearing, Removal top soil, rough grading, then finish grading.

Ground Motion: Seismic Systems

Earthquakes	are initiated when (due to slowly accumulated pressure) the ground slips along a fault plane on/near a plate boundary. Earth's crust is divided into several major plates
Waves of vibration	in the earth create ground motion on the earth
Epicenter	occurs on surface directly above the focus point or fault rupture.
Surface faulting	is the crack/split on the surface that is the layperson's vision of earthquakes
Earthquake Design:	against the vibrations caused by fault slippage and try to ensure that building are not built over fault zones. Earthquakes also trigger failure in the form of landslides, liquefaction, and subsidence
Soil/Earthquake impact:	Avoiding sites with a potential for liquefaction, landslides or subsidence requirements the best design approach; Ground shaking triggers subsidence/liquefaction in soils that are unconsolidated/saturated with water; Shaken sandy, water saturated soils cause the bearing capacity to reduce as it; liquefies and flows both laterally and vertically; Well built structures are vulnerable if site conditions/foundation design are ignored
cause of earthquake damage	ground shaking: Affects the building in three ways: internal forces, period/resonance, and torsion; Shaking causes damage by internally generated internal forces that come from the vibration of the building's mass
Mass and Earthquake	Increase in mass (or the weight of the building) will result in an increase in the force for a given execration (lightweight construction preferred)
Failure of vertical elements:	like columns or walls can occur by buckling, when mass pushed down due to gravity experts its force on a member bent or moved out of plumb
Period:	All objects have a natural/fundamental period...the rate at which they will vibrate if they are given a horizontal push; Natural period for a building varies from 0.05 to 2 seconds; Stiffness of construction materials and geometric proportions affect the period; Height is the most important consideration when dealing with period; Natural ground period is 0.4 seconds to 1.5 second; It's possible the motion the ground transmits to the building will be at its natural period; avoid amplification in building vibration not to coincide building period with the ground

Not good periods:	stiff building with short period isn't appropriate on a soft site with a long period. Earthquake shaking tends to be greater on soft ground than on hard ground. Earthquakes are more sever in areas of soft ground
Response spectrum:	shows the accelerations that may be expected at varying periods
Base isolation:	is based on shifting the building period towards the long period of the spectrum where the response is reduced
Close to Fault:	Locations closer to the fault from where the energy is release will experience higher frequency/shorter period ground motion. The farther the building is from the earthquake touch may be subjected to considerable long-period motion
The center of mass, or center of gravity	of an object is the point at which it could be exactly balance without any rotation resulting. Uniformly distributed mass results in the coincidence of a plan's geometric center with the center of mass. If the mass within a floor is uniformly distributed, then the resultant force of the horizontal acceleration of all its particles of mass is exerted through the floor's center. If the resultant of the resistance (walls or frames) pushes back through this point, balance remains
Torsion (very undesirable)	is a twisting action on a building.
Resist and Dissipate seismic energy:	Three basic characteristics of buildings help resist and dissipate the effects of seismically induced motion: damping, ductility, and straight/stiffness
Damping affects:	the dynamic behavior of the building and modifies its response to ground motion. When damped, buildings are inefficient in their vibration and when set in motion, return to their starting position quickly.
Ductility	the property of certain materials, typically steel, to fail only after considerable inelastic (permanent) deformation occurs; Good ductility requires special detailing of joints
Strength and stiffness	two of the most important characteristic of any structure. Analysis of forces is not precise and deliberately errs on the conservative side.
Stiffness (1/Deflection)	Deflection is a measure of stiffness…In the sizing of floor joists, deflection rather than strength governs because no one wants a bouncy floor...even though it's safe. In the design of a floor system, the joists might tolerate a certain deflectionbut the ceiling finish cannot.
Strength	Resisting a given load without exceeding a safe stress in the material is astrength problem
Relative rigidities:	of members are a concern of seismic analyst. As soon as a rigid horizontal element or diaphragm is tied to vertical resisting elements, it will force those elements to deflect the same amount

Environmental

Environmental impact considered site analysis: Reflection, air movement, and sun & shadow patterns. “Not” archeological finds

Development potential of parcel: Verify these issues: wetland/ endangered species/ hazardous waste. Not: acid rain has nothing be controlled.

After “sight” what other senses is important: hearing. “Not”: Touch, smell, taste
To remove noise: best way increase distance to receiver

Architectural Registration Examination

Site Planning Design

USC School of Architecture

"Dr. Saum K. Nour, Ph.D."
PE Civil, PE Electrical, PE Mechanical,
CPD, CIPE, CFPE, **LEED AP, AIA**

snour@Absoluteco.com

3839 Birch, Newport Beach, Ca 92660.
949 852 8700. 949 852 1918 fax

Covering the Nation

Soil damage

Water table:

- When soil is saturated, the line above is water table
- Parallels earth surface
- Varies with seasonal fluctuations
- Precipitation, on ground surface
- In practice: water table to be below foundation to avoid damage [hydro static/ capillary action]
- Water to be drained away "from building"
- Drainage tiles: 6" below lowest floor slab
- Open joists to be covered with wire mesh then coarse gravel or stone back fill
- Slab on grade with no hydrostatic pressure is on gravel fill (6"-8"), water not drawn by capillary
- Sealant are used in all connections

Water table:

Boundary between aeration (zone) & saturation zone

Increased moisture content in bearing soils effects:
Chance in volume and reduction in bearing capacity
“not” increase in cohesion, or decrease in compatibility

Sudden loss of shearing resistance in cohesion less soil

Liquefaction

“Not” plasticity, collapsing soil, or expansive soil

Unstable differential settlement: building failures due to unstable subsoil that causes differential settlement of foundation:

Based on large beds of clay contained in gravel

“not” stratified rocks, small boulders in gravel, or deep layer of dry sand and gravel

Erosion: Removal of vegetarian from site causes erosion
"not" pollution, disorientation, defoliation

To reduce potential vertical movement due to expansive clay:

- Over excavate below footing grade & fill with compacted gravel,
- Extend footings & foundations to a depth of consistent ground moisure
- Drain surface water away from foundation
- Control roof water run off

“Not”: Water proof foundation to reduce filtration plant trees near building to stabilize ground

Settlement: As wp (weight) of buildings increase, soil under footing compresses, reduce void volume then bldg settles. Even bedrock has to be verified slight even settlement is okay.. Differential settlement creates cracks/ failures continuous survey of site as construction occurs is required settlement continuous with time due to void, moisture, movements

Earth movement: Great with easy subsoil, clay swells (wet) & shrinks moisture content @ surface with clay creates each movements @ 5' earth movement is great. Serious issues if footings are different. Adjacent excavations affect clay moisture content this causes settlement or slippage @ sub surface clay slope surface + raw or moisture moves earth mass evidence: Structure with tilt or rows or sloping power poles

Cubic yard: Units measuring cuts & soils is volume "not" square yard (area), acres (area_, tonnage (weight)

Balancing cut & fill is for site grading
“not” Sediment control, land reclamation, footing excavation

Soil:

Soil: Mixture of rock particles, minerals, decayed organic materials (humus), water and air. Soils are different due to variation in composition.

Soil: layer covers regolith layer or loose rocks then the earth crust. Soil has three layers or horizons:

- Horizon A: Top layer: tiny rocks, humus, dark color, spongy, holds more water
- Horizon B: High iron and clay, minerals through rain travel to this
- Horizon C: Slate/Shale from bedrock- Crushed rocks and some minerals leached through rain

Soil of the World: Forest, prairie, Desert, Polar, Mountain, Grassland, Tropical

Forest:
Soil in Forest are not fertile
Very Acidic: Leaves such as pine needle, twigs
Heavy Rain leaches minerals into lower layers (Horizon B)
Top soil is thin
Trees have deep roots for food

Prairie:
prairie soils are fertile
Less rain therefore less leaching
Top soil is deep
High Humus
Without plant covering the soil becomes dry and wind blows away
When no top soil nothing grows

Desert:
Very Fertile
less humus
sparse of top soil with high minerals
irrigation: Crops grow
After two years of irrigation, top soi is too salty to grow

Polar:
Horizon B only.
Perma frost (Permanently frozen)
Tudra areas
Soil is black
water logged
no evaporation or drainage
short seasons
Plants are small
little to decay to make humus

Mountain
Depends on the side of the mountain
Rainy side-
    Lots of Humus
    Top soils to support trees and shrubs
Little grows on the other side
In tropical zone: More top soil if further away from equator

Grassland:
High calcium- Whitish color
Not enough rain to leach
Humus rich and deep
grow wheat and rye
Fertile for grazing

Tropical:
Variety of animals and plants
Fragile soil: Rainfall leaches all minerals
Only Aluminum oxides (Al2O3) and clay to remain
Rusty red color
No accumulation of top soil due to use of humus from dead plants and animals
If no trees, all surfaces would be clay and after the rain, the surface becomes clay rock

Types of Soil

Clay: Fine grained, firm cohesive is introduced by decomposition + hydration of rocks. Clay is plastic (wet) & hard (dry), impervious (relative), swells when absorbing water, shrinks when dry, very unstable & predictable for support of buildings maybe used for foundation & needs engineers.
Clay is smaller than sand or silt. Clay is cohesive.

Silt: Fine grained, sedimentary, <.002" or less
Silt plus water makes mud, soft, sticky, plastic

Sand: Loose granular, .002" to 1/4", not plastic, & not cohesive
"course- grained solid"= sand +gravel=
base foundation relative + excellent drainage =
relatively permeable
quick Sand= sand + moving water, unstable, "sink hole"

Gravel: Larger soil particles with most void has higher permeability than clay, sand, silt. 1/4" to 3 1/2"; greater than 3 1/2"= cobblestone, greater than cobblestone= boulder

Hard pan: Mixture of Gravel, clay, sand foundation phase

Decomposed rock: Disintegrated rock mass that were solid

Boulders: Rock detached from bedrock

Shale/ slate bedrock: Fine textured soft rock (sheets); Solid material/ earth's crust.

Humus**:** Well decomposed, more or less stable, organic matter in soil, dead plants, animals

Mulch: Conserve moisture and temperature, prevent surface compaction, reduce runoff, and erosion. Improve soil structure and control weed

Muck: combination of soil, water, higher mineral content than peat. The level of decomposed is high and original plant part cannot be identified.

Peat: peat (turf) is an accumulation of partially decayed vegetation matter or histosol. Peat forms in wetland bogs, moors, muskegs, pocosins, mires, and peat swamp forests.

Compost: Used as organic fertilizer; mixed nitrogen and soil. Compost is to permit organic material to become crumbly and to reduce carbon- nitrogen ratio of the material

Mortar: Cement + water+ sand+ Lime; less stiff than concrete and handle with trowel

Concrete/grout: Cement + water+ sand+ Gravel;

Grout: Quite fluid poured in bricks

Compare large amount of loose silt site and organic soil for cost:

Organic soil (peat) is elastic, weak, little cohesion and organic will cost more. It must be removed and replace.

Loose silt can be compacted.

Land has loose fill, sloped, and large area: Site usefulness:

Identify the potentials, level the site and make recreational. Do not deny based on soils.

Bulb tee foundation: Underpinning as a temporary support. Usually in gypsum concrete construction. In bridges, they are permanent.

Building built to next existing building with shallower foundation: Both footings must be at same length. Temporary support: major shoring to take place.

Expansive soil:

Locate the footings in soils below the zone of seasonal moisture change
Extend concrete piers below the zone of seasonal moisture change
Design foundation for soil bearing pressure greater than the swell pressure of the expansive soil
Expansive soil is silty, clayey expands wet
High upward pressure
Oversize the footings will not help- More area for the upward pressure.

Exceeding the load bearing capacity of soil:

Settlement can occur and uneven movement and cracks occur
Structure fails
Mat or raft foundation is good for poor soil
Not enough for poor soil with insufficient soil capacity- Even for mat
Overhanging to a pile is also not sufficient
Piles must transfer to deep bedrock is the only response

Boring and tests:

Soil test - No guessing- Liability

Test pits: Simple excavation, visual excavation of soil condition, soil layer in open pit (access to soil). Do not go below water table

Wash borings: >100', use 2" or 4" diameter + water jet to soften soil to find bed rock (mistake => boulder is not bedrock)

Soil load: Use loading platform, incremental load applied, pressure continues till settlement becomes regular loadings, test= (2) contemplated load tests

Core boring: More cost, more reliable, penetrates thru, diamond blade cut thru rocks, 5"sample taken out for tests. # of bores, locations, Geotechnical Engineer to analyze for city

Dry samples: Drive pipes with special sampling and tip, 5" samples/lifted/stored/test every 5" each, # of bore, location, plus depth

Properties >>>>>>>>>> Foundations >>>>>>>>>>>>Soil bearings

Specific gravity: Density/density of water used to determine void ratio

Grain size: For granular soil) to determine permeability, frost action, compaction, shear strength

Grain shape: To estimate shear strength

Liquid/ plastic limit: (In cohesive soil) to determine compressibility & compaction values

Water content: (Cohesive soil)

Void ratio: To determine compressibility

Slump test: To measure the consistency of a mix. Concrete, mortar and grout stiff to loose.

Unconfined compression: (Cohesive soil) to estimate shear strength

Percolation test: On site sewage disposal for property "not" evaporation test, soil alkalinity, or soil density

Soil exploration & testing: Intrinsic character of soil. "Not" bearing capacity, depth or water table or bedrock

Proctor test: Optimum moisture content and density of soil.

Test boring: Highly accurate data for specific site.

Compacted fill: If soil is soft. Remove and replace with compacted soil. Fill or imported soil. Compact every 6” layer (sheep foot roller). Compacted fill needed for buildings, walkways and pavements.

Sub surface investigation reports includes

- -Field results
- -Laboratory results
- -Foundation type recommendation

"Not”

- -Soil sieve analysis: This is an inner component data only important to lab. analyst

Number of test boring when uniform sub surface. More spaced boring; When building foot print is more complex & square feet is high number of test boring increases

“Not” affected: Encountering firm strata; Regardless of strata, boring extends to 20' min. unless rock is encountered

Geotechnical Engineer: Provides soil characteristics plus bearing capacity of soil

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.	

Footings

Piles are best for low bearing capacity (a boat) transmit load to deeper more firm soil. Structure with heavy loads on dense earth: Structural steel pile

-Jetted pile= rarely used
-Wood pile= light for moderate loads
-Boat footing, mat foundation= low bearing capacity

Pile with "driven to refusal":

Pile driven to a point where additional blows will result in no significant penetration. Pile does not need for bedrock

Wood piles: Where untreated wood piles permitted:

If they are below the longest ground water level.
If untreated wood is constantly wet.
They are in no danger of deterioration.
Wet and dry causes mold and decay.
They are not subject the allowable unit stresses.

Piles: When upper soils have insufficient bearing capacity, then piles transfer loads to firmer soil.

Load on footings= Reduction of soil's void volume, "not" shrinkage, differential settlement, reduce bearing capacity

Ratio of load to bearing capacities are high: best to use mat foundation
area is very high p/a= low match bad bearing capacity (bath tub)

6 story building with 25 ft of loose fill: Great beams and piles extending the loose fill.

Spread footings: Good soil at shallow depth. On re-compacted soil is not economical. Loose leaf with 5 ft depth will not satisfy

Mat foundation: Large whole building mat is only for fair to poor soil. Loose fill is not known to be used with mat foundation.

Foundations: Conventional: Concrete and cost less
Piles: Costly, wider range of materials. Timber, steel, concrete, very slow construction process

Frost:

Frost line level: Foundation design in northern climate is 5ft down dye to frost line level.

"Not" earthquake, against snow drift, rest on undisturbed soil

Frost action: Freezing then thawing---> heave of ground stress to building --> serious damage

Soil frost depth varies frost line= Soil does not freeze below frost line

Frozen footings: Place concrete footings below freeze line. Three to five feet below grade. Below frost penetration

If soil in parking lot rise in winter: Frost and heaving of sub soil - Ice expands

Footing excavation is frozen:

Excavate frozen ground
Never place concrete on frozen ground, when thaw, it shrink and cracks
Hating and thawing: Not practical, not reliable

Frost line in North Dakota: 6 ft

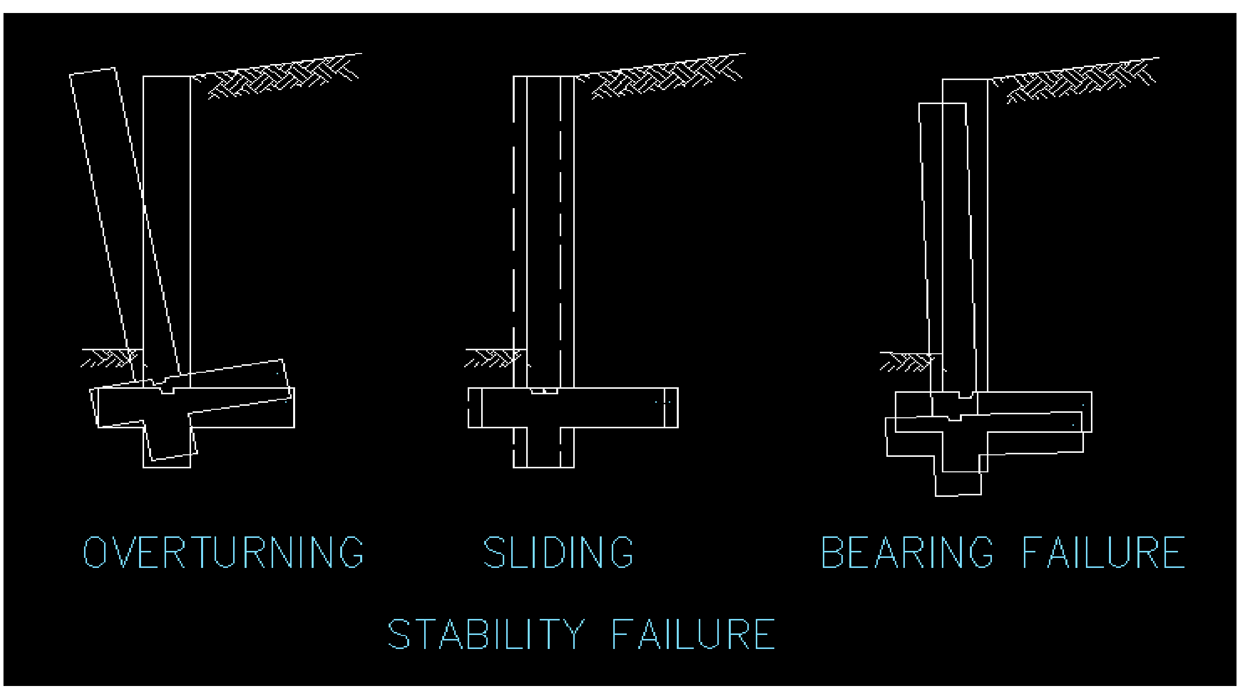
Foundation Types	
Area of Footing =	total wall or column load + weight of footing + any soil on top of footing / allowable soil bearing pressure
Earth Pressure on a wall (P) =	30 lb/ft3 x height of wall
Shallow Footing	Foundation transfers building loads to the earth very near the surface, within 1′-10′. Shallow foundations includes: spread footing foundations, slab-on-grade foundations, and rubble trench foundations.
Spread Footing:	Most economical…$ method. Delivers load directly to soil over a large area,. Strips or pads of concrete which transfer the loads from walls and columns to the soil. Common in residential construction. Relatively simple system considered a shallow foundation system,
Continous Footings	The most frequently used footing type at the exterior wall for load-bearing wall support systems is continuous wall footings. Not: mat footings; pile footings; isolated pad footings
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_
Driven Piles	Prefabricated piles that are driven into the ground by a pile driver. The act of driving the pile causes increased friction, caused by the compression of soil around the pile
Pile Cap	Concrete block into which the heads of the piles are embedded
Drilled Piles	Also known as caissons and CIDH piles. A cavity is bored to the designed depth then a reinforcing cage is introduced, concrete is poured in the bore.
Drilled pier	The drilled pier (caisson) shown above is belled in order **to increase the bearing area**;Not: prevent water infiltration; prevent caving; increase frictional resistance
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
Liquifaction	A loss of soil shear strength resulting in the movement of the surficial soil layers of a building site in a direction parallel to the ground surface under earthquake conditions is most likely caused by liquefiable soils. Not: a low bearing capacity; a gently sloping site;Not: a low bearing capacity; a gently sloping site;
Area of Footing	Area of the footing = load/safe bearing capacity. If the soil bearing capacity is 3000 psf [143 500 N/m2] and the applied load is 48,000 lbs [212 kN], 16 sf [1.5 m2] is the area for the footing.
Slab on Grade –	Concrete slab is poured into a mold (consisting of trenches and wood forms) that is created on site. There is no cavity between the existing earth and concrete. This type of construction is more typically found in warmer climate with out the issues of frost heave
Rubble Trench	Type of foundation that uses loose stone or rubble to minimize the use of concrete and improve drainage. Consisting of a rubble trench and layer which the concrete slab is then poured over.
Deep	Driven, Drilled Foundations

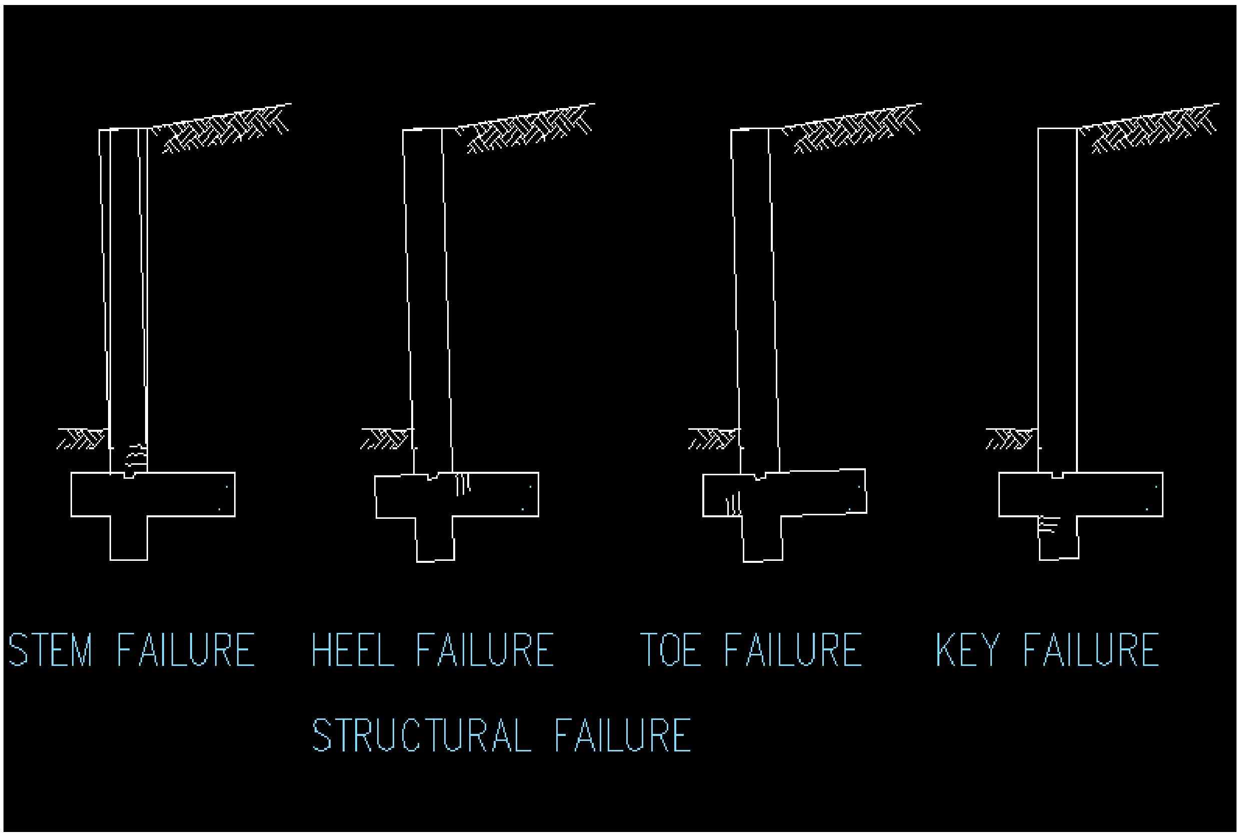
Base Isolation Systems	Designed to deal with seismic forces. It is a collection of structural elements which decouples a superstructure from its substructure in an event of an earthquake. Its goal is to dampen the extreme forces with decoupling isolation units. Some examples are spring-damper systems (similar to an automotive suspension) and sliding units.

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 conterforts 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



Stability failure	(1) Overturning.; (2) Sliding; (3) Bearing capacity.
Structural failure	Bending or shear failure of: stem; heel; toe; key.
retaining wall in slope	rotational stability failure
Stability analysis cantilever retaining wall:	(1) Check factor of safety against overturning; (2) Check soil bearing pressure (3) Check factor of safety against sliding.



Footings:	designed to balance load capacity of the soil and the load required (dictated by the weight of the structure).
Bearing Capacity	The capacity of soil to support the loads applied to the ground. *Ultimate bearing capacity* is the theoretical maximum pressure which can be supported without failure; *allowable bearing capacity* is the ultimate bearing capacity divided by a factor of safety
Testing	Soil Analysis is performed by drilling boring, bringing up sample of soil at various depths. Load test can also be performed at the site.
Soil Types	In descending order of bearing capacity: Rock; gravel and sand; slit and clay; and organic soils.
Settlement/Consolidation	When constant stress is applied to a soil that causes the soil particles to pack together more tightly, thereby reducing its volume.
Differential Settlement	When one part of a foundation settles more than another part.
Climate Influences- Frost Heave	Results from ice forming beneath the surface of soil during freezing conditions. The ice grows in the direction of heat loss (vertically toward the surface) starting at the freezing boundary, frost line, in the soil. The foundation is set below the frost line to counteract frost heave
Expansive Soil	Changes in soil moisture will influence soil volume. Clay soil are especially sensitive to moisture. Piles can be set below the seasonal soil change.
Groundwater	Foundations below the groundwater line with have to be design to counteract hydrostatic pressure

Drainage:

- Begins with grading all water on top surface away from building & out to right- away
- Gutters, flumes, berm, gentle wrap of paved surfaces direct water to drains, catch basins & penetration soil works

Pipe (trench) perforated outside next to foundation footing
-To reduce hydrostatic pressure on water.
"Not"
-Maintain uniform or increase hydrostatic pressure
-Decrease vapor pressure in basement room

Drainage: Connecting on site drainage to existing city drainage

Wastewater collection: Always flows by gravity, pipes at constant slope, mains are below street level (one to two pipes). Grades to transport solids is ½% to 2%, and diameters are up to 4 ft and 20 ft long

Surface water management: Natural or mechanical site drainage systems

Green codes: Minimum volume of water to ground water

Runoff: Amount water- What does not seep into ground beyond saturation.
Seepage is function o f porosity, slope, vegetation

5 year storm: Residential
25- 50 year storm: Shopping center

Drainage systems**:** Culvert, guiters, "sheet flows", pipes

"Check dams": To reduce speed at high slopes

Final/ finished ground surface: + positive drainage; Free of un-drained depressions. No water stagnation

To control or avoid erosion: Use channels, pipes, hard surface, lower grade, finally connect to underground pipes
Below traffic & surge pressures (-3 to -4ft in colder area).
Deep excavation may be cost prohibitive.
Destructive wears must be prevented.

Simpler the better: Minimum pipe length, access, slopes, …, filters

Green Code: Swales, surface drainage, native grasses used as green codes
Sub surface drains are function of permeability, depth of drain, size of drain, slope of drain, spacing of joints, perforated PVC/clay

Vapor extraction: Site contamination leads to ground water contamination: Clean up to remediate unsaturated zone: Vapor extraction "not" in situ incineration, bio degradation, photolysis

Extraction/treatment: Ground water remediation projects: Extraction/ treatment
“Not” with in situ aeration, biological barriers/filters, gas chromatography

Water detention areas: Used for control surface water run off,
Not: To create swimming & recreation
To create aesthetically pleasing vistas
To act as reservoir during drought

Permeable water aquifer
Aquifer: Underground permeable material through which water flows

Permeability: A measure of ease with a particular fluid flows through voids. "Not" compressibility, osmosis, or cohesion

Hydrostatic pressure: Fluid force exerting pressure on building.
“Not” dynamic, water, or wedge

If 5 yr storm is not adequate: Go for 10 year storm (100 year too costly), or use growth vegetation area for absorb or swales

To reduce complex drainage system:
Create thick ground cover of plant materials to absorb and slow down
Drainage to collect, conduct, and dispose rain
Paving does not absorb
Best is to greater absorption and percolation- Reduce erosion
Earth berm only diverts flow

Probability of poor drainage:
Flat site, high water table, no storm drain system

Septic tank: Soil must be pervious (permeable). Slope= 1 inch in 24 ft 1 inch/24 ft (not ¼”/ft- too fast). 100 ft from any body of water.

Rain water: Keep natural runoff and runoff after construction the same. Removal of vegetation decreases transpiration, impervious surfaces reduce infiltration.

Slopes

Sheet flows: Land 1 to 1 ½ % slope, adjacent to building: 2%

Drainage ditches: 2 to 10%

Grass slopes: Maximum 25%; turf: <25% for mowing; 25% max. grassland

Un-mowed (planted banks) lawns: Maximum 50% (ivy)
[>50%: Avoid erosion]

Flat: 4% or less- Considered
level <4% ; 4% intensive activity
Moderate: 4--> 10% slope effect to climb/ descend
easy grade 4%to 10%; 4-10% informal
Steep: 10-50 % steep/ unusable
step grade> 10%; >10% limited
>10% is costly & more complications,
split level = very usual
Grassy recreational <3%; 5%< erosion
Un-retained earth cuts: 50% to 100% depending on soil
Walk next to buildings max= 4%
Minimum slope of land 0.5%,
5% slopes of parking
2% away from building
Streets 10% max
Storm drains: 0.3% to 1%
Short ramp 15%
Pedestrians 10%
Parking stalls must have slopes of .5 to 10% max if slope is 25 ft in 100 ft run (25%) the area must be regarded as steep.
Vehicular slope limit is 15%.
Vehicular parking lot ramp: 12% at 32'. Rise @ 8 ft long transitions.
If the slope is greater than 10%, then slope of transitions is to be ½ slope of central portion. 12%/2= 6% and 6% of 8 ft= 5.76 " rise.
Pipes are sloped for self- cleansing (0.3% minimum)
Drainage ditch = 10% max

Legal surveying

Benchmark: Reference point of project

Public land of 1785: Created townships and sections

Easement on private property: Across created.
Not: Daylight, setbacks, landscaping

Land use restriction by authority having jurisdictions: Setbacks, height/area limits/zoning

Not: Covenants (Local restriction- Specific)
Not: Accessibility regulations: (No restriction) must do

Distance & compress bearings: Metes & bonds, "not" chaning- 66', datum elevation, or benchmark

Restrictive covenants on behalf of property owner, not any Engineers, Architects

Right-a-way: A right belonging to a party to pass over land of another.
"Not" : Purchase of land, taking property, picketing/strike

Street

Roadways smallest to largest

Local access streets: Low intensity fronting houses & often in forms of loops or cul de sac

Collector streets: Transition from local access to arterial intersections.
Intersections: Controlled by traffic signals, local streets with stop signs

Arterial streets: Continuous vehicular channels that connect with expressway through ramps generally two to three lanes

Expressways: Large movement between urban center and accesses are limited

Legal constraint on a proposed land:

Deed restrictions: zoning ordinances; easements. "Not" environmental impact statements (EIS). Only +/- impact on potential for the site

Practical & effective dry crawl space?

Provide tight & continuous ground cover using polyethylene film @ least 4 mil thick (vapor barrier floor & sub floor okay but not help)

Non confirming but legal existed prior to enactment of land use is grand fathered, not: -easement -dedicated -aggrieved
Deed restrictions: Legal restrictions imposed on land by private parties on buyers to maintain integrity of property

Zoning ordinances include: limited population density; segregated permitted uses, restricted lot coverage, not include: diminished fire danger.

Spot elevation: Proposed finished elevation of single point. Elevation of key structures such as building corners, manholes, and catch basins.

Seismic or resistivity survey: Limited but reliable but enough for foundation.

Zoning ordinances include: Provide building interiors with natural light and ventilation, inhibit fire spread from building to buildings, eventual widening of the streets, preserve setbacks

Topography

Find elevation on topography: The elevation on the two Contours are 60 and 55 ft the interval is 16 ft. What is the elevation 4 ft away from contour 55

60-55 = 5 ft elevation difference in 16 ft
4 ft is 25% of the distance (4/16)
5 (4/16) = 1.25 ft + 55 ft = 56.25 ft elevation

Slope: (Contour 1- contour 2)/ change in interval= V/H= G = 245-230/5 = 3:1
Topography: Land layout and Site Slope are critical in evaluating site worth and applicability. Cut and fill costs are not cheap.

Topography critical for routing storm water (natural slope)
not water, electric/ gas

Contour lines: Spaced @ given horizontal intervals show elevation of location_ terrain. Continuous elevation lines with equal elevation lines. Dashed lines are existing or natural topography. Solid lines: New modified contour lines. Lines never split and are always same elevations.

Contour lines: In building design: To minimize grading, buildings are designed in parallel to match hill side contour lines.

Contour lines: 5% grade, interval is 1 ft, G = V/H= 5/100= 1 ft/h= > H= 20 ft.

Highly irregular contour lines: Most appropriate for cluster type residential development. Concentrated grouping of residential space in open areas through clusters. Cluster was to condense large number of units. Lengths of street reduced, high roads, and moderate slopes.

Uniform slope: When spacing between contours is equal
Valley: When contours elevation increase outward
Ridge: Increase outward
Steep: When contour lines are close together

Topographic map includes: Property line, easements, and utilities, location of streams, roads, and buildings- Not shown: Soil conditions

Slope of land: Required for sanitary and sewer/storm. Slope is not required for gas, water, or electric

Arial photograph: Terrain conditions, nothing to do with sub-terrain

Parking

Site parking calculation: 50000 sqft, building 10000 sqft, parking: Building (3:1) ratio, 400 sqft per car: Number of parking slots

Building: Parking
10K: ? 1:3--> parking (3X 10K)---> 30K
30000/400= 75 parking

New rental center factor: Accessibility to market area traffic

FAR (Floor to Area Ratio): 30% in 12000 sqft lot. Therefore (0.3*12000)=) 3600 sqft allotted. If four story building, 900 sqft per floor, and 2700 sqft will be above grade.

60 degrees parking= Easy to use, not efficient
90 degree parking= Most efficient
Parking ANSi standard for handicap: 8 ft stall plus 5 ft sides 3 ft curb for access

Parking lot large: Do not do: Dead level paved areas causes ponding of water and dead end aisles creates congestions

Entrance versus exiting parking lot: Slow exit even stop to yield. Entrance faster speed of advancement road

Parking layout

Correct: traffic aisles arranged to serve buildings they serve
> Angled parking requires one way traffic
> Circulation of traffic in parking is continuous
> Slow (not rapid) traffic towards 90 degrees perpendicular parking layout

Area for parking cars: Good/car therefore 300 cars
300*400 cars= 120,000
For retail: 3000 to 4000 sqft parking per 1000 retail space

To reduce vehicle usage: Central city area:
Incentives for car pool, monthly rate parking fee,
-No parking (or united parking) with tax system earmarked for public transportation

Area for parking lot: 325 cars park @90 degrees parking.
325 cars x 400 square feet for = 130,000/ 43560 =2.98 acre

Road/carcirculations: Curviilinear is similar to natural environmental. Others "not" grid, radial, linear

Fastest volume of traffic- Free express way (no stops/lights). Not: Access, distributor, collector, arterial, highway, interchange

Land use and development use: Street system. Not: Topographic, climate (factors) or utility system

Shopping centers to be located @ intersection of arterial/collections

Street design criteria: Curb radii min.= 12'; traffic lanes (12ft); Intersections to be @ right angle; Avoid Compound curves; Parking lanes to be included

Street design criteria:

Light street: 4" roll-curb

Heavy traffic: 6" curb & gutter; 9'0" shoulder on each side of street and concrete paving. Asphalt is best choice. Vehicle width for lanes 11 to 12 ft

Power lines installed above: Are cheaper

Pedestrians circulations: Only safety matters
Non-ambulatory disabilities: Physical layout

2 Wheelchairs pass = 60" in diameter (clear 180 degree turn).
Walkway not interrupted by cracks or edge ½" or more in height.
Walkways not greater than 5% gradient.
Ramp minimum 36" side

Road Position: Gradient is 5%: 5:100
150 ft away elevation 142.5' on hill
5% of 150 ft= 7.5 ft
142.50 +7.5 = 150 ft <<<<<<<<<<<←--

Parking 361 cars minimum Accessible requirements

Over	150 - 249	5 + two cars per 100
	250- 349	7
	350- 449	9

Parking: 2 accessible cars stall: 8'+5'+8' = 21 ft

Landscapes:

Trees: Used for screen wind, increase ventilation

Vegetation: Capture moisture, reduce fog, increase sunlight reaching ground

Plats: Aesthetic value, screen or disguise as required, trees absorb sound

Planted area: Cooler during hot days, less heat loss during night

Deciduous tree: Looses leaves in winter

Coniferous tree: Has leaves throughout the year

Handicap

Handicap design: Path less that 1: 20; ramp< 1:12; <30 ft. max.

Handicap pathway surface: Asphalt surface is the best: smooth, no transition Bad: Tanbark, brick, flag stone are rough on wheel chair

Handicap slope maximum: Ramp 1:12 and flatter the better ramp anything steeper than 1:20 is a ramp.
Ramps other than those are used by non-handicap is limited 1:8

City planning

City planning: Mixture of central business district & presidential

-A viable community asset

"Not "prohibited due to land cost; all substandard units converted to commercial; future units to be low income & elderly

- Best orientation towards sea view: The maximum number of units facing the ocean

Site preparation

-Clear all object

-Demolish her plan

-All utilities to be dealt with

-Undisturbed plants to be protected

-Batter boards offset from building or excavations

-Top 6 inches of soil Removed

Catchment area: Market area or trade area, tributary area from which a facility derives its user population; depending on type & size of shopping center, the catchment area fluctuates with size on basis of traveling & convenience in reaching facility type & size of shopping center is primacy determined by its catchment basis

To reduce cost: Compact low cost housing development main cost: Grading, road construction, utility

Configuration of conventional suburban shopping mall

Axial: Anchor tenants very similar to linear but anchors create main axis for design

Precinctual organizational pattern:

Graduak accumulation of self-contained building complexes.

Each serving distinct activity & interrelated with neighbors. It allows growth in any direction. Flexible/compact

Street

Site issues- Bearing capacity, sub- surface, water shrinkage, seismic, stable earth

Life cycle

Life cycle components under Architect's control:

-Includes construction (15%), Operating, maintenance, & replacement, renovation … are in Architects control

-Not in control taxes & financing

- Financing cost can be reduced for fast track construction
- Higher quality materials reduce long term costs

Climate

Temperature climate:

Best configuration for a temperature climate

-Short wall facing west
-Overhang on long side on south
-Primary heat gain on roof
- Stagger horizontal or vertical
-Stacked high rise

City Planning: City (Northern, CA) or Minnesota best climate design

-Town structure closely dense, larger buildings grouped sheltering wind, but utilize sun/ solar

"Not" design loosely/free layout
-Dense but with shades
-Town character to be loosed/scattered

City planning - Thermal environment: Character of existing & new structures affects thermal environment: Shadow pattern.
"Not": Mechanical system, texture, foot prints

Climatic characteristics: Temperature, humidity, wind velocity

Solstice: Winter December 21st-Longest night, Summer June 21st- Longest day

In hot arid climate:
Thick walls-Thermal mass: Materials with high heat storage value used in arid lands. (Arizona, New Mexico)

Wide overhangs
High ceilings are good designs

Southwest desert buildings:

Most significant: Recognize the climate and other problems of the area.
Deeply recessed openings are best shading for glazing in any directions.
Shaded glass is more important than insulated glass.
Radiation is more value than conduction.
Roof area is not that critical when compared to recessed glazing.
Vertical louvers (especially south) diminish solar radiation

Solar radiation:

South wall get maximum winter radiation.
Roof and east / west walls receive maximum radiation in summer

Cold climates vapor barriers in attic: Minimize moisture migration.
Not: Serve secondary water proofing, support insulation, protection from insects

Roof overhang built in northern hemisphere seasonal adjustment for solar radiation: South facing overhang

Most important factor in residential units: Recieve sun part of winter day
Not: -West facing @ a premium
-Bedrooms away from harsh wind
-Mask units from breezes

Innovative technologies - Cost effective:
Site driven technologies: Wind turbines, photovoltaic, small scale hydroelectric. They are also relatively cost effective.
Fuel cell technologies and groundwater aquifer for cooling and heating depending on climate/environment.

Solar energy is limited in building on north side of high rises. High rises cause shadow on their northerly buildings

Solar: Sun chart shows**:** A) Path of sun by means of attitude & azimuth (21st day month). Sunrise to Sunset
B) Amount of sunshine based
C) Cloudiness not in chart
D) Heating degree days in not in chart

Solar site depends on slope & latitude. All earth @ same latitude gets same sun regardless longitude

Building Orientations: External influences: Climate, noise, views & solar. Foundation is not related.

Town 1 @ base of mountain & town 2 @ 3000' above town 1
Town 2 is always cooler

Rural versus urban climate - Planted rural area**:**
Stabilize microclimate hard surfaces swing temperature fast plants absorbs & store heat. Plats increase transpiration & increase rainfall. Plants purify air

Geothermal: Needs mechanical for design & Architect to implement. Landscape (& structural) not involved. Outside beneath earth

Best use of overhang:

Sun @ low angle is fully captured

Ideal orientation and fenestration based on climate:

Latitude
Adjacent reflective surfaces
Interior room functions
Building heights
Avoid tree screens of sunlight

HVAC is an external to building issue - Secondary concern

Wind

Air movement - Degree of comfort @75 F degrees, 30 R.M., 100 FPM = Quite pleasant.

Less than 50 FPM = Not noticeable.

> 25 F PM: Drafty & annoying

Wind: Open plaza windward side of high rise:
Shelter Hotel, relocate the entrance, placing walls, trees are not very effective

Wind: Two building, smooth surface and one is steps or jagged

-Smooth surface building creates more turbulence, "not" wind acts same way regardless
-Turbulence is more on stepped building energy is dissipated
-Turbulence is a minimum concern in high rise & street

Wind and pressure: When velocity doubles, the pressure quadruples.

$$P = c V^2$$

Aerodynamic Pressure:	the interaction between the wind and the building
Basic Wind Speed:	the wind speed with a 50 year average recurrence interval measured at 33'-0" above grade in Exposure C (flat, open terrain) It is a peak gust speed
Building drift:	the distance a building moves in wind
	CONTENT AREA: WIND FORCES
Down Slope Wind:	wind that flows down the slope of a mountain
Downburst:	An area of significantly rain-cooled air that, after reaching ground level, spreads out in all directions producing strong winds. Associated with thunderstorms
Exposure:	classification for the characteristics of the ground roughness and surface irregularities in the vicinity of a building
Hurricane:	spiraling wind systems that converge with increasing speed towards the storm's center (eye)
Main Wind Force Resisting System (MWFRS)	**:** a structural assembly that provides for the overall stability of the building and receives wind loads from more than one surface (eg: shear walls, diaphragms, rigid frames, space structures)
Northeaster:	cold, violent storm that occurs along NE coast and last for days
Special Wind Regions:	mountainous areas in the continental US
Straight Line Wind	**:** most common wind type, blows in a straight line
Thunderstorm:	rapidly forming storm that produces high wind speed
Tornado:	rotating column of air that extends from base of thunderstorm to the ground

Leed or sustainable design

Sustainable design: Economics, aesthetics, environments, mechanical systems

Natural step: Organized 1996, preservation of ecosphere & bio sphere (-5 within each to +5 miles above surface of earth).

Natural step principles

-Zone of earth that supports human life is highly fragile eco system last 100 years has affected the earth "wrong" biosphere affecting human is relatively stable & resistant 5 mile in/ out

--Vast majority of technological building environment is inefficient. innovation has improved, but not there

-Toxic substance affect large areas beyond time & space are above "great lakes" is toxic with DDT many years after it has been banned, jet streams bring toxicity elements & pesticides in other continents

-Recycling is only beginning: More buildings to be recyclable & biodegradable

LEED: Cost of design for Engineers & Architects increase
Vandalism: Impact is to use impact resistance materials
In housing projects

-Exterior paths & entrance doors are visible
-Surveillance, well lighted, avoid cursed paths
-Durable & vandal & tamper proof of elements

Planning phasing sustainable projects:

-Use native landscaping- functional, aesthetic..
-Sun orientation (neighbors...) topographic relief
-Scale of other buildings
-Location of project with respect to public transportation

Elements in sustainable design:

-Solar shading devices
-Urban heat island effect
-Fenestration & glazing

Sustainable goals: Use less, recycle, do not deplete natural resources, do not buy from long distance, least amount of demolition, keep existing

LEED indoor air quality: Sick building syndrome: Poor indoor Air Quality based on indoor tobacco smoking, inadequate ventilation, off gassing of fabrics and coatings

Leed substitution by Architects: Architectural supervision: Product substitution to insure original design standards are met

Leed: Requires Architect, Wetland Engineer, Energy Engineer Commissioners, Landscape Architect, Energy Model Engineers

Site selection

Site selection (Every Building): Sun orientation, topographic relief, scaleof adjacent buildings, location of trees and plants, landscaping, avoid erosion surfaces, and area prone to fire.

Next to flood lines 1 ft above and 100 ft away
Be next to public transportation

Flood Plain: Very limited construction: Agricultural or recreation, build only above flood plain, 100 year storm.

Notify Architect: When unknown object are uncovered during construction

CSI Specifications: Security steel gate is In section 10 for Specialties not doors, or metals, or equipments.

Site Preparation: Site clearing, Removal top soil, rough grading, then finish grading.

Ground Motion: Seismic Systems

Earthquakes	are initiated when (due to slowly accumulated pressure) the ground slips along a fault plane on/near a plate boundary. Earth's crust is divided into several major plates
Waves of vibration	in the earth create ground motion on the earth
Epicenter	occurs on surface directly above the focus point or fault rupture.
Surface faulting	is the crack/split on the surface that is the layperson's vision of earthquakes
Earthquake Design:	against the vibrations caused by fault slippage and try to ensure that building are not built over fault zones. Earthquakes also trigger failure in the form of landslides, liquefaction, and subsidence
Soil/Earthquake impact:	Avoiding sites with a potential for liquefaction, landslides or subsidence requirements the best design approach; Ground shaking triggers subsidence/liquefaction in soils that are unconsolidated/saturated with water; Shaken sandy, water saturated soils cause the bearing capacity to reduce as it; liquefies and flows both laterally and vertically; Well built structures are vulnerable if site conditions/foundation design are ignored
cause of earthquake damage	ground shaking: Affects the building in three ways: internal forces, period/resonance, and torsion; Shaking causes damage by internally generated internal forces that come from the vibration of the building's mass
Mass and Earthquake	Increase in mass (or the weight of the building) will result in an increase in the force for a given execration (lightweight construction preferred)
Failure of vertical elements:	like columns or walls can occur by buckling, when mass pushed down due to gravity experts its force on a member bent or moved out of plumb
Period:	All objects have a natural/fundamental period...the rate at which they will vibrate if they are given a horizontal push; Natural period for a building varies from 0.05 to 2 seconds; Stiffness of construction materials and geometric proportions affect the period; Height is the most important consideration when dealing with period; Natural ground period is 0.4 seconds to 1.5 second; It's possible the motion the ground transmits to the building will be at its natural period; avoid amplification in building vibration not to coincide building period with the ground

Not good periods:	stiff building with short period isn't appropriate on a soft site with a long period. Earthquake shaking tends to be greater on soft ground than on hard ground. Earthquakes are more sever in areas of soft ground
Response spectrum:	shows the accelerations that may be expected at varying periods
Base isolation:	is based on shifting the building period towards the long period of the spectrum where the response is reduced
Close to Fault:	Locations closer to the fault from where the energy is release will experience higher frequency/shorter period ground motion. The farther the building is from the earthquake touch may be subjected to considerable long-period motion
The center of mass, or center of gravity	of an object is the point at which it could be exactly balance without any rotation resulting. Uniformly distributed mass results in the coincidence of a plan's geometric center with the center of mass. If the mass within a floor is uniformly distributed, then the resultant force of the horizontal acceleration of all its particles of mass is exerted through the floor's center. If the resultant of the resistance (walls or frames) pushes back through this point, balance remains
Torsion (very undesirable)	is a twisting action on a building.
Resist and Dissipate seismic energy:	Three basic characteristics of buildings help resist and dissipate the effects of seismically induced motion: damping, ductility, and straight/stiffness
Damping affects:	the dynamic behavior of the building and modifies its response to ground motion. When damped, buildings are inefficient in their vibration and when set in motion, return to their starting position quickly.
Ductility	the property of certain materials, typically steel, to fail only after considerable inelastic (permanent) deformation occurs; Good ductility requires special detailing of joints
Strength and stiffness	two of the most important characteristic of any structure. Analysis of forces is not precise and deliberately errs on the conservative side.
Stiffness (1/Deflection)	Deflection is a measure of stiffness…In the sizing of floor joists, deflection rather than strength governs because no one wants a bouncy floor...even though it's safe. In the design of a floor system, the joists might tolerate a certain deflectionbut the ceiling finish cannot.
Strength	Resisting a given load without exceeding a safe stress in the material is astrength problem
Relative rigidities:	of members are a concern of seismic analyst. As soon as a rigid horizontal element or diaphragm is tied to vertical resisting elements, it will force those elements to deflect the same amount

Environmental

Environmental impact considered site analysis: Reflection, air movement, and sun & shadow patterns. “Not” archeological finds

Development potential of parcel: Verify these issues: wetland/ endangered species/ hazardous waste. Not: acid rain has nothing be controlled.

After “sight” what other senses is important: hearing. “Not”: Touch, smell, taste
To remove noise: best way increase distance to receiver

Architectural Registration Examination

Building Systems- Intro

"Dr. Saum K. Nour, Ph.D."

PE Civil, PE Electrical, PE Mechanical, CPD, CIPE, CFPE, **LEED AP, AIA**

snour@Absoluteco.com

3839 Birch, Newport Beach, Ca 92660. 949 852 8700. 949 852 1918 fax

Covering the Nation

Building Systems- Intro

DIVISION STATEMENT

Evaluate, select, and integrate mechanical, electrical, and specialty systems in building design and construction.

Content Areas

1. CODES & REGULATIONS (5-8% Score)
2. ENVIRONMENTAL ISSUES (10-15% Score)
3. PLUMBING (10-15% Score)
4. HVAC (18-23% Score)
5. ELECTRICAL (10-15% Score)
6. LIGHTING (18-23% Score)
7. SPECIALTIES (14-19% Score)

Vignettes

MECHANICAL & ELECTRICAL PLAN

Develop a reflected ceiling plan that integrates ceiling, lighting, mechanical, and structural systems and incorporates life safety considerations.

KNOWLEDGE / SKILLS

The division has been broken down into a listing of knowledge and skills directly related to each major content area.

1. CODES & REGULATIONS

A. Incorporate building codes, specialty codes, and other regulatory requirements in the design of mechanical, electrical, plumbing, conveying, and other specialty systems.

1. Government and Regulatory Requirements and Permit Processes
Building and life-safety codes affecting mechanical, electrical, acoustic, and lighting systems including thermal and moisture protection and adaptive reuse.

Most stringent and restrictive code applies when there are two competing or conflicting codes:

Not: State code vs Local vs Federal code

Cleanout in a system is the location for rooting the clogs' at beginning or logistically located within the sewer pipes

2. ENVIRONMENTAL ISSUES

A. Apply sustainable design principles to the selection, design, and construction of building systems.

Building Envelope Design Guide

BEDG
BUILDING ENVELOPE DESIGN GUIDE

The National Institute of Building Sciences (NIBS) under guidance from the Federal Envelope Advisory Committee has developed this comprehensive guide for exterior envelope design and construction for institutional / office buildings. The Envelope Design Guide (EDG) is continually being improved and updated through the Building Enclosure Councils (BECs). Any edits, revisions, updates or interest in adding new information should be directed to the BEDG Review Committee through the 'Comment' link on this page.

Introduction

Below Grade Systems

- Foundation Walls
- Floor Slabs
- Plazas, Tunnels, Vaults

Wall Systems

- Cast-In-Place Concrete
- Exterior Insulation and Finish System (EIFS)
- Masonry
- Panelized Metal
- Precast Concrete
- Thin Stone

Fenestration Systems

- Glazing
- Windows
- Curtain Walls
- Sloped Glazing
- Exterior Doors

Roofing Systems

Atria Systems

Related Resource Pages

- Air Barrier Systems in Buildings
- Blast Safety
- Seismic Safety
- Wind Safety
- Flood Resistance
- Indoor Air Quality and Mold Prevention
- CBR Safety
- Sustainability
- HVAC Integration
- Extensive Vegetative Roofs

1. Building Design
Examine environmental and sustainable principles and theories affecting the design of building engineering systems.

What Makes a Building Green?

A green building, also known as a sustainable building, is a structure that is designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. Green buildings are designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment.

What Are the Economic Benefits of Green Buildings?

A green building may cost more up front, but saves through lower operating costs over the life of the building. The green building approach applies a project life cycle cost analysis for determining the appropriate up-front expenditure. This analytical method calculates costs over the useful life of the asset.

These and other cost savings can only be fully realized when they are incorporated at the project's conceptual design phase with the assistance of an integrated team of professionals. The integrated systems approach ensures that the building is designed as one system rather than a collection of stand-alone systems.

Some benefits, such as improving occupant health, comfort, productivity, reducing pollution and landfill waste are not easily quantified. Consequently, they are not adequately considered in cost analysis. For this reason, consider setting aside a small portion of the building budget to cover differential costs associated with less tangible green building benefits or to cover the cost of researching and analyzing green building options.

Even with a tight budget, many green building measures can be incorporated with minimal or zero increased up-front costs and they can yield enormous savings(Environmental Building News, 1999).

What Are the Elements of Green Buildings?

Below is a sampling of green building practices.

Siting

- Start by selecting a site well suited to take advantage of mass transit.
- Protect and retain existing landscaping and natural features. Select plants that have low water and pesticide needs, and generate minimum plant trimmings. Use compost and mulches. This will save water and time.
- Recycled content paving materials, furnishings, and mulches help close the recycling loop.

Energy Efficiency

Most buildings can reach energy efficiency levels far beyond California Title 24 standards, yet most only strive to meet the standard. It is reasonable to strive for 40 percent less energy than Title 24 standards. The following strategies contribute to this goal.

Passive design strategies can dramatically affect building energy performance. These measures include building shape and orientation, passive solar design, and the use of natural lighting.

Develop strategies to provide natural lighting. Studies have shown that it has a positive impact on productivity and well being.

Install high-efficiency lighting systems with advanced lighting controls. Include motion sensors tied to dimmable lighting controls. Task lighting reduces general overhead light levels.

Use a properly sized and energy-efficient heat/cooling system in conjunction with a thermally efficient building shell. Maximize light colors for roofing and wall finish materials; install high R-value wall and ceiling insulation; and use minimal glass on east and west exposures.

Minimize the electric loads from lighting, equipment, and appliances.

Consider alternative energy sources such as photovoltaics and fuel cells that are now available in new products and applications. Renewable energy sources provide a great symbol of emerging technologies for the future.

Computer modeling is an extremely useful tool in optimizing design of electrical and mechanical systems and the building shell.

Materials Efficiency

Select sustainable construction materials and products by evaluating several characteristics such as reused and recycled content, zero or low off gassing of harmful air emissions, zero or low toxicity, sustainably harvested materials, high recyclability, durability, longevity, and local production. Such products promote resource conservation and efficiency. Using recycled-content products also helps develop markets for recycled materials that are being diverted from California's landfills, as mandated by the Integrated Waste Management Act.

Use dimensional planning and other material efficiency strategies. These strategies reduce the amount of building materials needed and cut construction costs. For example, design rooms on 4-foot multiples to conform to standard-sized wallboard and plywood sheets.

Reuse and recycle construction and demolition materials. For example, using inert demolition materials as a base course for a parking lot keeps materials out of landfills and costs less.

Require plans for managing materials through deconstruction, demolition, and construction.

Design with adequate space to facilitate recycling collection and to incorporate a solid waste management program that prevents waste generation.

Water Efficiency

Design for dual plumbing to use recycled water for toilet flushing or a gray water system that recovers rainwater or other nonpotable water for site irrigation.

Minimize wastewater by using ultra low-flush toilets, low-flow shower heads, and other water conserving fixtures.

Use recirculating systems for centralized hot water distribution.

Install point-of-use hot water heating systems for more distant locations.

Use a water budget approach that schedules irrigation using the California Irrigation Management Information System data for landscaping.

Meter the landscape separately from buildings. Use micro-irrigation (which excludes sprinklers and high-pressure sprayers) to supply water in nonturf areas.

Use state-of-the-art irrigation controllers and self-closing nozzles on hoses.

Occupant Health and Safety

Recent studies reveal that buildings with good overall environmental quality can reduce the rate of respiratory disease, allergy, asthma, sick building symptoms, and enhance worker performance. The potential financial benefits of improving indoor environments exceed costs by a factor of 8 and 14 (Fisk and Rosenfeld, 1998).

Choose construction materials and interior finish products with zero or low emissions to improve indoor air quality. Many building materials and cleaning/maintenance products emit toxic gases, such as volatile organic compounds (VOC) and formaldehyde. These gases can have a detrimental impact on occupants' health and productivity.

Provide adequate ventilation and a high-efficiency, in-duct filtration system. Heating and cooling systems that ensure adequate ventilation and proper filtration can have a dramatic and positive impact on indoor air quality.

Prevent indoor microbial contamination through selection of materials resistant to microbial growth, provide effective drainage from the roof and surrounding landscape, install adequate ventilation in bathrooms, allow proper drainage of air-conditioning coils, and design other building systems to control humidity.

Building Operation and Maintenance

Green building measures cannot achieve their goals unless they work as intended. Building commissioning includes testing and adjusting the mechanical, electrical, and plumbing systems to ensure that all equipment meets design criteria. It also includes instructing the staff on the operation and maintenance of equipment.

Over time, building performance can be assured through measurement, adjustment, and upgrading. Proper maintenance ensures that a building continues to perform as designed and commissioned.

2. Building Systems and their Integration

Consider relative environmental and sustainable design principles and details for integration into building engineering systems.

3. Implications of Design Decisions
Assess the impact of design decisions on aspects such as universal design, construction cost, operating costs, construction schedules, and flexibility.
4. Construction Details
Examine construction details for building engineering systems pertaining to environmental and sustainable design.
5. Indoor Air Quality
Examine the effects of building engineering systems and design on the quality of indoor air and related health issues.

What Causes Indoor Air Problems?

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 in enough outdoor air to dilute emissions from indoor sources and by not carrying indoor air pollutants out of the home. High temperature and humidity levels can also increase concentrations of some pollutants.

Pollutant Sources

There are many sources of indoor air pollution in any home. These include combustion sources such as oil, gas, kerosene, coal, wood, and tobacco products; building materials and furnishings as diverse as deteriorated, asbestos-containing insulation, wet or damp carpet, and cabinetry or furniture made of certain pressed wood products; products for household cleaning and maintenance, personal care, or hobbies; central heating and cooling systems and humidification devices; and outdoor sources such as radon, pesticides, and outdoor air pollution.

The relative importance of any single source depends on how much of a given pollutant it emits and how hazardous those emissions are. In some cases, factors such as how old the source is and whether it is properly maintained are significant. For example, an improperly adjusted gas stove can emit significantly more carbon monoxide than one that is properly adjusted.

Some sources, such as building materials, furnishings, and household products like air fresheners, release pollutants more or less continuously. Other sources, related to activities carried out in the home, release pollutants intermittently. These include smoking, the use of unvented or malfunctioning stoves, furnaces, or space heaters, the use of solvents in cleaning and hobby activities, the use of paint strippers in redecorating activities, and the use of cleaning products and pesticides in house-keeping. High pollutant concentrations can remain in the air for long periods after some of these activities.

Top of page

Amount of Ventilation

If too little outdoor air enters a home, pollutants can accumulate to levels that can pose health and comfort problems. Unless they are built with special mechanical means of ventilation, homes that are designed and constructed to minimize the amount of outdoor air that can "leak" into and out of the home may have higher pollutant levels than other homes. However, because some weather conditions can drastically reduce the amount of outdoor air that enters a home, pollutants can build up even in homes that are normally considered "leaky".

How Does Outdoor Air Enter a House?

Outdoor air enters and leaves a house by: infiltration, natural ventilation, and mechanical ventilation. In a process known as infiltration, outdoor air flows into the house through openings, joints, and cracks in walls, floors, and ceilings, and around windows and doors. In natural ventilation, air moves through opened windows and doors. Air movement associated with infiltration and natural ventilation is caused by air temperature differences between indoors and outdoors and by wind. Finally, there are a number of mechanical ventilation devices, from outdoor-vented fans that intermittently remove air from a single room, such as bathrooms and kitchen, to air handling systems that use fans and duct work to continuously remove indoor air and distribute filtered and conditioned outdoor air to strategic points throughout the house. The rate at which outdoor air replaces indoor air is described as the air exchange rate. When there is little infiltration, natural ventilation, or mechanical ventilation, the air exchange rate is low and pollutant levels can increase. Read more about ventilation in buildings

Top of page

Indoor Air Pollution and Health

Health effects from indoor air pollutants may be experienced soon after exposure or, possibly, years later.

Immediate effects

Immediate effects may show up after a single exposure or repeated exposures. These include irritation of the eyes, nose, and throat, headaches, dizziness, and fatigue. Such immediate effects are usually short-term and treatable. Sometimes the treatment is simply eliminating the person's exposure to the source of the pollution, if it can be identified. Symptoms of some diseases, including asthma, hypersensitivity pneumonitis, and humidifier fever, may also show up soon after exposure to some indoor air pollutants.

The likelihood of immediate reactions to indoor air pollutants depends on several factors. Age and preexisting medical conditions are two important influences. In other cases, whether a person reacts to a pollutant depends on individual sensitivity, which varies tremendously from person to person. Some people can become sensitized to biological pollutants after repeated exposures, and it appears that some people can become sensitized to chemical pollutants as well.

Certain immediate effects are similar to those from colds or other viral diseases, so it is often difficult to determine if the symptoms are a result of exposure to indoor air pollution. For this reason, it is important to pay attention to the time and place symptoms occur. If the symptoms fade or go away when a person is away from home, for example, an effort should be made to identify indoor air sources that may be possible causes. Some effects may be made worse by an inadequate supply of outdoor air or from the heating, cooling, or humidity conditions prevalent in the home.

Long-term effects

Other health effects may show up either years after exposure has occurred or only after long or repeated periods of exposure. These effects, which include some respiratory diseases, heart disease, and cancer, can be severely debilitating or fatal. It is prudent to try to improve the indoor air quality in your home even if symptoms are not noticeable.

While pollutants commonly found in indoor air are responsible for many harmful effects, there is considerable uncertainty about what concentrations or periods of exposure are necessary to produce specific health problems. People also react very differently to exposure to indoor air pollutants. Further research is needed to better understand which health effects occur after exposure to the average pollutant concentrations found in homes and which occurs from the higher concentrations that occur for short periods of time.

Top of page

Additional Resources

- Basic Information About Indoor Air Quality
- There are three basic strategies to improve indoor air quality
- Measuring Pollutant Levels and Weatherizing Your Home
- What if You Live in an Apartment?
- Do You Suspect Your Office Has an Indoor Air Problem?
- "The Inside Story: A Guide to Indoor Air Quality"

Top of page

About the Indoor Environments Division

The EPA's Indoor Environments Division (IED) is responsible for conducting research and educating the public about indoor environmental issues, including health risks and the means by which human exposures can be reduced. IED educates the public about health risks associated with a variety of indoor environmental pollutants and sources of pollution, including radon, mold and moisture, secondhand smoke, indoor wood smoke, and environmental asthma triggers.

The Indoor Environments Division has created partnership with public and private sector entities to help encourage the public to take action to minimize their risk and mitigate indoor air quality problems. In some cases, IED is able to provide funding support through cooperative agreements, such as with tribes, non-profit public health organizations and industry. Read more about Cooperative Agreement Funding in IED.

6. Sustainable Design
Manage adaptive reuse, recycling, and renewable resources related to engineering building system selection and design. Analyze environmental design and principles of building engineering systems related to life cycle, operations and maintenance analysis. Review resource management and conservation principles affecting the use of materials and energy consumption in building design, including the selection and use of energy, energy conservation, and waste management.

Sustainable Design

Sustainable design seeks to reduce negative impacts on the environment, and the health and comfort of building occupants, thereby improving building performance. The basic objectives of sustainability are to reduce consumption of non-renewable resources, minimize waste, and create healthy, productive environments.

Sustainable design principles include the ability to:

- optimize site potential;
- minimize non-renewable energy consumption;
- use environmentally preferable products;
- protect and conserve water;
- enhance indoor environmental quality; and
- optimize operational and maintenance practices.

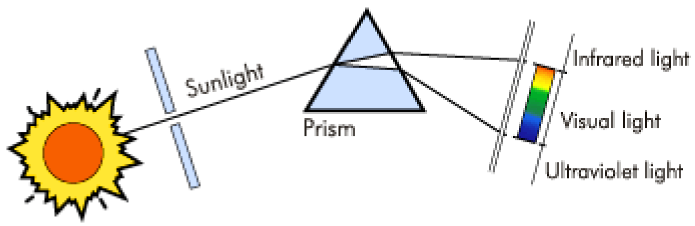
Utilizing a sustainable design philosophy encourages decisions at each phase of the design process that will reduce negative impacts on the environment and the health of the occupants, without compromising the bottom line. It is an integrated, holistic approach that encourages compromise and tradeoffs. Such an integrated approach positively impacts all phases of a building's life-cycle, including design, construction, operation and decommissioning.

7. Natural and Artificial Lighting

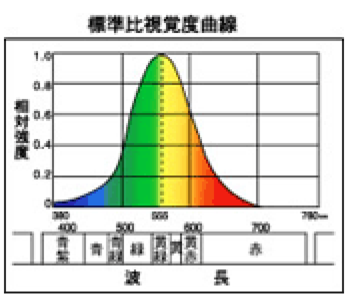
Utilize environmental design principles, theories, and details to determine the appropriate form of lighting such as daylight, solar control, energy consumption, and artificial lighting.

Natural and Artificial Light

When sunlight is directed through a prism and onto a screen, it is separated into a rainbow pattern on the screen. The colors are arranged in this rainbow pattern beginning with red, followed by orange, yellow, yellow-green, green-blue, blue, blue-violet and finally violet. This pattern is called the optical spectrum and represents the part of the electromagnetic spectrum visible to human eyes. Other parts of the spectrum invisible to human eyes include the infrared part of the spectrum which we can feel as warmth on skin, and the ultraviolet part of the spectrum which can be recorded on photographic film. These parts of the spectrum are utilized in a variety of ways. The portion of the optical spectrum which human beings perceive as brightest is yellow-green light with a frequency of 555nm.



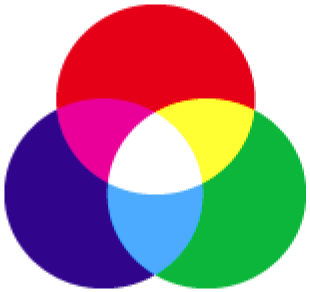
The intensity of light is perceived as brightness or darkness and serves as the basis for the brain's judgment of the light level. (Refer to the Standard Comparative Visual Sensitivity Chart)



Understanding Artificial Light

Artificial light sources are light sources which artificially combine just the necessary components of the optical spectrum. The way in which these components are combined determines the color rendering of the light source and thereby affects the way in which objects appear when illuminated with the light source

The Three Primary Colors of Light



Artificial light can be created by combining red (R), green (G) and blue (B) components as shown in the illustration.
Changes in the RGB ratios change the characteristics of the light and therefore the mixture ratios of RGB fluorescent substances is an important point to be taken into consideration when creating artificial lights

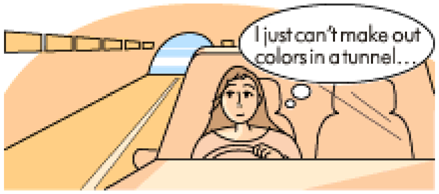
Three Band Fluorescent Lamps

HG X

HG X lamps are three band fluorescent lamps which apply the three primary colors of light. These bright lamps were developed to provide exceptional color rendering characteristics by increasing the yellow-green component which emphasizes brightness perception as compared with conventional fluorescent lamps and more carefully balancing the R, G and B components of the light

Why are Tunnels Colorless Worlds?

The orange colored low-pressure sodium vapor lights often used in tunnels provide monochromatic orange light Therefore your eyes perceive brightness but are unable to discriminate between colors



To Top of Page

8. Alternative Energy Systems and New Technologies
Investigate the environmental effects of the use of new energy systems, technological advances and innovative building products in building engineering systems design.

Examples of Alternative Energy Systems

Wind turbine or wind power
Hydro-electric
Fuel cell technologies
Geothermal power
Solar power
Biofuel and biodiesel applications

9. Adaptive Reuse of Buildings and/or Materials
Identify environmental issues related to the reuse of existing building engineering systems and the integration of new building engineering systems into existing or heritage buildings.

Category: Design
2G. Material Selection and Specification

Minimum Material Selection and Specification Experience: 160 Hours

Definition: The analysis and selection of building materials and systems for a project. The materials specified for a particular project communicate the requirements and quality expected during construction. Specifications are included in a project manual that is used during bidding and construction.

Tasks:

At the completion of your internship, you should be able to:

- Prepare specifications based on performance criteria
- Research, select, and specify materials

Knowledge of/Skill in:

- Adaptive reuse of buildings and/or materials
- Alternative energy systems and technologies
- Basic engineering principles
- Building design
- Building envelope
- Building Information Modeling (BIM) technology
- Building systems and their integration
- Characteristics and properties of construction materials
- Constructability
- Construction details

- Construction sequencing
- Critical thinking (e.g., analysis, synthesis, and evaluation of information)
- Design principles
- Furnishings, fixtures, and equipment
- Hazardous materials mitigation
- Implications of design decisions (e.g., cost, engineering, schedule)
- Indoor air quality
- Interior materials and finishes
- Interpersonal skills (e.g., listening, diplomacy, responsiveness)
- Life safety
- Managing quality through best practices
- Oral and written communications
- Problem solving
- Product evaluation, selection, and availability
- Project scheduling (e.g., construction document setup, storyboarding, staffing projections)
- Site design
- Specifications
- Sustainable design
- Technological advances and innovative building products
- Vertical circulation

Sun is lowest altitude from horizon in the sky in northern hemisphere on day of Winter Solstice

Not: Vernal or autumnal equinox, summer solstice

Potable Water: Water tested to be suitable for bathing, cooking, and consumption by humans

Not: Well water, ground water, grey water

Carbon monoxide, radon, formaldehyde, and nicotine are all classified as indoor-air contaminants

Not: Ventilation components, hydrocarbon-fuel emission, building-materials emission

Whole Building Design

by Don Prowler, FAIA - Donald Prowler & Associates

Revised and updated by Stephanie Vierra, Assoc. AIA, LEED AP BD+C - Vierra Design & Education Services, LLC

Last updated: 03-22-2012

The Role of Buildings and the Case for Whole Building Design

Buildings are deceptively complex. At their best, they connect us with the past and represent the greatest legacy for the future. They provide shelter, encourage productivity, embody our culture, and certainly play an important part in life on the planet. In fact, the role of buildings is constantly changing. Buildings today are life support systems, communication and data terminals, centers of education, justice, and community, and so much more. They are incredibly expensive to build and maintain and must constantly be adjusted to function effectively over their life cycle. The economics of building has become as complex as its design.

Data from the U.S. Energy Information Administration illustrates that buildings are responsible for almost half (48%) of all greenhouse gas emissions annually. Seventy-six percent of all electricity generated by U.S. power plants goes to supply the building sector[1] and buildings often contribute to health problems such as asthma and allergies due to poor indoor environmental quality. Safety is also paramount in buildings with security-related expenditures one of the fastest rising expenses.

The federal government has responded to these challenges by putting into place Executive Orders and Mandates.

The federal government has responded to these challenges by putting into place Executive Orders and Mandates. High performance buildings were defined in the Energy Policy Act of 2005 (Public Law 109-058) as: "buildings that integrate and optimize all major high-performance building attributes, including energy efficiency, durability, life-cycle performance, and occupant productivity".

The Energy Independence and Security Act (EISA) of 2007 further established a new and aggressive plan for achieving energy independence in our nation's building stock by the year 2030. The Act requires that federal buildings (new and renovations) achieve fossil fuel-generated energy consumption reductions on the order of 55 percent in the year 2010 to 100 percent in 2030. The Act also requires that sustainable design principles be applied to siting, design, and construction. It is of note that the Act defines High-Performance Buildings as the integration and optimization on a life cycle basis all major high-performance attributes, including energy conservation, environment, safety, security, durability, accessibility, cost-benefit, productivity, sustainability, functionality, and operational considerations. These issues are synonymous with whole building design.

Other private sector programs, such as the USGBC LEED® rating system, define standards and measures for sustainable buildings. Also, the Building Security Council's (BSC) Building Rating System and certification for professionals has been created to help measure and benchmark security in buildings. The private sector and industry have also responded by creating more products and systems that have multiple benefits. The knowledge, materials, and systems exist and are readily available to make a positive impact on the environment and on the quality of life of building occupants.

Whole Building Design encompasses all of these issues and programs and is an essential way of approaching building projects. Understanding Whole Building Design concepts will enable you to think and practice in an integrated fashion to meet the demands of today's as well as tomorrow's high-performance building projects.

The Philosophy and Components of Whole Building Design

The concept of "wholes" is not new. In 1926, Jan Christian Smuts, a South African Prime Minister and philosopher, coined the term "holism". He believed that there are no individual parts in nature, only patterns and arrangements that contribute to the whole. Buckminster Fuller also said back in 1969 while working on the space program: "Synergy is the only word in our language that means behavior of whole systems, unpredicted by the separately observed behaviors of the system's parts or any subassembly of the system's parts."

Whole Building Design draws upon these concepts of synergies and interconnectedness and consists of two components: an **integrated design approach** and an **integrated team process**. The "integrated" design approach asks all the members of the building stakeholder community, and the technical planning, design, and construction team to look at the project objectives, and building materials, systems, and assemblies from many different perspectives. This approach is a deviation from the typical planning and design process of relying on the expertise of specialists who work in their respective specialties somewhat isolated from each other.

Whole Building design in practice also requires an integrated team process in which the design team and all affected stakeholders work together throughout the project phases and to evaluate the design for cost, quality-of-life, future flexibility, efficiency; overall environmental impact; productivity, creativity; and how the occupants will be enlivened. The 'Whole Buildings' process draws from the knowledge pool of all the stakeholders across the life cycle of the project, from defining the need for a building, through planning, design, construction, building occupancy, and operations.

The Integrated Design Approach

Each design objective is significantly important in any project, yet a truly successful one is where project goals are identified early on and held in proper balance during the design process; and where their interrelationships and interdependencies with all building systems are understood, evaluated, appropriately applied, and coordinated concurrently from the planning and programming phase. A high-performance building cannot be achieved unless the integrated design approach is employed.

Design Objectives of Whole Building Design

In buildings, to achieve a truly successful holistic project, these design objectives must be considered in concert and in balance with each other:

- **Accessible**: Pertains to building elements, heights and clearances implemented to address the specific needs of disabled people.
- **Aesthetics**: Pertains to the physical appearance and image of building elements and spaces as well as the integrated design process.
- **Cost-Effective**: Pertains to selecting building elements on the basis of life-cycle costs (weighing options during concepts, design development, and value engineering) as well as basic cost estimating and budget control.
- **Functional/Operational**: Pertains to functional programming—spatial needs and requirements, system performance as well as durability and efficient maintenance of building elements.
- **Historic Preservation**: Pertains to specific actions within a historic district or affecting a historic building whereby building elements and strategies are classifiable into one of the four approaches: preservation, rehabilitation, restoration, or reconstruction.
- **Productive**: Pertains to occupants' well-being—physical and psychological comfort—including building elements such as air distribution, lighting, workspaces, systems, and technology.
- **Secure/Safe**: Pertains to the physical protection of occupants and assets from man-made and natural hazards.

- **Sustainable**: Pertains to environmental performance of building elements and strategies.

Whole Building Design provides the strategies to achieve a true high-performance building: one that is cost-effective over its entire life cycle, safe, secure, accessible, flexible, aesthetic, productive, and sustainable.

Through a systematic analysis of these interdependencies, and leveraging whole building design strategies to achieve multiple benefits, a much more efficient and cost-effective building can be produced. For example, the choice of a mechanical system might impact the quality of the air in the building, the ease of maintenance, global climate change, operating costs, fuel choice, and whether the windows of a building are operable. In turn, the size of the mechanical system will depend on factors such as, the type of lighting and controls used, how much natural daylight is brought in, how the space is organized, the facility's operating hours, and the local microclimate. At the same time, these same materials and systems choices may have an impact on the aesthetics, accessibility, and security of the project. A successful Whole Building Design is a solution that is greater than the sum of its parts.

The Integrated Team Process

To create a successful high-performance building, an interactive approach to the design process is also required. It means all the stakeholders—everyone involved in the planning, design, use, construction, operation, and maintenance of the facility—must fully understand the issues and concerns of all the other parties and interact closely throughout all phases of the project.

Who needs to be at the table at the outset of a project to ensure an integrated team process? Each project is unique and will require the team and expertise to be matched to the goals of the project. The team may include but is not limited to: the Architect, Landscape Architect, Owner, Client, Tenants, Engineers, Programmers, Interior Designer, Contractor, Specialists (Security, Telecom, Acoustics, LEED AP), Community Members or Other Stakeholders, Operations and Maintenance Personnel, and others such as a Real Estate Buyer. (See Engage the Integrated Design Process.)

A design charrette—a focused and collaborative brainstorming session held at the beginning of a project—encourages an exchange of ideas and information and allows truly integrated design solutions to take form. Team members—all the stakeholders—are encouraged to cross fertilize and address problems beyond their field of expertise. The charrette is particularly helpful in complex situations where many people represent the interests of the client and conflicting needs and constituencies. Participants are educated about the issues and resolution enables them to "buy into" the schematic solutions. A final solution isn't necessarily produced, but important, often interdependent, issues are explored. (See Planning and Conducting Integrated Design Charrettes.)

It is not enough to design the project in a holistic manner. It is also important to determine and measure the effectiveness and outcome of the integrated design solution over the defined life cycle. Consider conducting a Facility Performance Evaluation to ensure that the high-performance goals have been met and will continue to be met over the life cycle of the project. Consider retrocommissioning to ensure that the building will continue to optimally perform through continual adjustments. (See Building Commissioning and Document Compliance and Acceptance.)

Emerging Issues

As the world of buildings continues to change and grow in complexity, additional programs and information will have an impact on the entire design, planning and construction community. Among them is Building Information Modeling (BIM) software that is a continued trend in computer-aided design. Many buildings have been built directly from the electronic models that BIM creates, and some architects no longer create drawings but instead "build buildings inside their computers."

BIM has the potential to change the role of drawings for the construction process, improve architectural productivity, and make it easier to consider and evaluate design alternatives. BIM also aids in the process of integrating the various design teams' work, furthering encouraging and demanding an integrated team process.

High Performance Buildings are energy efficient, have limited environmental impact, and operate with the lowest possible life-cycle costs. There are a number of additional ways and tools to achieve high-performance buildings, such as the use of life-cycle cost analysis, integrated design processes, integrated energy solutions for the building envelope, and building commissioning.

Fluid Mechanics, Hydraulics, Dynamics

Fluid (Continuously deforms under shear stress):

- Parameters
- Fluid Properties/Characteristics
    - Gas
    - Liquid
        - Ideal Fluid Flow- Viscosity is constant- Newtonian Flow
        - Non-Newtonian Fluid Flow
            - Pseudo-plastic
            - Dilatants
            - Bingham
- Static Fluids
- Fluid in motion
    - Open Channel Flow- Civil Engineers
    - Closed pipes ,… - all engineers

Fluid Characteristics/Properties

- Density
  - Incompressible- When density of fluid does not change during the flow
  - Compressible- When density of fluid changes during the flow (i.e. gas dynamics)
- Viscosity
  - Newtonian- Viscosity is constant
  - Non-Newtonian- When viscosity is not constant (i.e. plastics or chemical industry)
- Molecular spacing
  - Molecular density
  - Attraction
  - Gases (very apart)
- Shapes and Volume
  - Gas: fills to match shape
  - Liquid: fills based on gravity
- Pressure
- Shear Resistance
  - Deforms under shear depending on viscosity -Versus solids
  - Resistance to motion based on viscosity and surface contact
- Phase Flow
  - Single phase flow: Gas or liquid
  - Two phase flow:
    - Gas and liquid
    - Gas and solid
    - Liquid and Solid
  - Three phase flow: Gas, liquid, solid (Coal sludge pipeline)

Fluid Parameters:

Pressure

If you press a surface with your thumb, the force exerted on the area of the thumb is the pressure exerted. Larger force gives larger pressure and lesser area increases the pressure. A knife easily cuts through materials, since the area exerted is very small.

Pressure = Force/Area

There is another way of looking at pressure, the weight of a person over two areas of the shoes is the pressure exerted on floor by the person. Regular shoes goes through snow, and Eskimos' large area shoes does not. The pressure surrounding us is the weight of the air above us. If you are at sea level and about 20 degrees C (Standard Temperature and pressure), the weight of 1 square inches of the air column al the way to the atmosphere is 14.7 lbs. The volume of air os 1"x1"x height of the air column to the atmosphere times density of air gives 14.7 lbs (approximately).
Pressure of atmosphere @Standard Temperature Pressure in other units are:

14.696	lbs/sq inches "Absolute"
1.0	Atmosphere
407.1	inches of water, inch water gage
33.93	feet of water, gage
29.921	inches of mercury
760	millimeter of mercury
760	Torr
1.13	Bars
1013	milliBars
1.013 x 105	Pa, Pascal
101.3	Kilo Pascal

Pressure (Under Force) versus Vacuum (Under suction):

The pressure in the atmosphere is near 14.7 psi (lbs per square inches). The zero (absolute pressure) psi pressure is at 14.7 psi lower than the atmosphere. If you purchase a pressure gage at the store, the gage needle shows zero value. This is known as zero gage pressure or 14.7 psi absolute pressure.

Absolute Pressure= 14.7 psi or P atmospheric + Gage pressure (measured value)

Under vacuum, same terminology is applied. The vacuum gages are set at zero at atmospheric pressure. Therefore all vacuum gage pressures have to consider the presence of atmospheric pressure surrounding them. If a container under vacuum is at 7 psi, gage pressure will show, 14.7-7 = 7.7 psi gage. If a pressure gage is shown to be 20 psi, the absolute pressure is 34.7 psi. In situations where the pressure is the difference in pressure, the 14.7 psi is cancelled out and it does not alter the naming of the pressure.

Change in Pressure = Absolute Pressure 2- Absolute Pressure 1= Gage Pressure 2 – Gage Pressure 1

Standard	**Temperature and**	**Pressure**
SI system	273.1˚K	101.325 K Pa
Scientific	0.0˚C	760 mm Hg
Natural Gas (Ca)	60˚F	14.696 Psia, 14.73, or 15.02 varies
Natural Gas (US)	60˚F	14.696 Psia, 14.73, or 15.02 varies
United States Engineering	0˚C= 32˚F	14.696 Psia

Density, specific Gravity, Specific Volume, and specific Weight

Density, r, is the ratio of mass to volume. **r =** Mass/Volume

Density @ STP of general fluids

Fluid	lbm/ft^3	kg/m^3
Air (STP)	0.0807	1.29
Air (70°F, 1 atm)	0.075	1.20
Alcohol	49.3	790
Gasoline	44.9	720
Glycerin	78.8	1260
Mercury	848	13600
Water	62.4	1000
Water	1.94 $slugs/ft^3$	1 kg/liter

Slug is to kilogram where pound force is to Newton. There is a distinction between lbm (pound mass) and lbf (pound Force). A person who is 100 kilogram mass is nearly 1000 Newton weight (force). Same person who is 200 lbm is 200 lbf. Why?

F = ma (from Newton's Law)

1 lbf = 1 lbm * 32.2 ft/sec^2

G_C = 1 = 1 lbf/[1 lbm * 32.2 ft/sec^2]

Therefore,

F = ma

200 lbf= 200 lbm * G_C * 32.2 ft/sec^2

= 200 lbm * {1 lbf/[1 lbm * 32.2 ft/sec^2]} * 32.2 ft/sec^2

= 200 lbm

A man who weighs 200 lbm is (200 lbf /32.2 ft/sec^2=) 6.21 Slugs

Specific volume, u, or 1/**r,** is the ratio of volume to mass. **u,** or 1/**r =** Volume/Mass, m^3/kg, ft^3/lb.

Specific Gravity (generally liquid) is the ratio of density of liquid to density of water. SG_{Liq}
Specific Gravity (Gas) is the ratio of density of liquid to density of air. SG_{Air}
Specific gravity is unit-less.

$SG_{Air} = r_{Air}/r_{Gas} =$ Molecular Weight (Gas)/Molecular weight (Air)= $MW_{Gas}/29.0 = R_{Air}/R_{Gas} = 53.3/R_{Gas}$

$$r_{Gas} = P/RT$$

$$r_{Air}/r_{Gas} = (P/RT)_{Air}/(P/RT)_{Gas}$$

Pressure and Temperature are constant

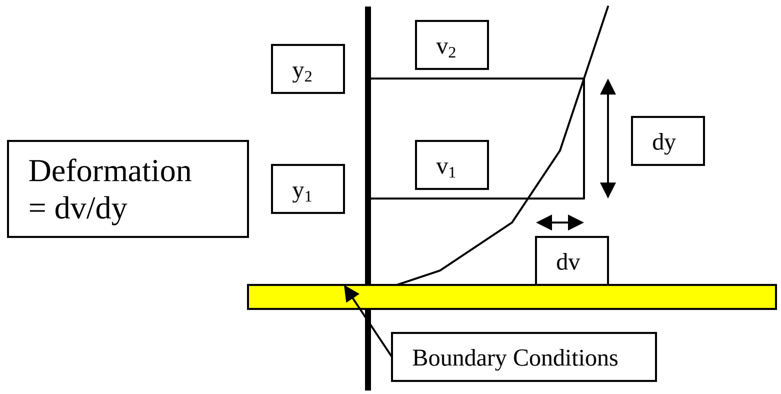
$$r_{Air}/r_{Gas} = R_{Air}/R_{Gas}$$

Specific weight, g, is the ratio of weight (versus mass) to volume.

$$g = rG = \text{Mass} * G/\text{Volume} = W/\text{Volume} = N/m^3 \text{ or } lbf/ft^3$$

Stresses, t

- t(P) = Surface stress vector at point P
- DF = Force acting on infinitesimal area DA
- DA = Infinitesimal area at point P
- t(P) = As limit of D A-> zero, DF/D A at point P
- t_n = Normal stress (90 degree perpendicular to surface) at point P
- t_t = Tangential stress (parallel to surfaces) at point P
- t_n = -P, pressure at point P
- t_t = mdv/dy= absolute dynamic viscosity of fluid (Velocity at boundary conditions/normal distance) Newton's law of friction or viscosity
- dv = Velocity at boundary condition (BC)
- dy = Normal distance, measured from boundary
- m = Absolute dynamics viscosity (measure of viscosity of fluid)



Modeling

Similarity (prototype):

- Mechanical
- Geometric
- Dynamic
- Viscous inertia
- Viscous versus inertia
- Inertia vs. Gravitational
- Surface tension
-

Mechanical = geometric and dynamic
Geometric = Geometric scaling

Lr = size of modeling/size or prototype
$Am/Ap= (Lr)^2$
$Vm/Vp= Lr^3$

Dynamic= Ratio of all forces: Inertia, gravity, viscosity, elasticity, fluid compressibility, tension, pressure

Viscosity versus inertia; inertia versus gravity, inertia versus surface tension

Distorted models: Based on geometric modeling. Since dynamic ratio may not apply, Dynamic Variations

Inertia versus Viscosity
Reynolds Number
LmVm/νm= Rem= Rep= LpVp/νp
Inertia/Viscous

Inertia versus Gravity
Froud Number
Fr=V2/Lg
Velocity/gravity

Surface Tension
Weber Number, We
We=LV2 ρ / s
Inertia versus Surface Tension

3. PLUMBING Basics - I

A. PRINCIPLES

Analyze and design plumbing systems.

Plumbing system consists of providing:

Water, gas, sewer, and storm water drainage to a facility.

Design consists of providing proper fixtures and equipment in addition to associated piping to service the facility. Water and gas are fed under pressure into building, where sewer and storm water are mostly under gravity flow

Plumbing Designers Tasks:

1. Define the work: Definition/scope of the plumbing task varies from site to site and may vary during the course of design. Tasks are clear:
(a) Identify and transcribe step wise scope of work and verify with all teams for its accuracies;
(b) List and identify all parties in the project;
(c) notify all parties (project managers, architect, …) all work and the delineation of the ending of the work.

2. Construction budget: Verify type of building and provide cost per square ft or complete construction cost. The estimating books and soft wares must be current to the economic conditions and the area being served. There are several available on internet.

3. Authorities having jurisdictions, codes, laws, standards, and guidelines: Identify all local, state, federal, agencies, and amendments are critical. Personnel administering the process are also important: Plan checkers, inspectors, building officials, …. The areas of mechanical, fire, health, sewer, insurance, finance are all related to the plumbing coinstruction and design. There are many national and local codes: International Plumbing Code, Uniform Plumbing Code, American Disabilities Act, International Code Councils are some of the few to mention.

4. Utilities and utility companies: Investigate all local conditions; create site utility plans, water, sanitary, gas, electric, topography (contour lines), right-a-ways or easements, hardscapes or landscapes, capacities, sizes, pressures, and materials. Other groups such as civil engineer, other utilities (electric, cable, …), public works, and other related agencies must be coordinated and notified. Backflow devices may be required.

5. Sewer: Verify all utilities concerns. Verify all point of connections, elevations, pipe inverts, topography, manholes, loading capacities, insurance issues. Final connections, easements and routing must be verified.

6. Water: Verify all utilities concerns. Design issues are: water pressure, meters, valves, hydraulic calculations, backflow prevention devices, pressure capacities for fire, domestic water usage

7. Gas: Verify all utilities concerns. Issues concerning gas piping designs are: Meter, valves, length of pipes, pressures, gas rating consumptions of the building, materials, routing, …

1. Building Design
Apply theory and principles of plumbing systems as a component of building design.

Theories in the plumbing system vary depending on the type of system. Water and gas piping under pressure are based on pressurized closed system, Sewer and storm drain are based on open channel flow theories.

Plumbing Design is sub-divided into:

- Collection of Data as project initial task
- Specifications and design
- Construction Services
- Administration.

2. Implications of Design Decisions
Determine the effects of plumbing systems design decisions and selection on issues such as construction cost, operating costs, construction schedules, and flexibility.

Design of plumbing systems are based on:

- Drainage systems
  - Interior drainage- Sewer systems
    - Backflow prevention
  - Exterior Drainage system- Site work
  - Vent piping system
- Domestic Water
  - Domestic cold water
  - Domestic hot water
    - Expansion/contraction
  - Backflow prevention
- Storm Water
  - Roof drainage
  - Site drainage
- Fuel Gas
- Machines
  - Sumps/ejectors
  - Pumps

Interior Drainage System are subdivided:

- Stacks
  - Connections
  - Sizing
    - Procedures in sizing
  - Flow in stacks
    - Terminal velocity
    - Capacity
    - Hydraulic Jump

- Waste
    - Indirect Waste
    - Direct Waste
    - Special Waste
    - Rate of Flow
        - In fixture Drains
        - In branches
        - Drain Size
        - Sanitary drainage fixture unit
- Test of DWV: Drain Waste Vent Systems

Pipe Installations subjects are:

- Cleanouts
- House Drains
- Branch connections to stack offsets
- Connection to sanitary house drains
- Backwater valve
- Drainage systems below sewer systems
- > 140 degrees F Waste

B. MATERIALS & TECHNOLOGY
Analyze and design plumbing systems.

1. Building Systems and their Integration
Consider integration and effects of plumbing design principles, systems, and details on the overall design of a building with consideration to technological advances and innovative building products.

2. Construction Details and Constructability
Examine plumbing system details, including the aspects of constructability and thermal and moisture protection.

Components:
Cleanouts:
Cleanout pipe size to match pipe size up to 4”. However, for larger pipe sizes, 4” clean-out is ok. Install them when:

a. **Any changes in direction greater than 45 degrees**
b. **Inside/Outside of the Building at point of exit (Wye branch or House trap)**
c. **Up to 4” Pipe: Every 50 ft maximum distance**
d. **4” to 10” pipe: Every 100 ft**
e. **Larger than 10”: manholes are required at every 150 ft or directional change**
f. **Base of all stacks**
g. **Proper access (18-24 inches), for roto rooters, fixture removal (generally 30”-36” per code)**

Waste (other than direct connections):
<u>Indirect Waste</u>: Indirect connections to sanitary must be trapped and vented. Discharge outlet must be 1.5 times indirect pipe size above flood level. Clean-outs are mandatory, since blockage is possible, in addition to very low velocity and low flow, extreme pneumatic effects. Examples are in sinks, lavatories, condensate drains.
<u>Special Waste</u>: (a) Tank overflows, tank empting lines, relieve valves discharge must be indirect waste drainage due to possible over pressurizations (b) Discharges with air breakers (floor sinks, roof drainage, …), (c)Cooling jackets, drip pans, steam expansion boiler overflows, …

Fluid Flow:
Rate of Flow in Fixtures, Q, gpm:

H **Mean vertical height, ft**

D Pipe diameter, inches

$$Q= 13.17\ D^2H^{1/2}$$

In branches, the flow is sum of of all fixtures to branch. It is uniform flow (assumed), branches are extended greater than 5 ft developed length for stability. Surcharging occurs from hydrostatic pressure. In short runs, due to high velocity, surcharging occurs. Branch flow rates are less than the stacks house. Stack pressure and branch pressures must be isolated when possible to avoid back pressure into branch. Stack flow is the sum of the stack as well as branches into the stack.

Scouring:
To insure all solid particles are at minimum terminal velocities (sand, grit, pebbles) within pipe, the flow must have minimum level. This will insure no deposition of blockage. 2 ft per second minimum and 4 ft per second for greasy fluid content is required. For 2" and 1 ½" pipe with full or half full flow velocities in sewer piping velocities are 1.98 and 1.85 ft per second. Minimize the length for these pipe sizes where possible.

Surcharging:
To accommodate overflow or certain peak loads, or when sewer and storm drainage are combined, surcharging is a possible event and must be accounted for. Vertical distances within manholes is measured for surcharging. This is measured from top of the pipes to the level surcharged within the vertical pipe or the manhole. Surcharging is used to permit smaller piping or less slope due to topography or for abnormal conditions.

Sewer Shapes:
Variable pipe shapes allow higher terminal velocity in low flow conditions and at higher flow rates, the velocity could remain the same. V= Q/A. As Q increases, A will increase, therefore the velocity remains constant (hydraulic radius increases)

Sanitary Sewer:
Public (when available) or private sewer in remote conditions for normal waste system must be fully contained and never at reach of human. Never mix the storm drain and sanitary unless treatments are provided.

Combined sewer and storm system: Now extremely rare. All combined system must be treated before reuse or discharge. Storm systems are used for overflow into the sewer system (flash floods).

Cleanout in a system is the location for rooting the clogs' at beginning or logistically located within the sewer pipes

Not: Vent, drain, or trap

Pressure relief valve in a diagram is a device to allow over pressure or temperature to vent out to approve location

Water closet-Plumbing fixture types is not permitted to connect to a waste stack vent

Not: Bidets, utility sinks, lavatories

Flush control for a handicapped accessible urinal is a maximum of 44" AFF.

Valve upstream of water heater circulation pump is a gate valve to be able to cut off pump and maintain it.

Not: Check valve and not exact use with Angle valve (90 degree bend), and globe valve

Vacuum breaker is not required for plumbing waste-drainage system

Not: Trap, vents, clean-outs are required for waste-drainage system

Plastic has the highest coefficient of thermal expansion.

Not: Steel, cast iron, glass

Air gap is required for refrigerators and sterilizers

Not: Heat recovery units, water closets, bathtubs, waste interceptors

4. HVAC

A. PRINCIPLES

Analyze and design heating, ventilating, and air conditioning systems.

- Fundamentals of Refrigeration
  - Cycles: Carnot Cycle, refrigeration cycle
  - The ideal and real vapour compression cycles.
  - Devices: Compressors, Controls devices
  - Fluids: Water, Ammonia, Refrigerants –types, properties, and the refrigerant chart.
- Fundamentals of Heat Transfer
  - Heat transfer modes (conduction, convection, and radiation)
  - Combined heat transfer and Basics of heat exchangers
- Fundamentals of Psychometrics
  - Properties of moist air
  - The Psychometrics chart
  - Representation and calculations of HVAC processes.
  - By-pass factor and apparatus dew point.

1. Building Design
Apply theory and principles of HVAC systems as a component of building design.

Cooling and Heating Load Calculation
- Load calculation methods.
- Load calculation psychometrics
- Internal heat gains
- Heat loss calculations
- Cooling load calculation using a modified CLTD/CLF method

- HVAC Equipment and System Selection
  - Unitary package equipment.
  - Unitary split system equipment.
  - Ground-source and water-loop heat pumps.
  - Chilled water systems.
  - Selection procedure for chilled water coils, air conditioners, and heat pumps.
  - Selection procedures for unitary heat pumps and furnaces.
  - Cooling towers
  - Economizers.

Design of Air Distribution Systems
- Space air diffusion
- Filtration
- Design considerations and air duct systems
- Duct layout and sizing
- Fans, fan laws, and flow control methods
- System curve and fan selection
- Design of fan-duct interface

Design of Water Distribution Systems

- Piping loop systems
- Head loss characteristics
- Design methods
- Piping layout and sizing
- System head and pump selection

Controls

- HVAC control component and circuits
- Unitary controls and circuits
- Central HVAC system controls

2. Implications of Design Decisions
Determine the effects of HVAC systems design decisions and selection on issues such as construction cost, operating costs, construction schedules, and flexibility.

Energy, Costs, and Economics

- Low- and high- efficiency HVAC system demand calculations.
- Energy consumption and cost calculations.
- Maintenance and replacement costs
- System Installation Costs.
- Case study –calculation of duct cost using duct cost program.
- Engineering economics and HVAC
- Discounted economic analysis.

3. Indoor Air Quality
Apply principles and theory of HVAC systems and design effects to determine impact on the quality of indoor air and related health issues.

Thermal comfort, Indoor air quality, calculation of required ventilation rates, Dedicated ventilation air system

Multiple-zone re-circulating system, Climate data, Heat Flow in Buildings, Thermal Properties of Building materials, Building heat transfer characteristics, Heat through duct work, Infiltration, Moisture control and migration

B. MATERIALS & TECHNOLOGY
Evaluate and select materials and construction details related to heating, ventilating, and air conditioning systems.

1. Building Systems and their Integration
Examine integration and effects of HVAC design principles, systems, and details on the overall design of a building considering technological advances and innovative building products.

- HVAC Equipment and System Selection
  - Unitary package equipment.
  - Unitary split system equipment.
  - Ground-source and water-loop heat pumps.
  - Chilled water systems.
  - Selection procedure for chilled water coils, air conditioners, and heat pumps.
  - Selection procedures for unitary heat pumps and furnaces.
  - Cooling towers
  - Economizers.

Controls
- HVAC control component and circuits
- Unitary controls and circuits
- Central HVAC system controls

2. Construction Details and Constructability
Identify and analyze HVAC system details including the aspects of constructability.

Design of Air Distribution Systems
- Space air diffusion
- Filtration
- Design considerations and air duct systems
- Duct layout and sizing
- Fans, fan laws, and flow control methods
- System curve and fan selection
- Design of fan-duct interface

Design of Water Distribution Systems
- Piping loop systems
- Head loss characteristics
- Design methods
- Piping layout and sizing
- System head and pump selection

3. Thermal and Moisture Protection
Apply detailed principles and analysis of thermal and moisture protection of HVAC systems.

Fan coil with four pipe system carries two pipes for heating and two pipes for cooling:
Not: Evaporative cooling, domestic hot water circulation, high rise fire safety systems
In a setting where the fan is obligated to have a bend, bend with 45 degrees is far better than 90 degrees or variation thereof.

Constant volume reheat has the highest operating cost for a large office building.
Not: Single zone- constant volume (small office), variable air volume, Double duct-constant volume
Single duct, Variable Air Volume systems are more efficient than constant volume system because: in a VAV system, with variable-pitch blades or variable-speed fans allow air to modulate from zero to maximum
Not: Fan runs at efficient levels and air volumes are controlled by manual dampers, duct sizes are reduced to save initial cost, low voltage equipment are needed
In a house design, the presence of a tree is positioned, depending the am vs pm, the sun moves. In North direction, No sun. In East direction the sun is from east and tree in east will block in morning, and south, the tree shades vary from morning to afternoon and in west, the sun is straight through glazing, therefore the tree can be placed on west.

Cooling tower using the water takes the heat away from building by spraying water over coils and passing air to cool the water
Not: Cooling coil, dehumidifier, heat pump

Chiller/cooling tower steps: Cooling tower to chiller is water: water is pumped from chiller to cooling tower for heat removal, the Freon and chiller are getting cool by cooling tower water in a heat exchanger, finally water is pumped into room and removes heat from room in fan coils.

U value of wall assembly: includes Resistance of air, wall, studs, interior and exterior film
Not: Orientation
Source of a building's heat loss: Air infiltration
Not: Occupants, isolation, electric lightning
Psychometric chart plot factors: Relative humidity, air temperature

Not: Air motion, mean radiant temperature, convection current, surface temperature

Equation for U * area *temperature difference= heat gain: Often underestimates summer heat gain since roof color (cool roof), roof mass and time of day also affects the heat gain.

Not: Entropy, roof texture, relative humidity

Heat is described through: Convection, conduction, radiation, enthalpy

5. ELECTRICAL

A. PRINCIPLES
Analyze and design electrical systems.

1. Building Design
Apply theory and principles of electrical systems as a component of building design.

2. Implications of Design Decisions
Determine the effects of electrical systems design decisions and selection on issues such as construction cost, operating costs, construction schedules, and flexibility.

B. MATERIALS & TECHNOLOGY
Evaluate and select materials and construction details related to electrical systems.

1. Building Systems and their Integration
Examine electrical design principles, systems, and details and determine the effects of integrating into the overall design of a building considering technological advances and innovative building products.

2. Construction Details and Constructability
Identify and analyze electrical system details including the aspects of constructability.

Ground rod is a 8 to 10 ft copper rod (1/2" or ¾") stabbed into earth soil to provide grounding for any electrical metering system.

Not: Breaker, disconnect switch, switch box

For large 16 story building, the best electrical distribution for minimum wire size and voltage drop is 277/480 volts, three phase 4 wire

Not: three wire of any voltage, 120/208 volt 4 way

Lightning protection can be provided by: A system of lightning rods and conductors extended to the ground, an overhead grid of wire conductors extended to the ground, a system of lightning rods connected to the building steel frame and then to the ground

If all electric building has a very smooth electric power profile: Retrofit of this building for lighting is the best reduction of power consumption.

GFI protection is required in residential restrooms

Not: No lower than 4'AFF, below toilet or lavatory fixtures, minimum 6 ft from tub or shower

Brach circuit breakers are in last panels downstream of feeders feeding the appliances.

6. LIGHTING

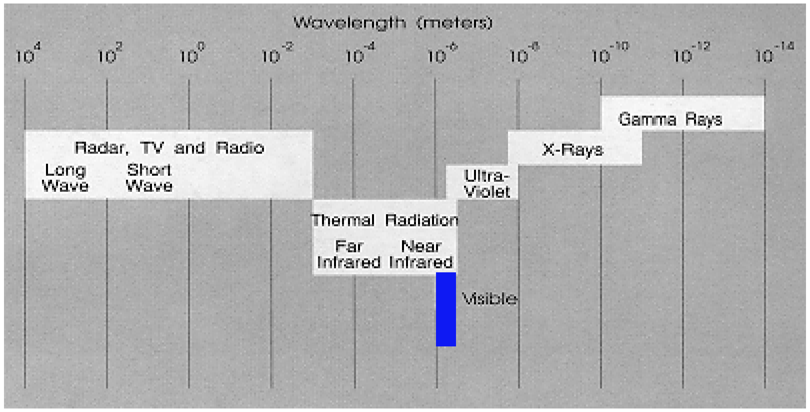
A. PRINCIPLES

Analyze and design natural and artificial lighting systems.

Basic Theory

Light is a form of radiant energy that travels in waves made up of vibrating electric and magnetic fields. These waves have both a frequency and a length, the values of which distinguish light from other forms of energy on the electromagnetic spectrum.

Visible light, as can be seen on the electromagnetic spectrum, represents a narrow band between ultraviolet light (UV) and infrared energy (heat). These light waves are capable of exciting the eye's retina, which results in a visual sensation called sight. Therefore, seeing requires a functioning eye and visible light.



Lighting Systems

Light can be produced by nature or by humans. "Artificial" light is typically produced by lighting systems that transform electrical energy into light. Nearly all lighting systems do so either by passing an electrical current through an element that heats until it glows, or through gases until they become excited and produce light energy.

Incandescent light sources are an example of the first method, called incandescence. Current is passed through a filament, which heats until it glows. Because this method is considered wasteful (most of the energy entering the lamp leaves it as heat instead of visible light, other light sources were pioneered that rely on the gaseous discharge method, including fluorescent, high-intensity discharge (HID) and low-pressure sodium light sources.

A typical lighting system is comprised of one or more of these light sources, called the **lamps**. Fluorescent, HID and low-pressure sodium lamps operate with a **ballast**, a device that starts the lamp and regulates its operation. Lamps and ballasts in turn are part of the l**uminaire**, or **light fixture**, which houses the system and includes other components that distribute the light in a controlled pattern.

Designing the Lighting System

To produce a new lighting system in a construction or renovation scenario, it must be designed. The designer must determine desired light levels for tasks that are to be performed in a given space, then determine the light output that will be required to meet those objectives consistently, taking into account all the factors that degrade both light output and light levels over time. Equipment must then be chosen and placed in a layout to produce the desired light distribution. The designer must also consider a range of quality factors in his or her design choices and equipment selection, including color, minimizing glare, safety and if required, aesthetics.

Managing the Lighting System

To properly manage an existing system, many types of professionals may be involved, from electrical contractors to facilities manager - - for our purposes in this case, we will call them lighting managers. The lighting manager must ensure that the existing lighting system consistently provides the most effective lighting at the lowest operating and maintenance cost. This may entail retrofitting or upgrading the system to reduce energy costs and/or increase performance, a planned maintenance program to keep the system operating at peak performance, and other activities that will ensure that the lighting system is continuously doing its job.

1. Building Design
Apply theory and principles of electrical systems as a component of building design.

It can be daunting trying to figure out what all the different terms of lighting mean and how to use them to devise a lighting plan. Here are some common terms and their meanings.

Beam Angle or spread - This is the shape of the light emitted from a bulb with reflective properties. The beam expressed in the form of an angle measurement can be wide, normal or narrow.

Color Rendering Index (CRI) - This is a scale of 1 to 100 to determine how the light will show the color of an object. With 100 being sunlight, that is the reference point. An object will appear as the color it should to the human eye. A lower CRI number will distort the color of an object.

Color Temperature - This is used to measure the color appearance of light. It is measured in units called Kelvin or K. Light sources below 3200K are considered warm and have reddish overtones. 4000K and above are considered cool and have bluish overtones. For reference a normal home will be in the 3000K area while Offices and retail establishments will be in the 4000K area. 5000k is reserved for such areas as an operating room or jewelry store.

Compact Fluorescent (CFL) - This is a term used for fluorescent bulbs that are made to take the place of incandescent lamps and are manufactured in shapes and sizes to accomplish this task. They outlast an incandescent about 10 times and use energy much more efficiently.

Foot candle - This is was originally the unit of measurement based on how much light will reach the surface of an object one foot away from a candle. It is now considered equivalent to a lumen which is the illumination of one square foot.

Work Plane - The work plane is considered to be an area about 30" off the floor. Lighting this plane should be your goal as this is where the majority of tasks are done.

I know you can read all these definitions and many more on the Internet, and still be confused. When it comes to recessed lighting which is when the layout is usually in question, it's all about spacing. Once you can visualize what pattern the light form you are using has, you can then accurately lay out the lighting properly.

The three factors that are most important when designing a lighting plan that works are the type of light, the color of the light and the spacing. The type of light fixture will determine the light pattern. Once a pattern is established the spacing can be figured out. Several factors can help when choosing the color of the light. Fluorescents tend to be colder or emit more of a blue light. Today there are some very good full spectrum bulbs that make fluorescent light a little warmer. Incandescent are the friendliest of all the colors and provide a welcoming and warm feeling. They do however, cast a yellow tone over everything in the room. In some cases this is a good thing. In other situations this may not be the best solution. Some wood cabinets, such as a bleached birch, tend to look yellow under incandescent light. Using a halogen bulb in these cases solves the problem. Below is a basic room lighting plan to give you ideas.

Discover how Residential Design Psychology helps you shape a home environment to support your emotions.

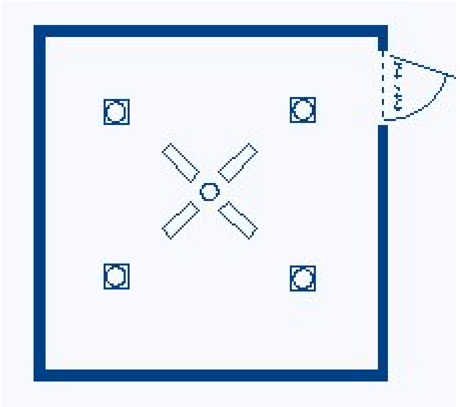
Design with Light

Lithonia Lighting

Kitchen Design

Lighting Online

Lighting Online



This is a 12 x 12 room, a typical bedroom. By placing these lights about 3 feet out from the corners we get a nice even distribution of light in the room. Using this plan we are also able to add a ceiling fan in the room with no adverse effects on the lighting plan

Lighting Principles and Terms

To choose the best energy-efficient lighting options for your home, you should understand basic lighting principles and terms.

Light Quantity

Illumination

The distribution of light on a horizontal surface. The purpose of all lighting is to produce illumination.

Lumen

A measurement of light emitted by a lamp. As reference, a 100-watt incandescent lamp emits about 1600 lumens.

Footcandle

A measurement of the intensity of illumination. A footcandle is the illumination produced by one lumen distributed over a 1-square-foot area. For most home and office work, 30–50 footcandles of illumination is sufficient. For detailed work, 200 footcandles of illumination or more allows more accuracy and less eyestrain. For simply finding one's way around at night, 5–20 footcandles may be sufficient.

Energy Consumption

Efficacy

The ratio of light produced to energy consumed. It's measured as the number of lumens produced divided by the rate of electricity consumption (lumens per watt).

Light Quality

Color temperature

The color of the light source. By convention, yellow-red colors (like the flames of a fire) are considered warm, and blue-green colors (like light from an overcast sky) are considered cool. Color temperature is measured in Kelvin (K) temperature. Confusingly, higher Kelvin temperatures (3600–5500 K) are what we consider cool and lower color temperatures (2700–3000 K) are considered warm. Cool light is preferred for visual tasks because it produces higher contrast than warm light. Warm light is preferred for living spaces because it is more flattering to skin tones and clothing.

A color temperature of 2700–3600 K is generally recommended for most indoor general and task lighting applications.

Color rendition

How colors appear when illuminated by a light source. Color rendition is generally considered to be a more important lighting quality than color temperature. Most objects are not a single color, but a combination of many colors. Light sources that are deficient in certain colors may change the apparent color of an object. The Color Rendition Index (CRI) is a 1–100 scale that measures a light source's ability to render colors the same way sunlight does. The top value of the CRI scale (100) is based on illumination by a 100-watt incandescent light bulb. A light source with a CRI of 80 or higher is considered acceptable for most indoor residential applications.

Glare

The excessive brightness from a direct light source that makes it difficult to see what one wishes to see. A bright object in front of a dark background usually will cause glare. Bright lights reflecting off a television or computer screen or even a printed page produces glare.

Intense light sources—such as bright incandescent lamps—are likely to produce more direct glare than large fluorescent lamps. However, glare is primarily the result of relative placement of light sources and the objects being viewed.

Lighting Uses

Ambient lighting

Provides general illumination indoors for daily activities, and outdoors for safety and security.

Task lighting

Facilitates particular tasks that require more light than is needed for general illumination, such as under-counter kitchen lights, table lamps, or bathroom mirror lights.

Accent lighting

Draws attention to special features or enhances the aesthetic qualities of an indoor or outdoor environment.

2. Implications of Design Decisions

Determine the effects of lighting systems design decisions and selection on issues such as construction cost, operating costs, construction schedules, and flexibility.

3. Natural and Artificial Lighting
Design principles and theories related to daylight, solar control, energy consumption, and artificial lighting.

B. MATERIALS & TECHNOLOGY
Evaluate and select materials and construction details related to natural and artificial lighting systems.

1. Building Systems and their Integration
Examine integration and effects of lighting design principles, systems, and details on the overall design of a building considering technological advances and innovative building products.

2. Construction Details and Constructability
Identify and analyze lighting system details including the aspects of constructability.

Familiarize yourself with the basic steps of the lighting design process for a more accurate project price tag

Most lighting design articles seem to focus on lamp efficiency, lamp life, CRI, luminaire aesthetics, cost, and all the claimed benefits of one lamp compared to another. The one topic that always seems to be missing, however, is the properly applied steps of a true lighting design. Most electrical contractors I work with don't use engineering data in their lighting projects. Instead, they rely on layouts from past jobs or just replicate what others are doing. By knowing the basic steps of the lighting design process, you'll be able to more accurately price a project and present it to your customer.

At the start of the design process, always consider the following:

- **Required footcandle (fc) requirement of an area, including what the customer may wants as far as lighting levels and quality of lighting.**
- **Code restrictions for energy savings, expressed as maximum watts per square feet, in specified areas. The two basic requirements come from the IECC (or COMcheck), which is supported by the U.S. Department of Energy (DOE) and is required by most states and jurisdictions, and California Title 24, which is more restrictive than COMcheck but also allows more flexibility.**
- **Photometric data, which can be obtained from most lighting manufacturers.**

A good way to show you how to use this information is to address each of these items through several example situations. So let's jump right in.

Office Space Example

Let's say we have a 10-ft × 12-ft office with an 8-ft-high T-bar ceiling. The Illuminating Engineering Society (IES) recommendation for fc lighting level in an office space is 50 fc to 100 fc, depending on the age of occupants and the specific task requirements. We'll use 50 fc as a target. The maximum watts-per-square-foot requirement for office space is 1.0. Using the COMcheck requirements, this allows for 120W of lighting.

Next, let's consider the following luminaires we might use in this space:

- **Luminaire #1 –** 2 × 4 grid, acrylic lens, three T8 lamps at 96W
- **Luminaire #2 –** 2 × 4 grid, acrylic lens, two T8 lamps at 64W
- **Luminaire #3** – 2 × 2 grid, acrylic lens, two T8 lamps (F17) at 34W
- **Luminaire #4** – 2 × 2 grid, indirect, low brightness, two T5 high output lamps at 54W
- **Luminaire #5** – Recessed specular reflector, two 26W double twin-tube (DTT) lamps at 52W

Luminaire #1 Calculations

Use the following equation to determine the appropriate number of luminaires needed for this space:

Number of luminaires = (Required fc × sq ft of space) ÷ [(lumen output of lamps) × (coefficient of utilization) × (light loss factor)] = [(50 fc) × (120 sq ft)] ÷ [(8,550 lumens) × (0.54) × (0.8)] = 1.6 fixtures

Thus, we would install two luminaires to meet the lighting requirements of this space.

Note: The values used in the above equation were acquired from the photometric report shown in the **Figure** (click here to see **Figure**) and the coefficient of utilization **Table** (click here to see **Table**). Three 32W linear fluorescent T8 lamps provide an output of 8,550 lumens. The coefficient of utilization (CU) is defined as the ratio of the lumens received on the work plane (i.e., the top of the desk) to the lumens emitted by the lamps. This is an important number and is simple to obtain. From the Figure, you can see that I chose an 80% ceiling reflectance (from the white T-bar grid), a 70% wall reflectance (from a light-colored paint), and a room cavity ratio (RCR) of 6.7 (rounded off to 7). RCR is simply the lighting efficiency of an enclosed space, and it can be easily found in lighting manuals or spec sheets. Light loss factor (LLF) is a number obtained by multiplication of all losses of light involved (i.e., dirt accumulation, lamp light losses, ballast losses, etc.). In this example, I simplified this calculation and plugged in a value of 0.8.

Installing two #1 luminaires in this space would provide a total wattage level of 192. However, because this is much larger than the 120W requirement noted earlier, it may not be a wise choice.

Do we have another alternative? Yes. We can use another value in the Figure to determine the number of luminaires required for this space.

The max candlepower distribution (CD) or candlepower is shown as 2,623 CD. This value is directly below the fixture. By dividing this CD value by the square of the distance in feet from the bottom of the luminaire to the top of the desktop, you will determine a new fc level. (Note: assume a distance of
5.5 ft from bottom of luminaire to top of desk.)

fc = 2,623 ÷ (5.5)2 = 87 fc

If we again assume a LLF of 0.8, then we end up with a final fc level of 70 (87 × 0.8).

This series of calculations shows a single luminaire provides an fc level well above the minimum recommended value of 50, which means this may be a good choice for this space. Based on this calculation method, we see that one luminaire would provide an fc level of 70 over the work desk and not exceed the maximum energy requirement of 120W.

Luminaire #2 Calculations

Following the same steps we used for Luminaire #1, we see that Luminaire #2 offers 5,700 lumens and 0.55 CU. Our initial calculations reveal that three luminaires would be needed to exceed the 50-fc requirement. Using the CD method results in an fc level of 52. This gives you the option of using two luminaires. (Note: the values for Luminaire #2 were pulled from a different photometric report, which is not included in this article due to space constraints.)

Luminaire #3 Calculations

Our calculations reveal that either method would require the use of six luminaires to exceed the 50-fc requirement. (Note: the values for Luminaire #3 were pulled from a different photometric report, which is not included in this article due to space constraints.)

Luminaire #4 Calculations

Our calculations reveal that either method would require the use of four luminaires to exceed the 50-fc requirement. (Note: the values for Luminaire #4 were pulled from a different photometric report, which is not included in this article due to space constraints.)

Luminaire #5 Calculations

Our calculations show that either method would require the use of five luminaires to exceed the 50-fc requirement. (Note: the values for Luminaire #5 were pulled from a different photometric report, which is not included in this article due to space constraints.)

A quick look back at our five different luminaire options and respective calculations reveals the best option is a balance between fc levels (and/or what the customer wants) and the maximum lighting energy that can be used in that space. In this case, luminaire #1 comes out on top.

Manufacturing Space Example

Let's say we are asked to design a lighting system for a manufacturing space that is 200 ft by 200 ft in size with a finished floor to bottom of luminaire height of 30 ft. The owner wants a light level of 50 fc maintained at ground level. In this case, "maintained" means including an LLF. We'll use a value of 0.7 for a dirty environment.

The maximum watts-per-square-foot requirement for manufacturing space is 1.0. For this example, we'll use Title 24 requirements, which allows 40,000W of lighting. Two different luminaire options will be analyzed.

- **Luminaire #1 – a high-bay fixture with a 350W high-output metal-halide lamp in a concentrated aluminum optical enclosure, rated at 400W.**
- **Luminaire #2 – a high-bay fluorescent fixture with six T5 high-output lamps and a task beam white reflector (concentrated downlight), rated at 363W.**

3. Natural and Artificial Lighting
Design components and details related to daylight, solar control, energy consumption, and artificial lighting.

Coefficient of utilization in lighting level calculations is the percentage of lamp lumens to reach the work plane

Not: Leave the luminaries, the amount lost due to age, lost due to environmental dust

Controlling lights within two spaces is a double switch

Not: Two single-pole, double-throw switch

7. SPECIALTIES

A. ACOUSTICS

Evaluate, select, and design acoustical systems.

Introduction

The sources of compressor station noise are generally well understood. They include engine and compressor casing noise, engine air intake and exhaust, and cooler inlet and outlet noise. Addressing noise generation at the design stage will clearly reduce the level of supplemental noise attenuation equipment yet, incredibly, the majority of compressor packagers continue to pound out compressors with conventional building designs, including acoustically transparent windows, translucent roof panels and ridge vents. Even when acoustic considerations are addressed in initial building design, much of the effort falls short of the mark, or introduces other operating complications.

Basic Acoustic Building Design

Conventional acoustic building design includes acoustic insulation and perforated liners. This approach is a good start and reduces internal noise for the operators as well as outside building noise. However, these buildings may still incorporate other elements that create noise sources.

High Elevation Noise Sources in Building Design

Ridge vents remain a common building component, even in acoustic building designs. Some operators measure acoustic building performance at a distance too close to the building to fully reflect noise emanating from the ridge vent, before it's reached the ground. As a result, that noise source may be more relevant further out from the building than the operator realizes. Some operators understand the problems windows pose in noise transmission and will specify windowless buildings. However, they're sometimes offset with the use of roof mounted translucent panels building lighting. Unless properly selected, translucent panels can remain a significant noise source with the operator again falling prey to the same misleading conclusions about the level of long distance noise attenuation.

Acoustic Ventilation in Building Design

Where acoustic building ventilation is incorporated, it is tempting for operators to use fewer but larger capacity ventilation hoods and fans to reduce capital costs. There can be a couple of problems with this approach. Concentrated, rather than evenly spaced ventilation can result in some portions of the building being improperly swept. A second, parallel problem has to do with gas detection. Gas detectors require a minimum retention time to work properly. In the event of gas leaks, improper building ventilation can render gas detectors ineffective or leave pockets or areas within the building improperly swept clean of leaking gases. As a result the operator may be unaware of explosive mixtures within the building and on sour sites H_2S can escape undetected into the building and surrounding environment In extreme cases the airflow through the building can be so severe as to weaken the building's structural integrity or interfere with the safe operation of doors and undermining emergency exit safety considerations. Another cost saving building ventilation technique is to steal some of the airflow from forced draft fan coolers and sweep that air through the building. One problem with this approach is the reduction in gas and engine cooling duty by 5 to 15%. Operators don't always consider the economics of the revenue loss arising from the lost gas production. Further, this ventilation provides some cooling around the engine but doesn't sweep the compressor end of the building. Finally, the static head on this air source is low raising the question of overall adequate building ventilation. Process cooling and building ventilation requirements both need to be properly sized and then a deliberate assessment made as to whether it is more effective and economic to use a larger than necessary cooler fan to also accommodate building ventilation, or size the cooling fan to it's process requirements and size the building ventilation for its needs.

1. Building Design
Apply theory and principles of acoustic systems as a component of building design.

Acoustics and Design

1. Introduction

What is covered:

- Basic acoustic terminology.
- Noise sources, design criteria for different buildings and spaces, assessment of noise levels, and noise control.
- Design issues associated with acoustic performance inside buildings due to internal or external noise sources.

What is not covered:

- Buildings where there are special acoustic constraints e.g. auditoria.
- Factories (and buildings where there is 24 hour work, e.g. hospitals) where it may be important to assess the effect of noise generated on adjacent dwellings.
- Sound systems in buildings. These may be required for emergency warning (e.g. fire alarm), paging system, lecture and conference rooms, sports stadia, railway stations etc.

Examples

- External environment: buildings adjacent to motorways where there may be a need for a sealed building with mechanical ventilation; How noisy can it be before a building cannot be naturally ventilated?
- Internal environment: Office space within factories next to noisy process plant. How can sound levels in offices be made acceptable?

Acoustic assessments through the design process: stages of design

STAGE	ISSUES
Site	Rural or industrial - planning regulations

	Transportation noise - roads/rail/aircraft (prediction of future levels)
	Industrial noise sources
	Airborne noise and/or vibration
Building form	Site planning and screening
	Ventilation - natural or mechanical
	Location of plant rooms
Detailed design	Room-to-room noise
	Outside-to-inside noise
	HVAC noise
	Room acoustics
	Sound insulation
	Sound systems
Supervision	Quality of construction
Commissioning	Compare actual noise levels to intended levels and criteria
Retrofit	Remedial action

References:

- CIBSE Vol A1 for criteria for design; Vol B12 for sound control in building services.
- British Standard Code of Practice BS8233:1987 Sound insulation and noise reduction for buildings.
- Croome DJ, Noise Buildings and People, Pergamon, 1977.
- Smith BJ, Peters RJ and Owen S, Acoustics and Noise Control, Longman 1982.

2. Basic Acoustic Terminology

- Sound power and sound pressure are expressed in dB - i.e.as a ratio relative to some reference level.

  Sound Power Level = PWL = 10 $\log_{10}(W_{source}/W_{ref})$ dB
  where: W_{ref} is 10^{-12} W; W_{source} is sound power in W.
  If sound power increases by a factor of 2, this is equivalent to a 3dB increase.

  Sound Pressure Level = SPL = 10 $\log_{10}(P^2 / P_{ref}^2)$ dB
  where $P_{ref} = 2 . 10^{-5}$ Pa; P = sound pressure in Pa

  For ducts with no attenuation, sound pressure propagation is 1-dimensional and the SPL is constant.
  For spherical spreading, a doubling of distance results in a 6dB reduction in SPL.

- Octave band calculation/measurement:
  The absorbing/insulating properties of materials vary significantly with frequency of the sound source. Thus measurements and calculations often need to be undertaken in octave bands (or 1/3 octave bands for more detailed work). A crude approximation sometimes used for broad-band noise is that transmission/absorption characteristics over the full acoustic spectrum is similar to the response at 500Hz. Note that the human ear responds to frequencies in the range 20Hz to 20kHz approximately.

- dB; dBA;
  The ear also responds in a non-linear way, with maximum sensitivity around 2 or 3 kHz and much lower sensitivity at low frequencies. A commonly used metric is the A-weighted dB (dBA) which is weighted according to the typical human ear's frequency response.

- L_{eq}; L_{A10}; L_{A90}

  L_{eq} is the time averaged sound pressure level and is used for time-varying signals.
  L_{A10} is the SPL which is exceeded for 10% of the time.
  L_{A90} is the SPL which is exceeded for 90% of the time (the "background" level).

- Absorption and insulation

Absorption is quantified as the absorption coefficient - the proportion not reflected
Insulation is quantified as the Sound Reduction Index SRI (in dB) - a measure of the reduction in transmission. It is a property of the building construction only.

- Reverberation time - the time it takes for a sound to decay by 60dB. It is governed by the absorption characteristics for the room.
  Sabine's formula is commonly used:
  T = 0.161 V / A
  where T is the reverberation time (s); V is room volume (m^3); A is total absorption (room surface area * average absorption coefficient + absorption of furniture/people, m^2).

- Level difference is simply the difference between source and received sound levels for airborne noise.
  The level difference is affected by the level of absorption and thus the reverberation time in the receiving room. It is therefore usually standardised (D_{nT}) to allow for the fact that most occupied domestic rooms have a reverberation time of about 0.5s.

- For impact noise, a standardised impact SPL is used - obtained by measurement with a standard source.

3. Noise Sources

3.1 Central Plant

Fans: Primarily resulting from turbulent fluctuations in air pressure, but can also result from vibrations. Axial fans generally have lower noise output than centrifugal fans except at low frequencies.

Pumps:

Other equipment: Boilers, motors, compressors etc.

3.2 Noise in Airflow Systems

Larger diameter ducts - lower air velocity, less noise.

- also need to reduce abrupt transitions to avoid turbulence Can add sound absorbent lining or attenuators(silencers).
- beware of possibility of breakout at any airgaps.

Diffusers - data from manufacturer, or estimate from CIBSE:

$$PWL = 32 + 13 \log_{10} A + 60 \log_{10} v$$

where A is the minimum open area in m^2 ; v is air speed in m/s
(e.g. for an air speed of 4m/s and a 200mm * 200mm opening; PWL ~50dB)

3.3 External Noise

- Road traffic
  - calculation of predicted SPL for new roads
  - measurement or calculation for existing roads
- Aircraft
- Rail
- Industrial sources - in general requires site survey to BS4142
- External equipment and plant

4. Design Criteria

4.1 Regulations

- Noise at Work Regulations - legal duties of employers (and equipment suppliers) to minimize hearing damage.
- Town and Country Planning Regulations - define environmental assessments for any major projects of more than local importance, or projects in sensitive areas.
- Detailed Building Regulations - performance criteria by conforming to design or by measurement - but only for housing.

4.2 Houses

For houses, background noise in the house due to external noise sources should be:

- <35 dB L_{Aeq} for the period 23:00 to 07:00 in bedrooms;

- <40 dB L_{Aeq} for the period 07:00 to 23:00 in living and dining rooms;
- <50 dB L_{Aeq} for the period 07:00 to 23:00 in less sensitive rooms.

The Building Regulations give acceptable constructions and connections for all parts of the building.

4.3 Other buildings

For other buildings, Noise Rating criteria are used:

- NR curves
- recommended noise ratings for spaces
- speech intelligibility (privacy)

There are no regulations governing acceptable noise levels in offices. BS8233:1987 recommends 40-45dB L_{Aeq} for private offices and small conference rooms, and 45-50dB L_{Aeq} for open-plan offices. This indicates that where external noise levels are in excess of 60dB L_{Aeq} (e.g. from road traffic noise), then a sealed office with mechanical ventilation will be required.

4.4 Reverberation Time

Acceptable reverberation times can be specified for rooms for best reception for speech or music. This is primarily of interest to large specialised spaces - auditoria, lecture theatres etc.

5. Assessment of Room Sound Level

To find the total sound pressure levels in a room: define individual noise sources and their PWL, include the modifying characteristics of the transmission paths (e.g. SRI), apply the acoustic properties of the receiving room (amount of acoustic absorption), and sum.

5.1 Outside Noise Environment

This is important, as it has implications for ventilation, and possibly glazing/constructions e.g. near airports or busy roads. Considerations include:

- external barriers around site - height is critical: note the potential impact on shading;
- magnitude of noise sources by measurement, or in case of traffic, calculation based on vehicle flow rates, speed, ratio of heavy/light vehicles, road surface, gradient, distance from road to building, screening correction.
- distance is important: with vegetation and <4m reception point, as high as 7dBA for doubling of distance; with a hard surface or water only 3dBA for a doubling of distance.

5.2 Internal Noise Environment

Consider paths for transmission in buildings.

$$SPL_r = SPL_s - SRI + 10 \log_{10} (S_w / A)$$

where: SPL_r is the sound pressure level in receiving room; SPL_s is the sound pressure level in source room; SRI is the sound reduction index; S_w is area of separating wall; A is total absorption in receiving room (surface area * average absorption coefficient + absorption of furniture/people, m^2).

6. Control of Noise

In all cases consider (in order) source, transmission path and receiver.

6.1 Planning to Control External Noise

- Control of source usually not possible (except by planning constraints).
- Transmission path can be influenced by:
    - location of the building on the site;
    - screening of the site;
    - internal planning of the building;
    - building form and orientation.
- Control at receiver by improving insulation of the building envelope, but the site itself may not be protected, so gardens/public areas may be noisy. The building must be well sealed to give maximum insulation, requiring mechanical ventilation.

6.2 Planning to Control Internal Noise

- Reduce noise at source where possible (e.g. acoustic enclosures for noisy machinery).
- Internal planning - ensure that adjacent rooms are compatible in terms of noise sensitivity and noise production.
- Improve room-to-room sound insulation.

6.3 Use of Mass

The sound insulation of any single-leaf wall or floor built without gaps depends mainly on its MASS. According to the MASS LAW, there will be an increase in sound insulation of about 5dB if the mass/unit area is doubled. The insulation also increases by about 6dB for a doubling of frequency. However, this is only true up to a critical frequency, beyond which there will be a dip in insulation. The critical frequency is about 100Hz for a one-brick wall, 200Hz for a half-brick wall. Critical frequencies in the range 100Hz to 1000Hz should be avoided.

6.4 Use of Isolation

Double leaf walls give good insulation if they are completely decoupled. For example, 2 sheets of plasterboard bonded together will give 30dB attenuation; this would increase to 50dB if they were perfectly isolated. In practice, attenuation may vary according to how rigid the link is between the two leaves and the width of the airgap. Absorbent quilt in the airgap improves performance - not because it is a good sound absorber, but because it helps to isolate the two leaves of the partition.

High levels of insulation can be achieved with care and expense - for example, separation of multiplex cinema auditoria of weighted standardised level difference (D_{nT}) of 65dB to over 70dB has been achieved by using 2 layers of 15mm plasterboard on separate studs, a large cavity with 100mm quilt inlay and careful head, base and edge detailing.

6.5 Control of Flanking Transmission

Detailing for houses are given in the Building Regulations. If flanking constructions are not properly specified (and constructed), the flanking transmssion can equal or even exceed direct transmission.

6.6 Quality of Detailing

Small flaws in construction can lead to large differences in insulation. For example, this may be due to:

- Small airgaps in mortar joints or under skirting boards. For example, an opening of area $0.1m^2$ (SRI of 0dB) in a facade of area $25m^2$ (SRI of 50dB) reduces the overall SRI value to 24dB.
- Mechanical bridging of air gaps (nails through floating floors etc).
- Excessive flanking transmission.

7. Example of Design Considerations: Hotels

Main Issues

- Hotels vary in standards, but many are near busy roads or airports, or in city centres.
- The main acoustic issues are noise break-in from outside, pnvacy between rooms, and ventilation noise.

Windows

- Windows in hotels have opening lights even in noisy situations; good weatherstripping and double glazing are essential.
- Balconies can give some protection from noise.

Privacy

- A reasonable standard is attained with separating walls and floors having an SRI of 50dB.
- Creation of a lobby outside the en-suite bathroom will isolate corridor noise.
- Cross-talk attenuation to bathroom extracts will prevent plumbing sounds being transmitted.
- Single door to corridors should be rated at 35dB.
- Room televisions should not be fixed directly to room separating walls.

Ventilation Noise

- This should be kept within NR35 in any hotel and down to NR25 in good standard bedrooms.
- Connections to outside and chiller plant should be remote from bedrooms, or well-screened and attenuated.

8. Example of Design Considerations: Offices

Main Issues

- Complaints from office workers arise from intrusive outside noise, high noise levels within offices and poor insulation between cellular offices.
- BS8233: 1987 recommends 40-45dB L_{Aeq} for private offices and office conference rooms, and 45-50dB L_{Aeq} for open-plan offices.
- Above a general level of 57 dBA, occupants have to raise their voices to offset the background noise, which further raises internal levels.

Outside Noise Levels

- This can influence the form of the office complex: natural ventilation for a 15m deep template or natural ventilation plus ventilated core for an 18m deep template allows in traffic and industrial noise. A deep plan sealed fully mechanically ventilated office building gives a more controlled environment.
- 4/12/6 glazing is usually adequate, but better glazing combinations (6/20/10) or even double windows may be required in exceptional circumstances.

Atria

- Glazing panels act as low frequency absorbers but are otherwise strongly reflective.
- With hard floor and wall surfaces, the space will be reverberant without absorptive panelling on about 25 % of the wall surface. Trees and furniture can help as sound absorbers; water features can help to mask sound.
- There is little data available but two centres monitored had ambient noise levels around NC50 (similar to NR50) due to ventilation plant and continuous escalator operation. Sound levels were very uneven.

Internal Noise Levels

- These can be kept reasonable with a sound-absorbing ceiling, carpet and screened workstations.
- Modern office equipment is much quieter than older equipment (e.g. laser printers are typically 64dBA at 1m compared to 83dBA for mechanical printers).

Privacy

- There is a usually a hierarchy of privacy in offices: senior management have offices with greater privacy and lower ambient noise.
- Privacy between workstations is only typically around 17-20dBA in open-plan offices - less than required for speech privacy. There is some evidence that resulting interruptions can lead to loss of productivity: improving privacy can improve productivity by 3-10%.

Relationship of background noise and annoyance in offices

Activity + ventilation noise (dBA)	Staff in an adjacent workstation annoyed by normal speech (%)
35	65
40	40
45	25
47	16
55	4

- Good quality partitioning with care at the ceiling and floor junctions is required to improve insulation.
- In cellular offices, proprietary 50mm metal-skinned panels with mineral wool core can achieve 30-35dB average SRI if well-installed, or 40-45dB if high performance panels are used.
- Sound conditioning systems can be used to generate broadband noise to mask speech from surrounding workstations, but it is difficult to set the correct levels.

Computer rooms

- These have inherently high noise levels, the acceptability of which is dependent on the occupants.
- If staff workstations are within the computer room, a background level of NR45-50 should apply; NR60 may be acceptable for intermittent occupation.

- Measures to reduce noise in the room air handling units include lower air velocities, ducted supply and return with silencers, and double skin casings.

2. Building Systems and their Integration
Examine integration and effects of acoustic design principles, systems, and details on the overall design of a building considering technological advances and innovative building products.

Architectural acoustics

From Wikipedia, the free encyclopedia
Jump to: navigation, search

Architectural acoustics is the science of noise control within buildings. The first application of architectural acoustics was in the design of opera houses and then concert halls. More widely, noise suppression is critical in the design of multi-unit dwellings and business premises that generate significant noise, including music venues like bars. The more mundane design of workplaces has implications for noise health effects. Architectural acoustics includes room acoustics, the design of recording and broadcast studios, home theaters, and listening rooms for media playback.

Contents

[hide]

Building skin envelope

This science analyzes noise transmission from building exterior envelope to interior and vice versa. The main noise paths are roofs, eaves, walls, windows, door and penetrations. Sufficient control ensures space functionality and is often required based on building use and local municipal codes. An example would be providing a suitable design for a home which is to be constructed close to a high volume roadway, or under the flight path of a major airport, or of the airport itself.

Inter-space noise control

The science of limiting and/or controlling noise transmission from one building space to another to ensure space functionality and speech privacy. The typical sound paths are room partitions, acoustic ceiling panels (such as wood dropped ceiling panels), doors, windows, flanking, ducting and other penetrations. An example would be providing suitable party wall design in an apartment complex to minimise the mutual disturbance due to noise by residents in adjacent apartments.

Interior space acoustics

This is the science of controlling a room's surfaces based on sound absorbing and reflecting properties. Excessive reverberation time, which can be calculated, can lead to poor speech intelligibility.

Sound reflections create standing waves that produce natural resonances that can be heard as a pleasant sensation or an annoying one.[1] Reflective surfaces can be angled and coordinated to provide good coverage of sound for a listener in a concert hall or music recital space. To illustrate this concept consider the difference between a modern large office meeting room or lecture theater and a traditional classroom with all hard surfaces.

Interior building surfaces can be constructed of many different materials and finishes. Ideal acoustical panels are those without a face or finish material that interferes with the acoustical infill or substrate. Fabric covered panels are one way to heighten acoustical absorption. Finish material is used to cover over the acoustical substrate. Mineral fiber board, or Micore, is a commonly used acoustical substrate. Finish materials often consist of fabric, wood or acoustical tile. Fabric can be wrapped around substrates to create what is referred to as a "pre-fabricated panel" and often provides good noise absorption if laid onto a wall. Prefabricated panels are limited to the size of the substrate ranging from 2 by 4 feet (0.61 × 1.2 m) to 4 by 10 feet (1.2 × 3.0 m). Fabric retained in a wall-mounted perimeter track system, is referred to as "on-site acoustical wall panels". This is constructed by framing the perimeter track into shape, infilling the acoustical substrate and then stretching and tucking the fabric into the perimeter frame system. On-site wall panels can be constructed to accommodate door frames, baseboard, or any other intrusion. Large panels (generally, greater than 50 square feet (4.6 m^2)) can be created on walls and ceilings with this method. Wood finishes can consist of punched or routed slots and provide a natural look to the interior space, although acoustical absorption may not be great.

There are three ways to improve workplace acoustics and solve workplace sound problems – the ABCs.

- A = Absorb {via drapes, carpets, ceiling tiles, etc.)
- B = Block (via panels, walls, floors, ceilings and layout)
- C = Cover-up (via sound masking)

While all three of these are recommended to achieve optimal results, C = Cover-up by increasing background sound produces the most dramatic improvement in speech privacy – with the least disruption and typically the lowest cost.

Mechanical equipment noise

Building services noise control is the science of controlling noise produced by:

- ACMV (air conditioning and mechanical ventilation) systems in buildings, termed HVAC in North America
- Elevators
- Electrical generators positioned within or attached to a building
- Any other building service infrastructure component that emits sound.

Inadequate control may lead to elevated sound levels within the space which can be annoying and reduce speech intelligibility. Typical improvements are vibration isolation of mechanical equipment, and sound traps in ductwork. Sound masking can also be created by adjusting HVAC noise to a predetermined level.

3. Implications of Design Decisions

Determine the effects of acoustic systems design decisions and selection on issues such as construction cost, operating costs, construction schedules, and flexibility.

4. Construction Details and Constructability
Identify and analyze acoustic system details including the aspects of constructability.

COMMON ACOUSTIC CONSTRUCTION MATERIALS

Wood and metal studs and joists – construction framing members with which most of you are familiar. The most common framing for walls is either 2x4 wood studs or 3.5" metal studs. Which is more cost effective – metal or wood – will largely depend on the relative price of wood and steel in different parts of the country. For acoustical purposes, metal does offer resiliency benefits worth considering for maximum benefit. For those of you that are not used to building things, bear in mind when figuring your dimensions that lumber is not really the actual dimensions indicated by the name. For instance, a 2x4 is not; it is actually 1½"x3½". A 2x6 is 1½"x5½", etc.

Gypsum wallboard ("GWB," "drywall," "SheetRock") is commonly available in ½" and ?" thicknesses. It is far and away the most common building material in North America for interior finish construction. Unless you have a home built prior to the 1950s, you probably have gypsum board finish to your walls and ceilings. (Plaster on lathe was much more common – and incidentally much better for sound isolation than gypsum board – in homes prior to the construction boom of the 1950s.)

Plywood is usually ¾" (but is available in a variety of thicknesses from larger lumber yards) and is either available with flat edges, or with tongue and groove edges for tight floor construction.

The **Particleboard** family:

• Low density fiberboard, or LDF, is typically called chipboard. It's the stuff out of which most inexpensive, DIY furniture is made.
• Medium density fiberboard, or MDF, is more typical of shelving and loudspeaker enclosures. It has some very good acoustical properties and we like using it for many varied applications.
• High density fiberboard, or HDF, is also available, but is quite rare and quite heavy. Very high-end cabinetry will often employ HDF.
• Oriented strand board, or OSB, is often used in residential construction as a low-cost floor underlayment.
• Straight up particleboard is usually a version of LDF, but can also be the name given to a higher grade of OSB.
• Other materials we make mention of in Acoustics 101 include gypsum board screws of various thread sizes and lengths, construction adhesives including vinyl flooring adhesive, silicone caulk, etc. Wherever possible, we have provided make, model and cost information as appropriate for any non-Auralex materials we mention.

Reverberation: Persistent sound reflection from enclosed space

Not: Creep, Dampening, frequency

Vibration isolator: is springs, plastics, or dampening device to reduce vibration of equipment on walls, floors, etc.

Not: Resilient hanger, flexible coupling, paver pedestal

Duct lining is most effective reduction of low frequency noise

Not: Mufflers, dampers, turning vanes

Sabins: Units of sound absorption

Not: Watts, decibels, degrees

Absorption is best effective control of noise generated in a space

Not: Reflection, focusing, diffusion

B. COMMUNICATIONS & SECURITY
Evaluate, select, and design communications and security systems.

Suppliers of **fire prevention** systems, **linear heat detection** systems, **fire alarm systems** , and **suppression systems** , as well as facility communications and **security systems, early warning fire detection** systems, **early warning air sampling fire detection** systems, and **linear heat detection** systems.

Fi**re protection** and **fire warning** are key in ensuring the safety of your employees and assets. We employ **early warning system** s much more sophisticated than a simple **smoke detector** . By the time **smoke detection** occurs, in many cases it is already too late. That's why we offer **linear heat detection** systems that often can sense potential fire hazards due to overheating before combustion occurs. We also have fire **suppression systems** that can control or eliminate a fire before it gets out of control. We also offer a **fire alarm service** that includes **monitoring** from our **central station** . All of our fire safety products comply with the **Life Safety** Code established by the National **Fire protection** Association.

Systems provides:

- System Design
- Fire Detection
- **Smoke Detection**
- Fire **Suppression systems**
- **Fire Prevention**
- Hand Held Extinguishers
- **Early Warning System**
- Kitchen Hood Suppression
- **Fire alarm service**
- **Fire alarm systems**
- **Early Warning fire detection**
- Fire System Inspection
- Facility Security
- Communications Systems

All of **fire protection** and **fire warning** systems are **Life Safety** Code compliant. One provides a complete range of customized life, property and productivity protection systems statewide **-** with the important benefits of local ownership and operation.

CONCEPT and DESIGN
We at Mac Systems evaluate your specific needs and develop a plan for you. A plan you can count on to provide facility safety and compliance

with state and local regulations. Our in-house engineers utilize the latest Computer Aided Design and Electronic software to prepare detailed engineering drawings of the proposed installation.

INSTALLATION
Components selected for reliability and cost effectiveness are installed quickly and efficiently according to specifications. Each yyyy Systems crew takes pride and satisfaction in knowing your project is installed professionally.

INSPECTION, TESTING and MAINTENANCE
To maintain confidence in your **fire alarm systems** , fire suppression and **security systems** and to comply with the multitude of insurance, state and local regulations, yyyy Systems employees teams specially dedicated to inspection, testing and maintenance. We provide you and the regulatory agencies with factual, detailed information on system readiness and compliance. No other **fire alarm service** is as comprehensive and trough in their testing, inspection and maintenance.

.

1. Building Design
Apply theory and principles of acoustic systems as a component of building design.

2. Building Systems and their Integration
Examine integration and effects of communications and security design principles, systems, and details on the overall design of a building considering technological advances and innovative building products.

3. Implications of Design Decisions
Determine the effects of communications and security systems design decisions and selection on issues such as construction cost, operating costs, construction schedules, and flexibility.

4. Construction Details and Constructability
Identify and analyze communications and security system details including the aspects of constructability.

C. CONVEYING SYSTEMS
Evaluate, select, and design elevators, escalators, moving walkways, and other conveying systems.

Elevators

- An elevator is a button-controlled popular form of commercial building transportation that moves people and products from floor to floor. For example, in a 12-story building the elevator is designed to stop at each floor. Attached to one end of a steel cable, an elevator is like a steel cage, with cables moving up and over a sheave (a grooved drive wheel) and downward toward a counterweight of iron blocks. The elevator is powered by an electric motor which moves the car as well as the counterweight between the enclosed staff and steel guide rails.

Escalators

- Escalators, another form of commercial transportation, consist of a chain of moving steps that transport large number of people between floors. The step treads remain horizontal while moving people. Like elevators, escalators are used all over the world. However, escalators transport pedestrian traffic to places where elevators are impractical. Shopping malls, department stores and hotels as well as public buildings use escalators.

Moving Walkways

- Moving walkways, usually found in airports, are designed to move people over long distances, usually between different terminals. Moving walkways are similar to an escalator. The only difference is that the steps lay flat, like a conveyor belt. Passengers are able to move from gate to gate or from one baggage area to the next. Moving walkways, like elevators and escalators, offer a smooth and convenient ride for people while providing outstanding energy efficiency for commercial building operators.

Read more: Types of Transportation Systems for Commercial Buildings | eHow.com
http://www.ehow.com/info_8087331_types-transportation-systems-commercial-buildings.html#ixzz1vQkATwtm

1. Building Design
Apply theory and principles of conveying systems as a component of building design.

2. Building Systems and their Integration
Examine integration and effects of conveying systems design principles and details on the overall design of a building considering technological advances and innovative building products.

3. Implications of Design Decisions
Determine the effects of conveying systems design decisions and selection on issues, such as construction cost, operating costs, construction schedules, and flexibility.

4. Construction Details and Constructability
Identify and analyze conveying system details including the aspects of constructability.

D. FIRE DETECTION AND SUPPRESSION
Evaluate, select, and design fire detection and suppression systems.

Detector:

A device suitable for connection to a circuit that has a sensor that responds to a physical stimulus such as heat or smoke.

Air Sampling–Type Detector, A detector that consists of a piping or tubing distribution network that runs from the detector to the area(s) to be protected. An aspiration fan in the detector housing draws air from the protected area back to the detector through air sampling ports, piping, or tubing. At the detector, the air is analyzed for fire products.

Automatic Fire Detector, A device designed to detect the presence of a fire signature and to initiate action. For the purpose of this Code, automatic fire detectors are classified as follows: Automatic Fire Extinguishing or Suppression System Operation Detector, Fire–Gas Detector, Heat Detector, Other Fire Detectors, Radiant Energy–Sensing Fire Detector, Smoke Detector.

Automatic Fire Extinguishing or Suppression System Operation Detector, A device that automatically detects the operation of a fire extinguishing or suppression system by means appropriate to the system employed.

Combination Detector, A device that either responds to more than one of the fire phenomena or employs more than one operating principle to sense one of these phenomena. Typical examples are a combination of a heat detector with a smoke detector or a combination rate-of-rise and fixed-temperature heat detector. This device has listings for each sensing method employed.

Electrical Conductivity Heat Detector, A line-type or spot-type sensing element in which resistance varies as a function of temperature.

Fire–Gas Detector, A device that detects gases produced by a fire.

Fixed-Temperature Detector, A device that responds when its operating element becomes heated to a Pre-determined level.

Flame Detector, A radiant energy–sensing fire detector that detects the radiant energy emitted by a flame.

Heat Detector, A fire detector that detects either abnormally high temperature or rate of temperature rise, or both.

Line-Type Detector, A device in which detection is continuous along a path. Typical examples are rate-of-rise pneumatic tubing detectors, projected beam smoke detectors, and heat-sensitive cable.

Multi-Criteria Detector, A device that contains multiple sensors that separately respond to physical stimulus such as heat, smoke, or fire gases, or employs more than one sensor to sense the same stimulus. This sensor is capable of generating only one alarm signal from the sensors employed in the design either independently or in combination. The sensor output signal is mathematically evaluated to determine when an alarm signal is warranted. The evaluation can be performed either at the detector or at the control unit. This detector has a single listing that establishes the primary function of the detector.

Multi-Sensor Detector, A device that contains multiple sensors that separately respond to physical stimulus such as heat, smoke, or fire gases, or employs more than one sensor to sense the same stimulus. A device capable of generating multiple alarm signals from any one of the sensors employed in the design, independently or in combination. The sensor output signals are mathematically evaluated to determine when an alarm signal is warranted. The evaluation can be performed either at the detector or at the control unit. This device has listings for each sensing method employed.

Other Fire Detectors, Devices that detect a phenomenon other than heat, smoke, flame, or gases produced by a fire.

Pneumatic Rate-of-Rise Tubing Heat Detector, A line-type detector comprising small-diameter tubing, usually copper, that is installed on the ceiling or high on the walls throughout the protected area. The tubing is terminated in a detector unit containing diaphragms and associated contacts set to actuate at a predetermined pressure. The system is sealed except for calibrated vents that compensate for normal changes in temperature.

Projected Beam–Type Detector, A type of photoelectric light obscuration smoke detector wherein the beam spans the protected area.

Radiant Energy–Sensing Fire Detector, A device that detects radiant energy, such as ultraviolet, visible, or infrared, that is emitted as a product of combustion reaction and obeys the laws of optics.

Rate Compensation Detector, A device that responds when the temperature of the air surrounding the device reaches a predetermined level, regardless of the rate of temperature rise.

Rate-of-Rise Detector, A device that responds when the temperature rises at a rate exceeding a predetermined value.

Smoke Detector, A device that detects visible or invisible particles of combustion.

Spark Ember Detector, A radiant energy–sensing fire detector that is designed to detect sparks or embers, or both. These devices are normally intended to operate in dark environments and in the infrared part of the spectrum.

Spot-Type Detector, A device in which the detecting element is concentrated at a particular location. Typical examples are bimetallic detectors, fusible alloy detectors, certain pneumatic rate-of-rise detectors, certain smoke detectors, and thermoelectric detectors.

Clean Agent

Several Clean Agents are available for consideration. This firm is active in **FM200(ECS & ADS), NOVEC1230, FE-13, Argonite, CO2,** and **Stat-X (aerosol).**

***FM200 (FE227ea)** is both UL listed and FM Approved. N.F.P.A 2001, *Standard on Clean Agent Fire Extinguishing Systems,* approves this agent for total flooding purposes. The agent is discharged within 10 seconds and therefore minimizes by-products of combustion and damage due to loss by fire. FM200 is clean and leaves no residue, therefore eliminating costly after fire clean up. FM200 is colorless and odorless. FM200 is acceptable for use in occupied spaces. The operating temperature is 32F to 130F.

FM200 systems are intended to protect:

- Data Processing Facilities
- Telecommunications facilities
- Process Control Rooms
- High Value Medical Facilities
- High Value Industrial Equipment Areas
- Libraries, Museums, Art Galleries
- Anechoic Chambers
- Flammable Liquid Storage Areas
- Petrochemical Installations
- Gas Turbines
- Steam Turbines
- Power Generation Plants
- Packaging Plants

FM200 systems are designed for the following classes of fire:

- Class A Surface Type fires (wood or other cellulose type materials)
- Class B; Flammable Liquids
- Class C; Energized Electrical Equipment

*** FM200 is NOT acceptable for all classes of fire.

***NOVEC1230** is both UL listed and FM Approved. N.F.P.A 2001, *Standard on Clean Agent Fire Extinguishing Systems,* approves this agent for total flooding purposes. The agent is discharged within 10 seconds and therefore minimizes by-products of combustion and damage due to loss by fire. NOVEC1230 is clean and leaves no residue, therefore eliminating costly after fire clean up. NOVEC1230 is colorless and odorless. *It is also ZERO in Ozone depletion and has an atmospheric life of 5 years so is very high on the "Green" list for suppression agents.* NOVEC1230 is acceptable for use in occupied spaces. The operating temperature is 0F to 130F.

NOVEC 1230 systems are intended to protect:

- Data Processing Facilities
- Telecommunications facilities
- Process Control Rooms
- High Value Medical Facilities
- High Value Industrial Equipment Areas
- Libraries, Museums, Art Galleries
- Anechoic Chambers
- Flammable Liquid Storage Areas
- Petrochemical Installations
- Gas Turbines
- Steam Turbines
- Power Generation Plants
- Packaging Plants

NOVEC 1230 systems are designed for the following classes of fire:

- Class A Surface Type fires (wood or other cellulose type materials)
- Class B; Flammable Liquids
- Class C; Energized Electrical Equipment

*** NOVEC1230 is NOT acceptable for all classes of fire.

***Argonite** is a blend of inert gas (50% / 50% pure argon / nitrogen). Both gases are naturally occurring substances and present in the atmosphere, and as such, have no ozone depletion potential and no direct global warming risk. The operating temperature is -20F to 130F.

Argonite systems are intended to protect:

- Electric and Electronic Equipment Rooms
- Data Centers
- Telecommunications
- Flammable Liquids
- Subfloors and Concealed Spaces
- Delicate Artifacts
- High Value Assets
- Places Where Other Extinguishing Media Could Be Directly Destructive
- *** Argonite is NOT acceptable for all classes of fire.

***FE-13** is a compound of carbon, fluorine, and hydrogen. It is colorless, odorless and electrically non-conductive. FE-13 is both UL listed and FM Approved. N.F.P.A 2001, *Standard on Clean Agent Fire Extinguishing Systems* approves this agent for total flooding purposes. It is approved for use in occupied spaces. FE-13 is clean and leaves no residue, therefore eliminating costly after fire clean up. The operating temperature is -40F to 130F.

FE-13 systems are intended to protect:

- Industrial High Ceiling Spaces
- Locomotives
- Mining equipment
- Offshore Oil Platforms
- Oil And Gas Processing Facilities
- Pumping Stations
- Refinery Control Areas
- Turbine Enclosures
- Unheated Storage Areas
- Snow Making Control Houses

FE-13 systems are designed for the following classes of fire:

- Class A Surface Type fires (wood or other cellulose type materials)
- Class B; Flammable Liquids
- Class C; Energized Electrical Equipment

*** FE-13 is NOT acceptable for all classes of fire.

CO2 is 99% carbon dioxide. A naturally-occurring atmospheric element, Carbon Dioxide dissipates into the air allowing an almost immediate return to "business as usual" without the interruption of a costly clean-up and the expense of damage to assets from suppressant residue. This results in fewer repair costs and reduced downtime. Carbon Dioxide (CO2) is a colorless, odorless, electrically-nonconductive gas whose density is approximately 50% greater than air. A Kidde Carbon Dioxide System suppresses fire by providing a blanket of heavy gas that absorbs heat from the fire and reduces the oxygen content of the atmosphere to a point where combustion becomes impossible. Because Carbon Dioxide is an ideal suppressant for a wide variety of industrial applications, three system configurations are efficient to protect different hazard types: Total Flooding—ideal for enclosed hazard areas, Local Application—used to protect a specified hazard area in an open floor plan, or a Local Hose Line— cost effective protection for fighting smaller fires throughout a hazard.

CO2 systems are intended to protect:

- Flammable Liquid Storage Areas
- Marine Applicationsb
- Quench And Dip Tanks
- Large Commercial Fryers
- Engine And Electrical Rooms
- Spray Booths And Paint Lockers
- Turbine Generators
- Printing Presses
- Rolling Mills
- Dust Collectors
- Industrial Ovens
- Mixing Operations

CO2 systems are designed for the following classes of fire:

- Class A Surface Type AND Deep Seated fires (wood or other cellulose type materials)
- Class B; Flammable Liquids

- Class C; Energized Electrical Equipment

*** CO_2 is NOT acceptable for all classes of fire.

Dry Chemical

GENERAL SPECIFICATION

A pre-engineered, fixed pipe, automatic dry chemical fire suppression system shall be provided and installed for the hazard including work area, plenums and all exhaust ventilation pits and associated ductwork requiring protection.

CODES/STANDARDS COMPLIANCE

The system shall conform to, and be in accordance with, the following:

1. UL 1254, Underwriters Laboratories Standard for Fire Extinguishing Systems for Protection of Industrial Hazards

2. FM Approvals, where applicable

3. NFPA 17, Standard on Dry Chemical Extinguishing Systems

4. NFPA 33, Standard for Spray Application Using Flammable or Combustible Materials

5. NFPA 34, Standard for Dipping and Coating Processes Using Flammable or Combustible Liquids

6. The manufacture Instruction Manual and all applicable addenda, as identified by Underwriters Laboratories.

7. All applicable insurance company requirements.

8. All applicable local and state codes and standards,

9. NFPA 70 – National Electrical Code (NEC)

10. NFPA 72 – National Fire Alarm Code

11. Requirements of the Local Authorities Having Jurisdiction (AHJ).

The types of hazards and equipment that can be protected using dry chemical extinguishing Systems include the following:

- Flammable or combustible liquids
- Flammable or combustible gases
- Combustible solids, including plastics, which melt when involved in fire
- Electrical hazards such as oil-filled transformers or circuit breakers
- Textile operations subject to flash surface fires
- Ordinary combustibles such as wood, paper, or cloth
- Restaurant and commercial hoods, ducts, and associated cooking appliance hazards such as deep-fat fryers

Dry chemical extinguishing systems shall not be considered satisfactory protection for the following:

- Chemicals containing their own oxygen supply, such as cellulose nitrate
- Combustible metals such as sodium, potassium, magnesium, titanium, and zirconium
- Deep-seated or burrowing fires in ordinary combustibles where the dry chemical cannot reach the point of combustion

Multipurpose dry chemical shall not be used on machinery such as carding equipment in textile operations and delicate electrical equipment. Before dry chemical extinguishing equipment is considered for use in protecting electronic equipment or delicate electrical relays, the effect of residual deposits of dry chemical on the performance on electronic equipment shall be evaluated.

Multiple Systems Protecting a Common Hazard:
Where two or more systems are used to protect a common hazard, they shall be arranged for simultaneous operation. Operation of a single actuator shall cause all systems to operate.

Systems Protecting Two or More Hazards:

Where two or more hazards could be simultaneously involved in fire by reason of their proximity, the hazards shall be protected by either of the following:

- Individual systems installed to operate simultaneously
- A single system designed to protect all hazards that could be simultaneously involved

- Any hazard that will allow fire propagation from one area to another shall constitute a single fire hazard.

Dry Chemical Requirements and Distribution:

The following factors shall be considered in determining the amount of dry chemical required:

- Minimum quantity of dry chemical
- Minimum flow rate of dry chemical
- Nozzle placement limitations including spacing, distribution, and obstructions
- High ventilation rates, if applicable
- Prevailing wind conditions, if applicable

Compensation for Special Conditions.

Additional quantities of dry chemical and additional nozzles, if necessary, shall be provided to compensate for special condition(s) such as high ventilation rates or prevailing wind conditions that could adversely affect the extinguishing effectiveness of the system.

Special Considerations:
Where systems protect hazards that are normally heated, the power or fuel supply to heaters shall be shut off automatically upon actuation of the extinguishing systems. Where systems protect hazards that have flowing flammable or combustible fluids or gases, the systems shall be provided with automatic means to ensure shutoff of power and fuel valves upon operation of the extinguishing systems. Where systems protect hazards that have conveyors moving flammable or combustible materials or commodities, the conveyors shall be automatically shut off upon operation of the extinguishing systems. All shutoff systems shall be fail-safe. All shutoff systems shall require manual resetting prior to restoration of the operating conditions existing before operation of the extinguishing systems. All shutoff devices shall function with the system operation. Expellant gas that is used to pneumatically operate shutoff devices shall be taken prior to its entry into the dry chemical tank.

Personnel Safety:
Where total flooding and local application systems are used and there is a possibility that personnel could be exposed to a dry chemical discharge, suitable safeguards shall be provided to ensure prompt evacuation of such locations. Safety procedures shall provide a means for prompt rescue of any trapped personnel. Safety items to be considered shall include, but not be limited to, the following:

- Personnel training
- Warning signs
- Pre-discharge alarms
- Discharge alarms
- Respiratory protection

Total Flooding Systems:

A total flooding type of system shall be used only where there is a permanent enclosure surrounding the hazard that adequately enables the required concentration to be built up. The total area of unclosable openings shall not exceed 15 percent of the total area of the sides, top, and bottom of the enclosure. Where unclosable openings exceed 15 percent of the total enclosure surface area, a local application system shall be used to protect the entire hazard. Pre-engineered total flooding systems shall be permitted to protect permanent enclosures having unclosable openings greater than 15 percent, only when listed for such use. Deep-seated fires involving solids subject to smoldering shall be protected by multipurpose dry chemical systems where the dry chemical can reach all surfaces involved in combustion.

Hazard Specifications:

Enclosure. In the design of total flooding systems, the characteristics of the enclosure shall be as specified in 6.2.1.1 through 6.2.1.4. The total area of unclosable openings for which no compensation is provided shall not exceed 1 percent of the total area of the sides, top, and bottom of the enclosure. Unclosable openings having an area in excess of 1 percent and not exceeding 5 percent shall be compensated for by the provision of additional dry chemical. Unclosable openings having an area in excess of 5 percent of the total enclosure area and not exceeding 15 percent shall be screened by local application of additional dry chemical. Pre-engineered systems shall be permitted to protect the permanent enclosures with unclosable openings using different amounts of dry chemicals from those specified only when listed for such use.

Leakage and Ventilation. The leakage of dry chemical from the protected space shall be minimized because the effectiveness of the flooding system depends on obtaining an extinguishing concentration of dry chemical. Where possible, openings such as doorways, windows, and so on, shall be arranged to close before, or simultaneously with, the start of the dry chemical discharge. Where forced-air ventilating systems are involved, they shall be either shut down or closed before, or simultaneously with, the start of the dry chemical discharge.The quantity of dry chemical and the flow rate shall be sufficient to create a fire-extinguishing concentration in all parts of the enclosure.

Volume Allowances. In calculating the net volume to be protected, allowance shall be permitted for permanently located structures that materially reduce the volume

Local Application Systems:
Local application systems shall be used for the extinguishment of fires in flammable or combustible liquids, gases, and shallow solids (e.g., paint deposits) where the hazard is not enclosed or where the enclosure does not conform to the requirements for total flooding.

Extent of Hazard. The hazard shall be isolated from other hazards or combustibles so that fire will not spread outside the protected area. The entire hazard shall be protected. The hazard shall include all areas that are or might become coated by combustible or flammable liquids or shallow solid coatings and all associated materials or equipment that might extend fire outside or lead fire into the protected area. The design of the system shall consider the location of the hazard, which might be indoors, partly sheltered, or completely outdoors. For flammable liquid fires, the nozzles shall be placed tankside or overhead, or a combination of tankside and overhead within the limits of the listing, and located to prevent splashing during discharge.

Coated Surfaces. Coated surface areas shall be treated as if they were deep-layer flammable liquid areas (because no distinction has been made in this standard).

Duration of Discharge. The minimum effective discharge time shall be determined by the required minimum quantity of dry chemical and the minimum application rate. Minimum effective discharge time for pre-engineered systems shall be determined with NFPA 17 Chapter 9.

Pre-Engineered Systems:

Pre-engineered systems shall be installed to protect hazards within the limitations of the listing.

Fire-extinguishing systems referenced in NFPA 17, chapter 9.1.1 shall comply with ANSI/UL 1254, *Pre-Engineered Dry Chemical Extinguishing System Units*, or equivalent listing standard. Only system components referenced in the manufacturer's listed installation and maintenance manual or alternative suppliers' components that are listed for use with the specific extinguishing system shall be used.

Pre-engineered dry chemical systems shall be of the following types:

- Local application
- Total flooding
- Hand hose line
- Combination of local application and total flooding

Water Mist

What is Water-Mist ?

Water-Mist systems utilize clean water as fire-fighting agent.

Water is the oldest, the most widely used, and the most widely available fire fighting agent in the world:

- Non-toxic
- Environmentally friendly
- Has superior fire fighting capabilities in a wide range of applications

Water-Mist systems distribute water in fine spray of small droplets

Size of droplets defined as *Water-Mist* is specified in the relevant standards

Use and Limitations:
Water mist systems shall be permitted for use with a wide range of performance objectives, including the following:

- Fire extinguishment
- Fire Suppression
- Fire Control
- Temperature Control
- Exposure Protection

Water mist systems shall not be used for direct application to materials that react with water to produce violent reactions or significant amounts of hazardous products. Such materials include the following:

- Reactive metals, such as lithium, sodium, potassium, magnesium, titanium, zirconium, uranium, and plutonium
- Metal alkoxides, such as sodium methoxide
- Metal amides, such as sodium amide
- Carbides, such as calcium carbide
- Halides, such as benzoyl chloride and aluminum chloride

- Hydrides, such as lithium aluminum hydride
- Oxyhalides, such as phosphorus oxybromide
- Silanes, such as trichloromethylsilane
- Sulfides, such as phosphorus pentasulfide
- Cyanates, such as methylisocyanate

Water mist systems shall not be used for direct application to liquefied gases at cryogenic temperatures (such as liquefied natural gas), which boil violently when heated by water. When selecting water mist to protect a hazard area, the effects of water runoff on the environment shall be considered.

Water mist systems shall be described by the following four parameters:

- System application
- Nozzle type
- System operation method
- System media type

System applications shall consist of one of the following three categories:

- Local-application systems
- Total compartment application systems
- Zoned application systems

Local-Application Systems. Local-application systems shall be designed and installed to provide complete distribution of mist on or around the hazard or object to be protected. Local-application systems shall be designed to protect an object or a hazard in an enclosed, unenclosed, or open outdoor condition. Local-application systems shall be actuated by automatic nozzles or by an independent detection system.

Total Compartment Application Systems. Total compartment application systems are designed and installed to provide complete protection of an enclosure or space. The complete protection of an enclosure or space shall be achieved by the simultaneous operation of all nozzles in the space by manual or automatic means.

Zoned Application Systems. Zoned application systems are a subset of the compartment system and are designed to protect a predetermined portion of the compartment by the activation of a selected group of nozzles. Zoned application systems shall be designed and installed to provide complete mist distribution throughout a predetermined portion of an enclosure or space. This shall be achieved by simultaneous operation of a selected group of nozzles in a predetermined portion of the space by manual or automatic means. Zoned application systems shall be actuated by automatic nozzles or by an independent detection system.

Nozzle Types.

Water mist nozzles shall be classified as one of the following three types:

- Automatic
- Nonautomatic
- Hybrid

System Requirements.

Deluge Systems.
Deluge systems shall employ nonautomatic nozzles (open) attached to a piping network connected to the fluid supply(ies) through a valve controlled by an independent detection system installed in the same area as the mist nozzles. When the valve(s) is activated, the fluid shall flow into the piping network and discharge from all nozzles attached thereto.

Wet Pipe Systems. Wet pipe systems shall employ automatic nozzles attached to a piping network pressurized with water up to the nozzles.

Preaction Systems.
Preaction systems shall employ automatic nozzles attached to a piping network containing a pressurized gas with a upplemental, independent detection system installed in the same area as the nozzles. Operation of the detection system shall actuate a tripping device that opens the valve, pressurizing the pipe network with water to the nozzles. The pressurized piping in all preaction systems shall be supervised to ensure piping integrity.

Dry Pipe Systems.
Dry pipe systems shall employ automatic nozzles attached to a piping network containing a pressurized gas. The loss of pressure in the piping network shall activate a control valve, which causes water to flow into the piping network and out through the activated nozzles.

Media System Types.

Water mist systems shall be classified by two media system types:

- Single fluid
- Twin fluid

1. Building Design
Apply theory and principles of fire detection and suppression systems as a component of building design.

SPRINKLERS

How Do Sprinkler Heads Work?

Did you ever notice that a common gag for TV sitcoms is to have the automatic fire protection sprinklers go off? It's always the same, some smoke happens and all these sprinkler heads soak the hapless suckers standing there. Since almost none of us ever experience a sprinkler head discharge, the TV show experience seems true to many people. Please understand that it's completely false.

Smoke sets off smoke alarms, not sprinkler heads. Only heat makes sprinkler heads flow water. A typical sprinkler head has a thermal fuse of 174 °F that must melt to release water flow. The head next to it won't go off unless it too melts. So intense heat sets off sprinkler heads, and only the actual heads that experience the intense heat.

Sprinkler heads have either a glass bulb heat sensitive mechanism or a metal fusible link. With this type of activation, only the sprinkler heads directly above the fire tend to flow water. Therefore, the maximum amount of water douses the hottest fire location.

Different temperature sprinkler heads are used for various situations. The table below shows common options.

Color of liquid inside bulb	Temp in °F	Temp in °C
Orange	135	57
Red	155	68
Yellow	174	79
Green	200	93
Blue	286	141
Mauve	360	182
Black	440	227

You can find much more information on sprinkler heads at Tyco Fire and Building Products or at Reliable Sprinkler.

Top of Page

What Should I Know About Sprinkler Systems?

A wet sprinkler system has a series of water distribution pipes and sprinkler heads throughout every space in a facility. The sprinkler heads are typically located between 10' and 15' on center in both directions. The pipes are full of water, so if heat from a fire raises the temperature, the fusible link or glass bulb will break and allow water to flow onto the fire. The amount of water may be in the 15 to 40 gallons per minute range, which is much less than a fire hose that may flow 250 to 1000 gallons per minute. In theory, the sprinkler system will control the fire with much less water damage to the facility.

Generally systems have control valves for maintenance and repairs that must be monitored with anti-tamper switches. Flow controls also are typically monitored so any flow in the system, especially during non-occupied times, gets reported quickly. If you want a much more detailed explanation of sprinkler systems, go to the Stanford University Intro to Automatic Fire Protection Systems.

While sprinklers aren't required in all buildings, the current US building codes (IBC and UBC) provide many design advantages for buildings that include sprinklers. Egress requirements, building construction type, fire separation requirements and many more design items have relaxed requirements in sprinklered buildings. Hence many Design Professionals specify sprinklers and consider it an overall cost savings.

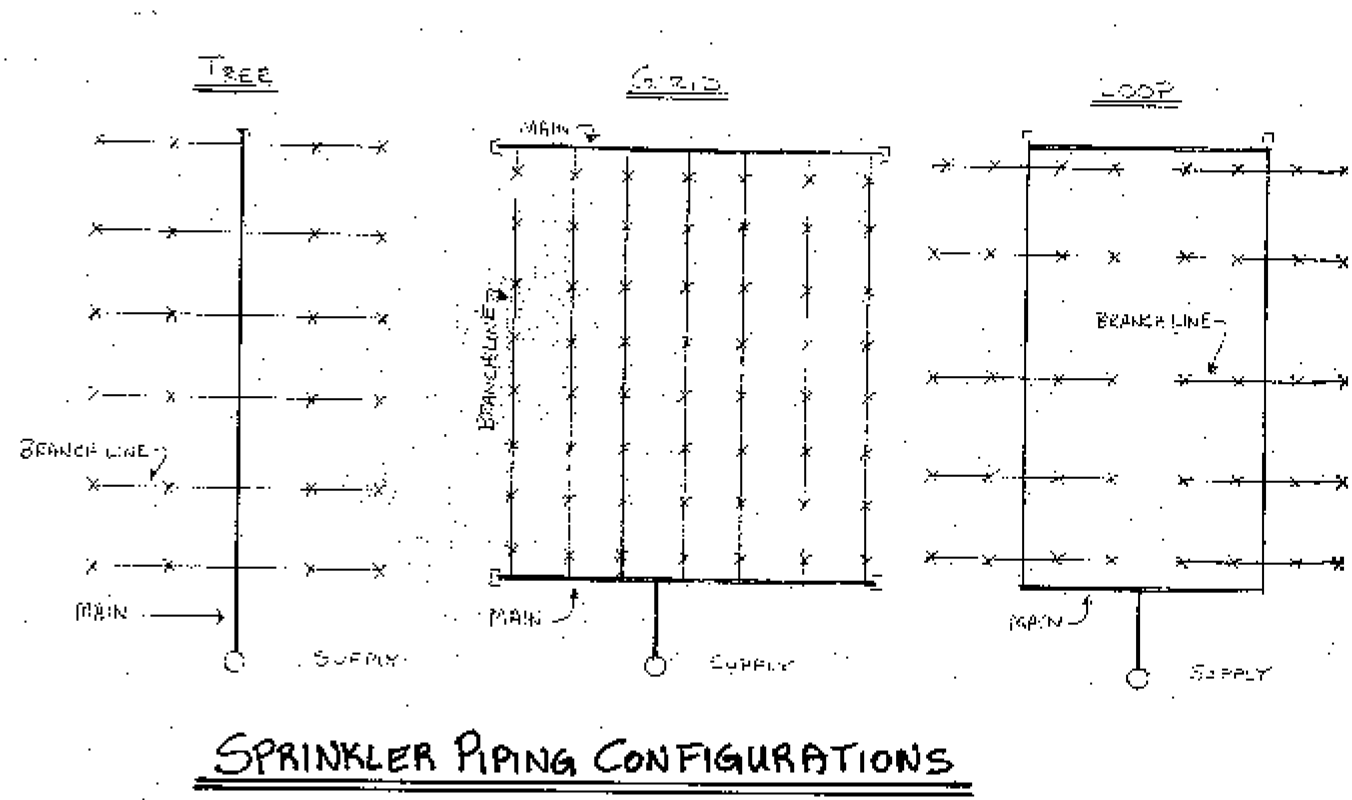
Where water may freeze in the pipes, a dry sprinkler system can be used. An air compressor must provide air at a pressure higher than the water pressure in the sprinkler system so the dry system remains full of compressed air. When a sprinkler head activates, the air rushes out and the water soon (less than one minute) follows. Dry systems have several complications not found with wet systems, so only get used where pipe freezing is a concern.

Deluge systems don't use sprinkler heads to control the water flow. The piping is open at the point of water discharge and the water flow is controlled by a valve connected to the fire alarm system. A deluge system will have water flowing from all discharge points simultaneously, as soon as the fire alarm calls for flow. Only in special occupancies in which rapid fire spread is a major concern do deluge systems get installed.

Pre-action sprinkler systems provide another layer of safety from accidental sprinkler discharge. You can imagine a museum or a library could sustain tremendous losses from water damage, so they want to assure that sprinkler heads don't discharge by mistake. Though system types vary, generally an action (the flowing of water at a head location) must be proceeded by a pre-action (a smoke or heat alarm confirming that a fire is likely in progress). So a Pre-Action sprinkler system has a double check prior to water flowing.

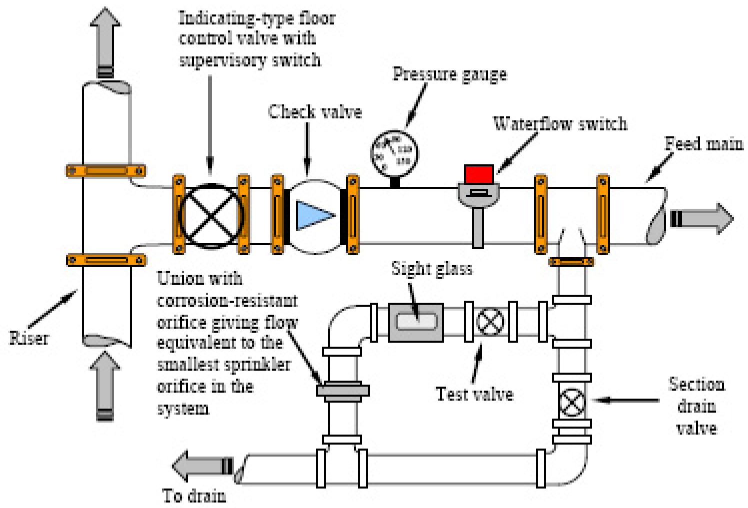
What Piping Configurations are Common?

The sketch below shows various common piping configurations.



The other component of the sprinkler piping is the control valving. While requirements vary based on local rules, the following US Department of Defense sketch shows a typical layout.

Figure 4-1 Floor Control Valve Assembly



Top of Page

What are the Basics of Sprinkler System Design?

It's a good idea to understand sprinkler system design (the basics aren't too complicated). The National Fire Protection Association (NFPA) sets the design standards in the publication NFPA-13. The following few steps show the process.

1. Determine the level of fire hazard for the building.
    1. Light Hazard (offices, churches, hospitals, nursing homes, gyms, schools, theaters, residential, etc.)

   2. Ordinary Hazard Group 1 (bakeries, dairy plants, electronic plants, glass manufacturing, parking garages, etc.)
   3. Ordinary Hazard Group 2 (chemical plants, mercantile, paper mills, repair garages, woodworking shops, etc.)
   4. Extra Hazard Group 1 (aircraft hangars, plywood manufacturing, printing, textile plants, etc.)
   5. Extra Hazard Group 2 (asphalt saturating, flammable liquid spraying, manufactured home plants, plastics processing, etc.)

2. Find the Design Area and Density
0. Design Area = the worst case area in a building where a fire could burn
   1. Design Density = the gallons per minute of water per square foot that should flow onto the Design Area
3. Sprinkler Head locations and piping design

An example always helps. An office building has a light hazard classification, the Design Area is the most remote 1,500 sf and the Design Density is 0.1 gallons per minute/sf. Therefore this system requires 1,500 sf x 0.1 gpm/sf = 150 gallons per minute to be discharged over that most remote 1,500 sf area. If we look instead to a manufacturing facility, the Design Density changes to 0.2 gpm/sf. Therefore, we'd need 300 gpm to be spray over the most remote 1,500 sf area.

The table below from the US Department of Defense provides some of the design basics. To really understand the design work, you need a copy of NFPA-13, but this table shows the basic concept.

Table 4-1 Sprinkler System and Water Supply Design Requirements for Sprinklered Facilities

OCCUPANCY CLASSIFICATION[a]	SPRINKLER SYSTEM		HOSE STREAM ALLOWANCE L/Min (GPM)	DURATION OF SUPPLY Minutes
	DESIGN DENSITY L/min/m² (GPM/ft²)	DESIGN AREA m² (ft²) [b]		
Light Hazard	4.1 (0.10)	280 (3000)	950 (250)	60
Ordinary Hazard Group 1	6.1 (0.15)	280 (3000)	1900 (500)	60
Ordinary Hazard Group 2	8.2 (0.20)	280 (3000)	1900 (500)	90
Extra Hazard Group 1	12.2 (0.30)	280 (3000)	2840 (750)	120
Extra Hazard Group 2	16.3 (0.40)	280 (3000)	2840 (750)	120

[a] Refer to Appendix B for occupancy hazard classification.
[b] See paragraph 4-2.3.3.

Note: The protection requirements identified in Table 4-1 are based on standard commercial practices followed throughout civilian industry for highly protected risk (HPR) properties. Table 4-1 represents the minimum requirements necessary to establish minimum comprehensive life, mission, and property loss prevention. Table 4-1 was adapted as a result from detailed studies by Factory Mutual of loss experience from 1956 to 1965, loss experience in selected occupancies from 1966 to 1977 and from 1981-1990, and fire test data.

What Public Domain Documents are Available for Further Study?

The Dept of Defense has created a manual for Fire Protection Engineering for Facilities which is an excellent introduction to sprinkler systems. This 129 page handbook is officially called UFC 3-600-01 (September 2006).

Tricks of the Trade & Rules of Thumb for Sprinkler Basics:

1. Sprinkler heads act independently, only discharging water when the temperature at that head exceeds the allowable range.
2. A sprinkler head flows about 40 gpm, while a fire hose flows in excess of 250 gpm.
3. Pre-Action sprinkler systems provide a double check prior to water flowing.

2. Building Systems and their Integration
Examine integration and the effects of fire detection and suppression design principles, systems, and details on the overall design of a building considering technological advances and innovative building products.

3. Implications of Design Decisions
Determine the effects of fire detection and suppression systems design decisions and selection on issues such as construction cost, operating costs, construction schedules, and flexibility.

4. Construction Details and Constructability
Identify and analyze fire detection and suppression system details including the aspects of constructability.

Dry Pipe sprinkler system (versus wet-pipe sprinkler) is designed so that sprinkler water pipe will not freeze in unheated spaces (very cold areas)

Not: since it is lighter and less expensive, fewer valves and fittings, no water corrosion

scale.

Begin to Understand HVAC Systems?

The heating, ventilating and air conditioning (HVAC) systems drive occupant comfort in buildings. HVAC systems control the air temperature, of course, but also to intake outside air, exhaust or filter contaminated air and efficiently use energy. Since HVAC systems are complicated, many Construction Supervisors don't bother to learn about them. That's a mistake. Most of the occupant complaints about the buildings we build involve HVAC systems, so we should all be paying more attention to how these systems get designed and installed.

If you take the time to understand the basics of HVAC systems, you'll discover valuable knowledge that you'll use on every project. Start by watching these well done training videos by Price which show the Basics of HVAC.

Another excellent Price training video is Comfort Criteria, which explains how occupants actually experience the HVAC system in action.

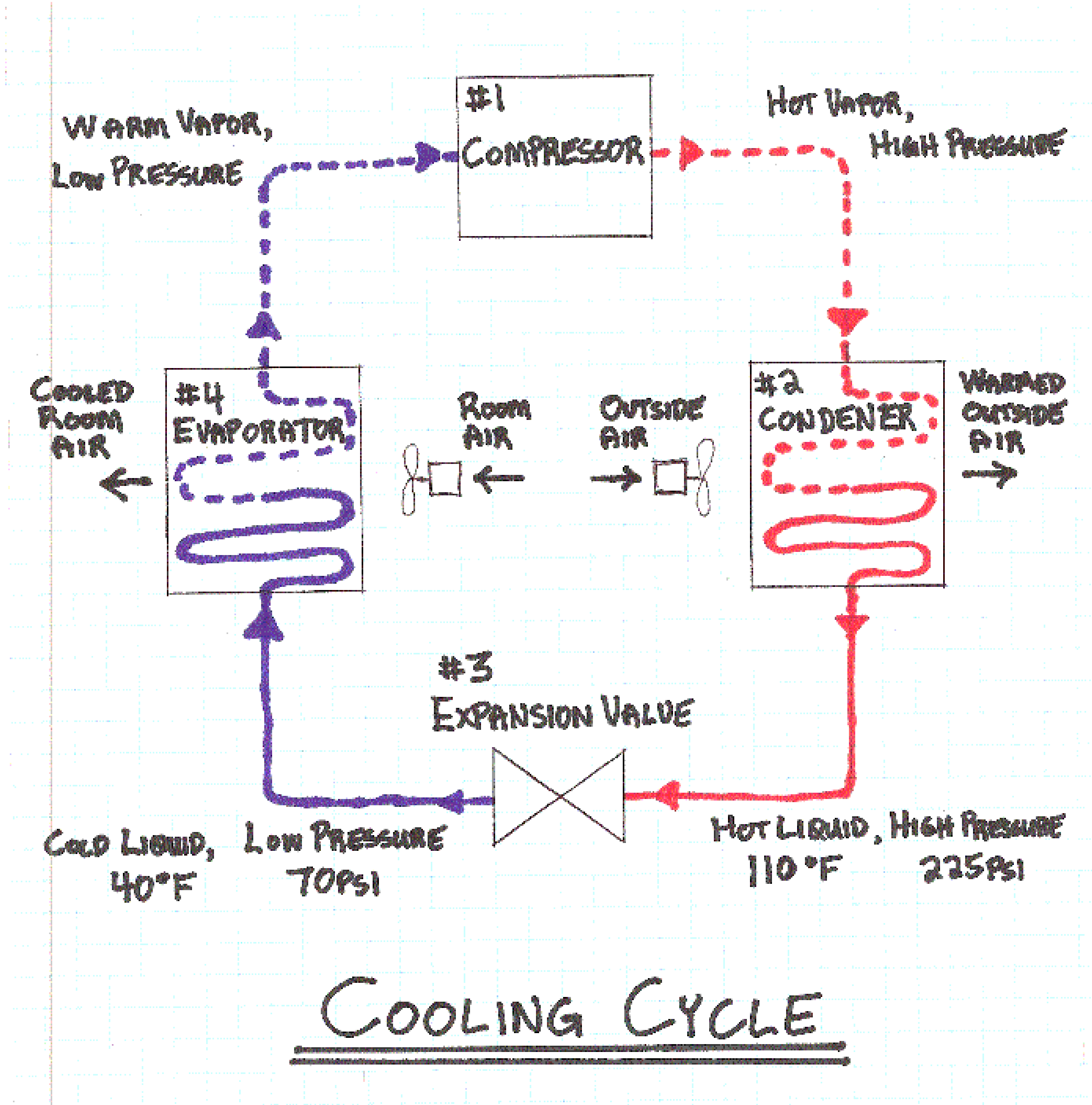
What are the Basic Types of HVAC Systems?

Whenever you consider an HVAC system, begin with a few basic questions.

1. What is the fuel used for heating? Gas, oil, coal, electricity, etc.
2. What is the type of cooling? Electric heat pump, electric air conditioner, chiller, gas air conditioner, etc.
3. How is the heat or cooling delivered to the occupant space? Hot and cold ducted air system, hot and cold water system (hydronic or steam), radiant heat system, etc.
4. What is the ventilation? Summer ventilation with intake louvers and fans, supply and return air with outside air introduced for ventilation, dedicated ventilation system, etc.

Unfortunately, answering the questions above doesn't lead you right into understanding the HVAC system because of the many options. Answering the questions above puts you on the right track for beginning to understand the system, though. The next step is to know about a few basic systems and recognize a common HVAC system when you see it.

For the rest of this section, I'll describe a few HVAC systems that you may encounter on the jobsite. Understanding the basics of how the system works will help you to understand more later. The first thing that you need to understand with almost any HVAC system is the basics of air conditioning. The sketch below explains the air conditioning cycle.


#1
COMPRESSOR
WARM VAPOR,
LOW PRESSURE
HOT VAPOR,
HIGH PRESSURE
#2
CONDENSER
WARMED
OUTSIDE
AIR
#4
EVAPORATOR
COOLED
ROOM
AIR
ROOM
AIR
OUTSIDE
AIR
#3
EXPANSION VALUE
COLD LIQUID,
40°F
LOW PRESSURE
70PSI
HOT LIQUID, HIGH PRESSURE
110°F
225PSI
COOLING CYCLE

To understand the cooling cycle, follow the numbers below:

1. The compressor takes the low pressure refrigerant and compresses it, increasing both the temperature and the pressure. The actual temperature and pressure depend on the refrigerant being used.

2. The condenser blows outside air over the refrigerant vapor, turning it into a liquid, typically about 25 F above the outside air temperature. Hence the hot air blowing out of the condenser.

3. The expansion valve changes the refrigerant from a high pressure liquid to a low pressure liquid, dramatically lowering the temperature as well.

4. The evaporator allows the warm room air to blow over the coils with cold refrigerant liquid, transferring heat to change the cold liquid to a warmer gas. Refrigerants are selected by their ability to absorb significant amounts of heat as they change state from a liquid to a gas.

A good website for more detailed information on all aspects of HVAC work is the HVAC Prime Source.

Now I'll lead you through a few basic HVAC systems, to help you name a few common systems.

Heat Pumps: Like a refrigerator working in reverse, a heat pump extracts the heat from the air (or water) and uses it for heating. The cooling cycle is the normal vapor compression refrigerant process that's described above. The most common air to air heat pumps have the compressor and condenser in an outside unit. Then the refrigerant piping goes to an inside air handler unit which houses the expansion valve and the evaporator. These Split Systems normally have a 75' limit for the length of the refrigerant piping. During very cold weather, the heating side of the heat pump won't be able to pull enough heat from the outside air, so electric back-up resistive heaters are required. A separate system must be installed to bring outside air into the space. Heat pumps usually have one thermostat for the entire heat pump zone. System simplicity and low initial cost are the main benefit, while short life span (7 years is typical) and lack of control options are the principal drawbacks.

Roof Top Units (Packaged Units): These complete heating and cooling units sit on the roof or outside on the ground and duct the conditioned air into the space. The heating side often uses gas furnaces, but other fuel options are available. The complete cooling cycle shown on the above sketch happens in the roof top unit. Since the units are outside, the mixing of outside air with the return air can be done easily. These packaged units produce a certain air temperature that goes into the duct distribution. Often the roof top unit produces cool air and certain zones may need that air warmed with electric duct heaters. System simplicity and low initial cost are the main benefit, while the main drawbacks are large vertical ducts running floor to floor and system control options.

Water Source Heat Pumps: Also called a one pipe system, a single pipe carries water through the building which the individual water source heat pumps use for their heat source or heat sink. Typically the water in the loop pipe is about 80 F. This system requires a boiler to raise the loop water temperature and a cooling tower to lower the loop water temperature. Each zone, then, has a dedicated water source heat pump that is located inside the building. One of the benefits of this system is the ability to have a heat pump needing cooling and putting heat into the loop water while another heat pump calls for heating and takes heat out of the cooling loop. This system is extremely energy efficient during those times of the year. The main drawback is probably all the compressors located all through the interior, both for noise and maintenance.

Chillers: The above systems are all considered Direct Expansion (DX) systems because the units provide for direct expansion of the refrigerant in the air cooling coils. Chillers, on the other hand, make cold water that gets distributed by pipes to air cooling coils. Chiller systems also require boilers to make hot water for the heating cycle. A two pipe system either cools or heats and a system changeover must occur to go from cooling to heating. In the cooling cycle, the one pipe supplies the cold water while the other pipe returns the warmed water (warmed by passing through the cooling coils with air blowing over the coils). A four pipe system doesn't need a system changeover, as each cooling coil unit has both a hot water supply and return and a cold water supply and return piped to it. The energy efficiency of these systems and the excellent control options are the biggest benefits, while initial cost and maintenance complexity are the drawbacks.

Heaters: Hot air furnaces may burn gas, oil, coal, wood, etc. Radiant heaters, which produce infrared radiation which heats objects rather than the air adjacent to the heater, can be fueled by gas or electric. Electric resistance heaters are also common. Direct fired gas heaters, which use 100% fresh air and innovative fan distribution can also be an excellent heating solution for large spaces.

Fans and Ventilation: The use of fans to ventilate a space for cooling and/or expulsion of indoor pollutants can be done in many ways. From a simple toilet exhaust fan to huge wall fans interconnected with wall louvers used for summer cooling, there are many ways to ventilate.

How Does Air Distribution Work?

Since most of the HVAC systems installed in commercial buildings use air distribution, take some time to understand how air flows from diffusers. The training modules produced by Price do an excellent job of teaching the concepts in a few minutes. Review the space air diffusion video to learn more.

What Should I Know about Rough Sizing Systems?

Have you ever talked to the Project Owner as he contemplates adding a few rooms to the project? That type of discussion happens occasionally on the construction site, as Owner's seem to always be considering options and changes during construction. If an owner discusses adding 1000 sf of office, it's handy to know that about 3 tons of air conditioning will be needed. As I've mentioned before, that general knowledge of building provides a sense of competence that can carry you far.

So how do you have a sense of rough sizing HVAC systems? Consider the type of projects you build and consult the table below for the area factor. The above example used a 1000 sf office space, which has about 350 sf per ton of air conditioning. So 1000 sf/350 sf/ton = about 3 ton.

Building Type	SF/ton
Office areas or retail	350
Conference rooms	100 to 200
Dedicated computer rooms	50 to 100

Classrooms	250
Industrial	300
Arenas	150 to 200
Residential	600 to 700

Therefore, if you're building a school, just remember that every 1,000 sf will need about 4 tons of air conditioning. Of course, you need to remember that this rough sizing varies by the amount of insulation, the amount and orientation of glazing, the amount of exterior wall and the climate.

If you want to further rough size air duct systems, you may want to purchase a Ductulator, a hand held rotating calculator that aids in understanding air duct sizes, air velocities and air flows. These additional rules of thumb will help you use it:

1. Normal comfort air conditioning uses about 400 cfm per ton.
2. Precision air conditioning (for dedicated computer rooms) uses about 500 cfm per ton.
3. Dehumidification uses about 200 cfm per ton.
4. Air flow at diffusers should be 600 to 700 feet per minute to be fairly quiet.
5. Air flow in main ducts should be 1,000 to 1,200 feet per minute to be fairly quiet.
6. Air flow for kitchen exhaust hoods will be in the 2,500 feet per minute range.

What Should I Know about HVAC Energy Usage?

While we construct the buildings, other people will live and work and play in them for many years afterward. Learn to contemplate how the building will work for those future occupants. With the understanding of a few basic concepts, you can have a sense of how the building will use energy in the future.

The average amount spent on energy use for office buildings seems to be about $1.80/sf per year. So a 10,000 sf office building will pay about $18,000 per year for electric, gas and oil. Lighting tends to be the largest part of that cost for most commercial buildings. The new energy conservation codes require less than 1 watt/sf of lighting energy usage, but many existing buildings use 2 to 3 watts/sf for lighting. An example below illustrates:

LIGHTING

10,000 SF OFFICE BLDG

$$10{,}000\,SF \times \frac{2\,WATT}{SF} \times \frac{1\,KW}{1000\,WATT} \times \frac{12\,HR}{DAY} \times \frac{6\,DAY}{WK} \times \frac{52\,WK}{YR} \times \frac{\$.10}{KWHR} = \$7{,}488$$

CHECK CALC FROM US DOE ANNUAL LIGHTING TABLE LINK

$$10{,}000\,SF \times \frac{8.2\,KWHR}{SF} \times \frac{\$.10}{KWHR} = \$8{,}200$$ (CLOSE TO COST ABOVE)

THEREFORE LIGHTING COSTS ABOUT $.75/SF PER YEAR

TOTAL ENERGY

$$10{,}000\,SF \times \frac{\$1.80}{SF/YR} = \$18{,}000/YEAR$$

HVAC

TOTAL		LIGHTING		HVAC	
$\frac{\$1.80}{SF/YR}$	−	$\frac{\$.75}{SF/YR}$	=	$\frac{\$1.05}{SF/YR}$	OR $10,500/YEAR

The energy use of commercial buildings is shown in this US Department of Energy report. The lighting use of commercial buildings is shown in this US DOE report. Finally, the costs per sf spent on energy are shown in this US DOE report.

What Public Domain Documents are Available for Further Study?

The Dept of Defense has created a manual for Heating, Ventilating, Air Conditioning and Dehumidifying Systems is an excellent introduction to HVAC. This 234 page handbook is officially called UFC 3-410-02N (June 2005).

The US Dept of Defense, HVAC Control Systems provides 454 pages of details regarding designing of an HVAC system. The name of this document is UFC 3-410-02A (May 2003).

If you want to follow a design for research laboratories (with lots of good practical discussion points), go to A Design Guide for Energy Efficient Research Laboratories.

Another resource, is the US Dept of Defense HVAC Air Supply Manual. It has 64 pages of information and is officially named UFGS-23 00 00 (October 2006).

For information on Central Heating Plants, review the 230 page manual issued by the US Dept of Defense, officially named UFC 3-430-08N (January 2004).

The US Dept of Defense has created a guide to Cooling Buildings by Natural Ventilation. This 183 page has the official name UFC 3-440-06N (January 2004).

The US Dept of Defense Ductwork and Accessories Manual provides 31 pages of information regarding HVAC ductwork and is officially namedUFGS-23 30 13.00 20 (July 2006).

The Dept of Defense has created a manual for designing Industrial Ventilation, officially named UFC 3-410-04N (October 2004).

The US Dept of Defense Industrial Ventilation provides 50 pages of details regarding ventilation systems. The name of this document is UFGS-23 35 19.00 20 (July 2006).

A Manual for Ventilation Assessment in Mechanically Ventilated Commercial Buildings is available from the US Dept of Commerce. This document is 124 pages, named NISTIR-5329.

Further information regarding HVAC System Testing is provided by the US Dept of Defense. This 33 page document is officially titled UFGS-23 08 01.00 20 (April 2006).

The Naval Facilities Engineering Command provides Maintenance and Operations of Ventilation Systems which is a 74 page document overview of HVAC systems. This document has the official name of SN-0525-LP-194-6400.

The Noise and Vibration Control Manual provided by the US Dept of Defense is a 152 page document, officially named UFC 3-450-01 (May 2003).

A complete guide to Thermodynamics, Heat Transfer, and Fluid Flow is provided in a 3-part manual. Volume I is titled DOE-HDBK-1012/1-92 (June 1992) and is 138 pages, Volume II is 32 pages and titled DOE-HDBK-1012/2-92 (June 1992), and Volume III titled HT-03 is 12 pages.

The Dept of Energy provides information on the Fundamentals of Valves, in this 52 page document officially named DOE-HDBK-1018/2-93

For information on compressed air systems, review the US Dept of Defense Compressed Air Manual, officially named UFC 3-420-02FA (May 2003).

Tricks of the Trade & Rules of Thumb for HVAC Basics:

1. HVAC stands for Heating, Ventilating and Air Conditioning and the main standard setter is ASHRAE, American Society of Heating, Refrigeration and Air Conditioning Engineers.

2. 1 ton of cooling = 12,000 btu/hour (power)

3. 1 kilowatt-hour = 3412 btu (energy or work)

4. When thinking about air flows into and out of a room or a building, remember that inflows have to balance with outflows, just like for your checkbook.

5. Heat always transfers from warmer to cooler.

6. Always think about the control of moist air (and condensation) in HVAC systems.

7. Normal comfort air conditioning uses about 400 cfm per ton.

8. Air velocity over 100 feet/minute on occupants tends to annoy them.

9. Office buildings tend to pay about $1.80/sf per year for energy.

Electrical Systems Design

- Different types of services and service equipments.
- Understand the schematic and actual wiring diagram.
- Apply the actual wiring diagram in Electrical Systems Design.
- Understand the different parts of an electrical plan.
- Understand the proper way of sizing a conductor and circuit breaker.
- Understand the actual load analysis method of electrical design.
- Understand the proper way of sizing a conductor and protection for motor loads.
- Understand the proper way of sizing transformer and generator.
- Calculate the voltage drop for feeders.
- Understand the proper way of sizing low voltage switchgear.
- Understand the proper way of sizing the KAIC rating of a circuit breaker.

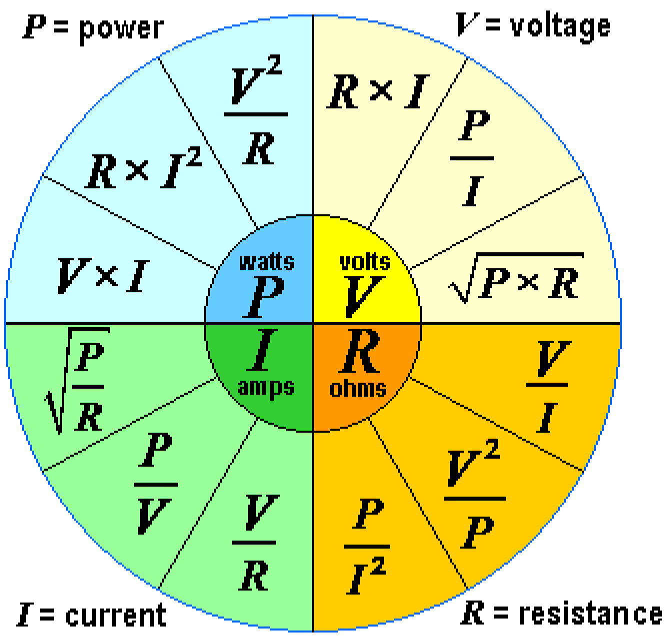
B) RESIDENTIAL BUILDING WIRING INSTALLATION
1) Different Types of Services
2) Service Equipments
3) Schematic Diagram
4) Actual Wiring Diagram

C) BUILDING ELECTRICAL DESIGN
1) General Notes & Specifications
2) Legend & Symbols
3) Location Map
4) Power Lay-Out
5) Basic Motor Computation
6) Branch Circuit Conductor and Circuit Breaker Coordination
7) Lighting Lay-Out
8) Load Schedule
9) Riser or One Line Diagram
10) Service Entrance Computations

D) Grounding Installations for Commercial and Industrial Applications
1) Ungrounded Installations
2) Preventing Electrical Ground
3) Designing Grounding Installations

F) HIGH-RISE BUILDING
ELECTRICAL DESIGN

1) General Introduction
2) Pre-Design Factors
3) Building Description
4) Riser Diagram
5) Load Computation
6) Voltage Drop Computation
7) Feeder & Su b- feeder Computations
8) Transformer Sizing
9) Motor Load Computation
10) Elevator Load Computation
11) Main Feeder Computation
12) Emergency Systems Computation or Generator Sizing
13) Low Voltage Switchgear (LVSG) Computation
14) Fault Current Calculation
15) P r o t e c t i v e D e v i c e Coordination Analysis
16) Injection of Fault Currents a n d T r i p p i n g T i m e Evaluation
17) Customizing and Importing t h e T i m e C u r r e n t Coordination Graph
18) Practical Exercises (Short Circuit, Load Flow,



ELECTRICS DEPARTMENT

Basic electricity:

Electricity is the flow of electrons from one place to another. Electrons can flow through any material, but does so more easily in some than in others. How easily it flows is called resistance. The resistance of a material is measured in Ohms.

Matter can be broken down into:

- **Conductors:** electrons flow easily. Low resistance.
- **Semi-conductors:** electron can be made to flow under certain circumstances. Variable resistance according to formulation and circuit conditions.

- **Insulator:** electrons flow with great difficulty. High resistance.

Since electrons are very small, as a practical matter they are usually measured in very large numbers. A Coulomb is 6.24 x 10^{18} electrons. However, electricians are mostly interested in electrons in motion. The flow of electrons is called current, and is measured in AMPS. **One amp is equal to a flow of one coulomb per second** through a wire.

Making electrons flow through a resistance requires an attractive force to pull them. This force, called Electro-Motive Force or EMF, is measured in **volts**. A Volt is the force required to push 1 Amp through 1 Ohm of resistance.

As electrons flow through a resistance, it performs a certain amount of work. It may be in the form of heat or a magnetic field or motion, but it does something. This work is called Power, and is measured in Watts. One Watt is equal to the work performed by 1 Amp pushed by 1 Volt through a resistance.

NOTE:

AMPS is amount of electricity.
VOLTS is the Push, not the amount.
OHMS slows the flow.
WATTS is how much gets done.

There are 2 standard formulae that describe these relationships.

Ohm's Law: Where

R = Resistance (ohms)
E = Electro-motive Force (volts) <>I = Intensity of Current (amps) **R = E / I**

To express work done: **Power formula (PIE Law):**

Where:

P = Power (watts)
I = Intensity of Current (amps)
E = Electro-motive Force (volts)

P = IE

This law is often restated in the units of measure as the West Virginia Law:

W = VA
for
Watts = Volts x Amps

All this is important because all electrical equipment has a limit to how much electricity it can handle safely, and you must keep track of load and capacities to prevent failure, damage, or a fire.

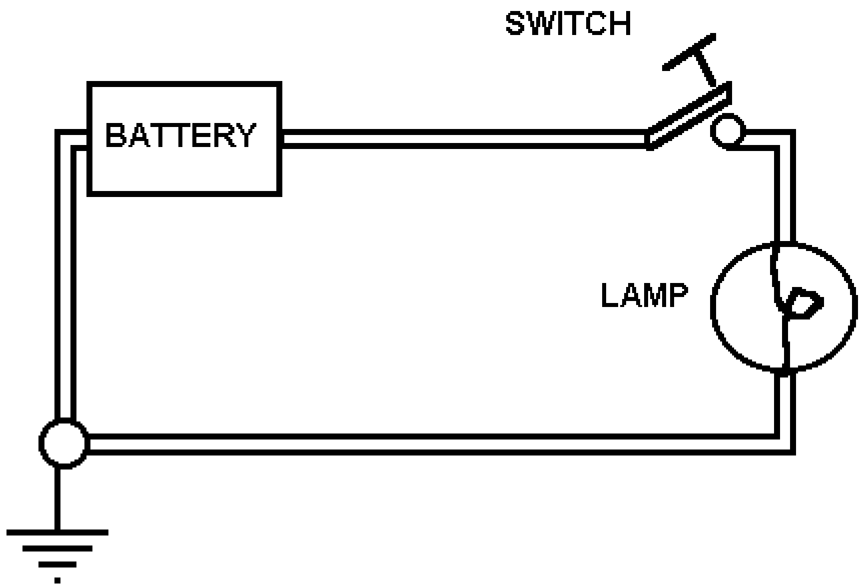
For example, a lamp is rated at 1000 w. @ 120 v. That means that at 120 volts it will use:

1000 w. / 120 v. = 8.33 a.

A common shortcut is to use 100 v. instead of 120. This makes calculating easier and builds in some headspace. So:

1000 w./ 100 v. = approx. 10 a.

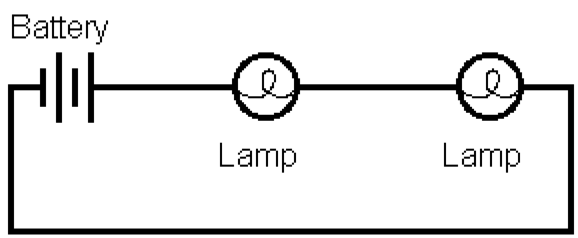
A Simple Circuit:



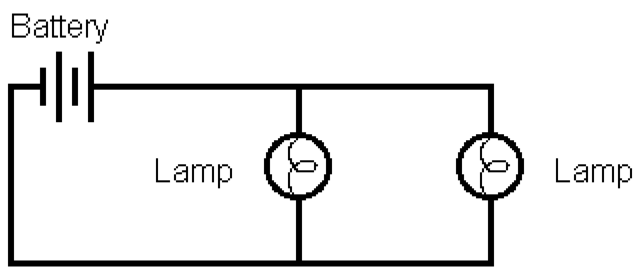
The simplest circuit has a power source, like a battery or outlet, a wire running from the "hot" side to a "load", then a wire from the load back to the power source. There is also usually a switch to "open" or "close" the circuit. The load will function only when the circuit is closed or complete.

In more complex circuits where more than one load is connected, they may be either in series or in parallel. In a series circuit, current must pass trough one to get to the next. Voltage is divided between them. If one goes out, they all go out.

SERIES



PARALLEL



In a parallel circuit, each load is electrically connected to the source at the same point, each gets the full voltage simultaneously. If one goes out, the rest stay lit.

Most circuits are combinations of the two types. Circuit breakers and fuses are in series with the load, but multiple loads on a circuit are paralleled.

Circuit breakers and fuses can be placed in the supply circuit **before** the plug, as in lighting circuits, or **between the plug and the load** internally, as in most sound equipment, or both.

Cable, connectors, and circuits are all rated in amps according to size.

Cable

There are many types of cable, but the electrical code allows only certain types to be used. Stage use is very hard on equipment. Cable may be walked on, runover by scenery or vehicles, pulled and dragged, and pinched. The emphasis is therefore on flexibility and durability.

For single circuit used, ONLY type S or SO cables are permitted. Type S is a heavy-duty rubber covered cable. Type SO is a heavy duty Neoprene (synthetic rubber, oil resistant) covered cable. It must be a three wire cable, with black, white and green conductors. Type SJ, with a lighter weight rubber covering, is specifically NOT permitted. For single conductor feeder cable use, welding cable was once common is specifically NOT permitted. It must be Types SC, SCE, PPE or similar Entertainment and Stage Cable, which has an extra-heavy duty cover and very flexible wire inside.

Wire gauge	Ampacity
#18	7 a.
#16	10 a.
#14	15 a.
#12	20 a.
#10	25 a.
#00 (2/0)	300 a.
#0000 (4/0)	405 a.

These are approximate values for the cables typically used in theatre. Other types and methods may be rated differently.

Connectors

Connectors allow temporary connections to be made and broken quickly and safely. Male connectors have exposed contacts. Female connectors have internal contacts inside an insulating shell with holes for plugging the two together. Think biology.

The male is always on the load side of a connection, the female on the line side; "the female has the power!"

parallel Blade (Edison): the standard household plug, this is found on much equipment but is not durable enough for stage lights. The standard configuration, two parallel blades and a U-ground, is rated at 15 a. only. Usually the"hot" terminal is copper colored and the "neutral" is silver colored, and the "ground" is green.

Stage Pin (a.k.a. NEMA designation, 5T-20): has round 1/4" pins, and is very durable. Most common dedicated stage connector. Rated at 20 a. The center pin is "ground", the outside pin nearest the ground is the "neutral", and the other is the "hot".

3-pin Twist Lock (a.k.a. NEMA L5-20): has three curved blades which are locked into the receptacle by rotating it 1/8 turn after insertion. Rated at 20 a. One blade has a tab bent towards center; that is the ground. The slightly larger blade with silver screw is "neutral", and the small blade with the copper screw is "hot".

Cam-locks: single wire connector for large wire, 2/0 or 4/0. Locked in place by rotating 1/2 turn after insertion. Comes in colors to indicate which leg is which. Rated at over 400 a. In most common size on stage. Also available in a mini-cam size for #1 cable, rated at 100 a.

Cable Accessories:

Two-fers: Y-cord with one male and two female connectors, for plugging two devices into one outlet.

Three-fers: same thing, 3 females.

Adaptors: a male connector on one end and a female of a different type on the other. Used to plug a device into a different type of outlet.

POWER DISTRIBUTION

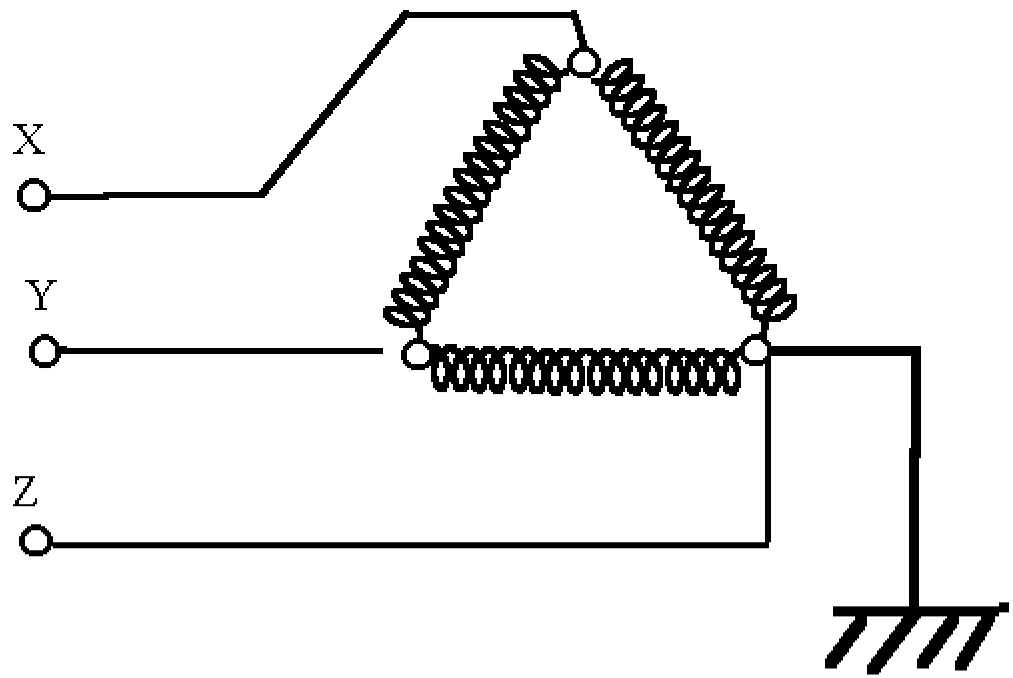
There are broadly two form in which electricity can be generated, Direct Current and Alternating current. **Direct Current** is the type of electricity supplied by a battery. One terminal is positively charged, the other negatively charged, and electricity flows from one to the other, always in the same direction. However, while it is simple to make and control, DC does not travel well over long distances; it gets used up by the resistance in the transmission lines, and is gone before it gets to where it is needed.

Alternating Current also has a positive and a negative terminal, but the polarity and the direction of flow alternates many times per second. In the United States, electricity alternates polarity 120 times per second, or 60 full cycles per second, i.e. 60 Hz. AC can travel well over long distances, and so it the choice for power distribution lines.

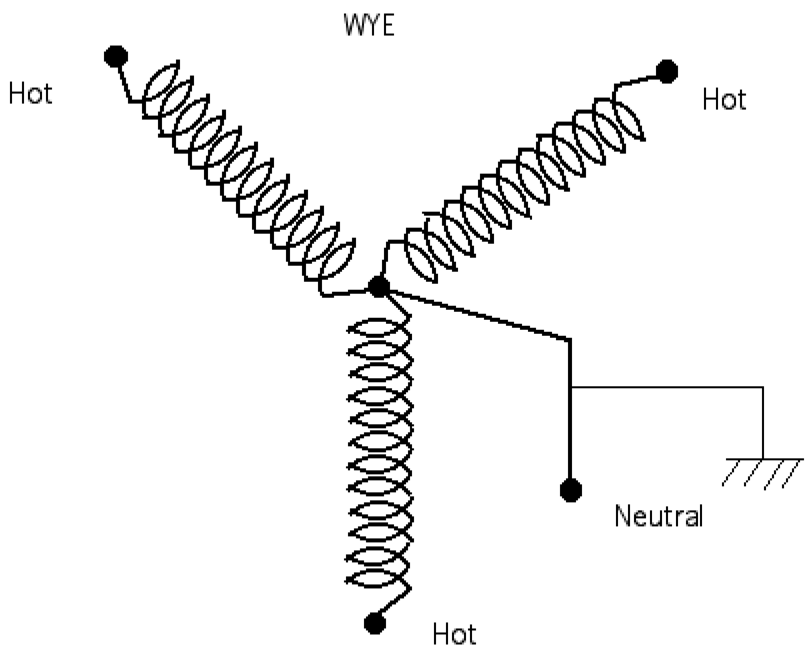
There is no difference between amps or volts between AC or DC. Some devices can ONLY operate on one type of system or the other, but otherwise a volt is a volt.

Road shows and concert tours typically bring in their own lighting and sound rigs, which means their dimmer racks and sound distribution boxes must be tied in to a power source able to supply large amounts of current.

Power is usually generated at a distance from where it is used. It is supplied as 3-phase power at very high voltages.This allows many kilowatts to flow through fairly small conductors because amperage is effectively small. There are 3 hots, each 120 degrees out-of-phase with the next when their sine waves are plotted against each other, hence the term "3 phase". There is no neutral. This configuration is called Delta, and is the same type (at much lower voltages) use to run 3-phase motors.

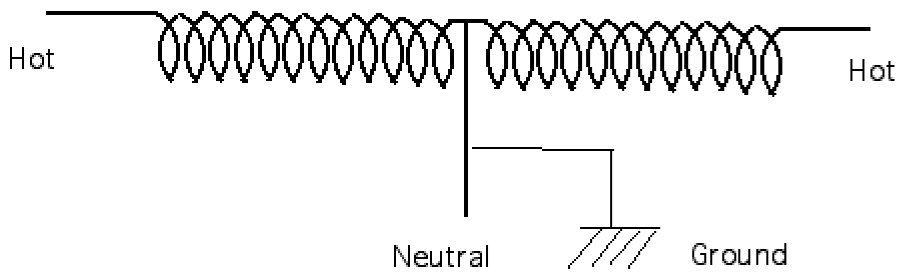


The power level is brought down through a series of substations. At each step transformers reduce the voltage and increase the amperage until it reaches the line transformers outside the building. At that point, the Delta service is converted to a Wye service, and is brought into the building at the "service entrance".



The Wye service has the same three hot legs, plus an electrical neutral created at the transformer. By this time in either Wye or Delta, the line voltage has been brought down to where each hot terminal is 120 volts above earth potential, called "ground", and in the case of a Wye service, each hot is also 120 v. above the Neutral as well. However, due to the geometry of the hot phases, there is a difference of 208 v. (not 240 v.) between any two hots in either type of 3-phase system.

This is different from the Single-phase system found in some older theatres, and commonly in private homes.



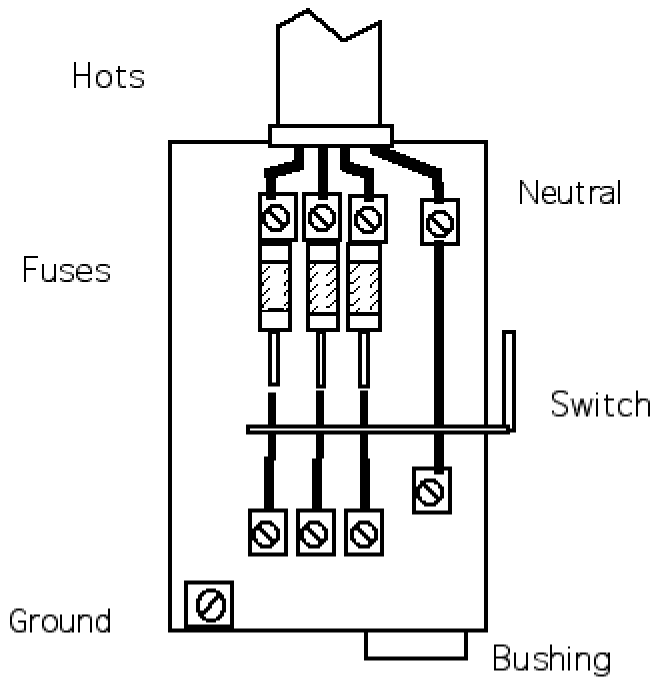
In this service two hots are drawn from each end of one phase of a Delta (hence Single phase), and a neutral created at the transformer. These are brought into the building at the service entrance. Between either hot and the neutral there is 120 v., just as in the Wye system. However, there is 240 v., not 208 v, between the two hots. Single phase is rarely found in industry, including theatre, because it is not as efficient for supplying the large amounts of power needed.

At the service entrance the Neutral of the Wye (or of a single phase) system must be bonded to a grounding system buried in the earth outside. It is VERY important that the ground and neutral NOT be connected at any other point, or an unsafe situation could be created.

Tying in Power

When in comes to permanent commercial wiring, the Electrical Code requires that only licensed electricians do the work. However, the Code has an exemption for the Entertainment industry. "Qualified Personnel" are allowed to make TEMPORARY hookups to an electrical service. That means that a qualified stagehand can tie a portable dimmer rack to a distribution box, but cannot run permanent wires to that box OR install a PERMANENT dimmer rack. The key phrase is "Qualified personnel". Only stagehands have who been trained to do so are allowed to make hookups. The Code also grants another exemption to theatre not found in other industries. Theatre is allowed to use single conductors and connectors (that is feeder cable with Camlock connectors). But as it is VITAL that the connections be made in the proper order, only trained and qualified personnel are permitted to make those connections.

The distribution box where temporary equipment is tied in to the electrical supply is called a Company Switch, a Distro, or a "Bull switch".



Inside the distro are lugs for connecting the wires. There are three lugs for connecting the "hot" wires, each of which is connected to a fuse or a circuit breaker. They are typically referred to as Leg A, B, and C; or leg X, Y, and Z. They may be black or marked with any color EXCEPT White, light grey, or green. There is also a lug for the Neutral, which does NOT have a fuse or breaker, which MUST be marked white or light grey, and a lug for the Ground wire, which is usually bolted directly to the metal distro box. (According to Code, the box and its conduit are suppose to be grounded, but if they are not, a separate grounding wire, marked with green, must be run to the box.) There will also be an access hole through which the temporary wires are passed. The hole should have a bushing to prevent the box from cutting through the insulation of the wire.

The proper procedure MUST be followed when connecting the cables, or an unsafe situation can occur. DO NOT TAKE SHORTCUTS!

- Lay out the feeder tails so they are ready to be connected. NOTE: Code requires the use tails which can be disconnected within 10 feet of the distro box). The tails should NOT be connected to the feeder cables yet.
- Turn off the bull switch if it is not already off (the box will not open if the switch is on unless the box is broken). Open the box and MAKE SURE the "hot" terminals are really "dead" using a meter or tester.
- Insert the Green tail wire and fasten securely to the ground lug.
- Insert the White white and fasten to the Neutral lug.
- Insert the Hot tails one at a time and attach them securely to the three "hot" terminals, the ones attached to the fuses or breakers. These wires are usually marked with Black, Red, and Blue. It does not really matter at this point which wire is connected to which hot terminal, but the convention is usually in the order: Black, Red, Blue.
- Close the box and make sure the connectors on the tails are clear. Turn on the Bull switch.
- Test each wire with a meter by carefully inserting the leads from the meter into the open feeder connectors. You should get:
    - Between Neutral and Ground: 0 volts.
    - Between each Hot wire and Neutral: 120 v.
    - Between each Hot wire and the Ground: 120 v.
    - Between each Hot and any other Hot: 208 v.

  If you get ANY OTHER READINGS, check your wiring again!

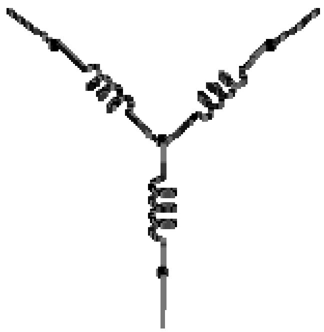
- If everything checks OK, turn off the Bull switch and inform the road electrician.

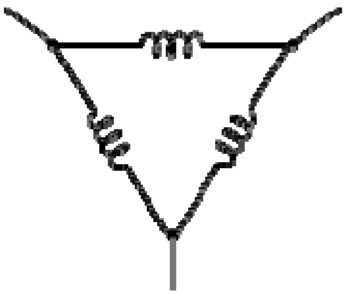
When the feeder cables are connected to the dimmer rack or sound distro, and when the feeders are connected to the tails, **CONNECT THEM IN THE SAME ORDER!**, That is: **first Green, then White, then the three Hots.** Connect them with the power turned off but always treat them as though the power is on anyway. Someday it may be!

Also, **<u>NEVER</u> PLUG THE HOTS IN FIRST!** The equipment may try to close a circuit through two hots and put 208 v. through a circuit meant for 120 v., and destroy the equipment, or worse yet electrocute someone!

Delta and Wye 3-phase circuits

- Phase voltage
- Line voltage
- Phase current
- Line current



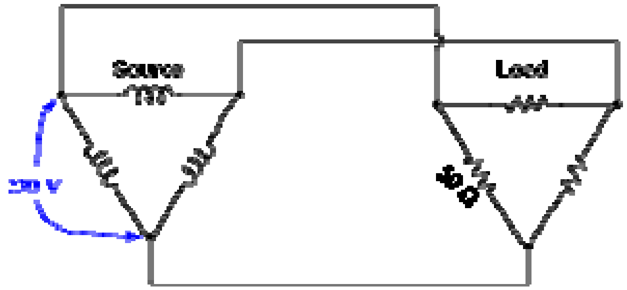


In which circuit (Y or Delta) are the phase and line currents equal? In which circuit (Y or Delta) are the phase and line voltages equal? Explain both answers, in terms that anyone with a basic knowledge of electricity could understand.
Where phase and line quantities are *un*equal, determine which is larger.

Explain the difference between a *balanced* polyphase system and an *unbalanced* polyphase system. What conditions typically cause a polyphase system to become unbalanced?

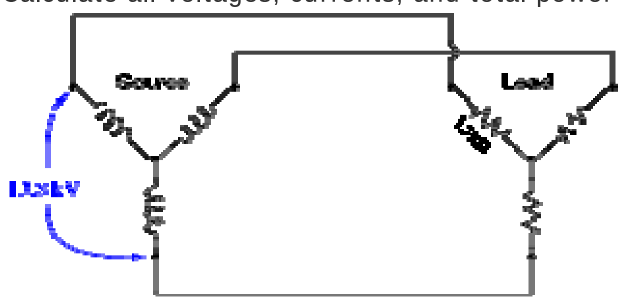
In a balanced Y-connected power system, calculate the phase voltage (E_{phase}) if the line voltage (E_{line}) is 480 volts.

Calculate all voltages, currents, and total power in this balanced Delta-Delta system:

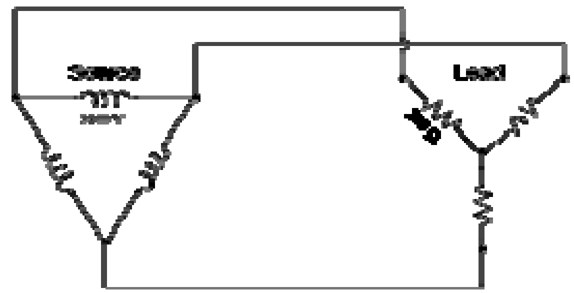


Question 5:

Calculate all voltages, currents, and total power in this balanced Y-Y system:

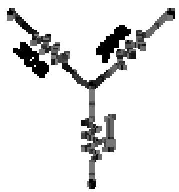


Calculate all voltages, currents, and total power in this balanced Delta-Y system:



Question 8:

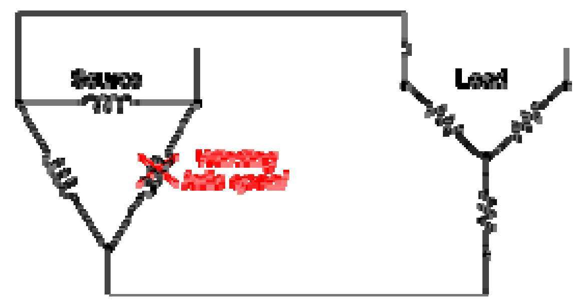
What resistor values would we have to choose in a Delta configuration to behave exactly the same as this Y-connected resistor network?



Reveal Answer

Question 9:

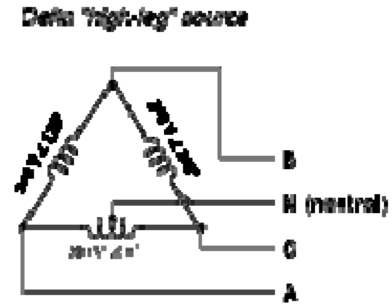
What will happen in each of these systems to the phase voltages of the load, if one of the source phases fails open?



Reveal Answer

Question 10:

A common three-phase source connection scheme is the *Delta high-leg* or *Four-wire Delta*, where each phase coil outputs 240 volts:

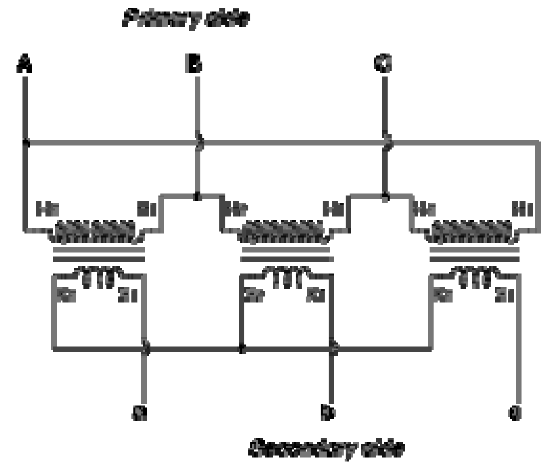


Identify the different voltages obtained from this coil configuration, and which connection points each voltage is measured between.

Reveal Answer

Question 11:

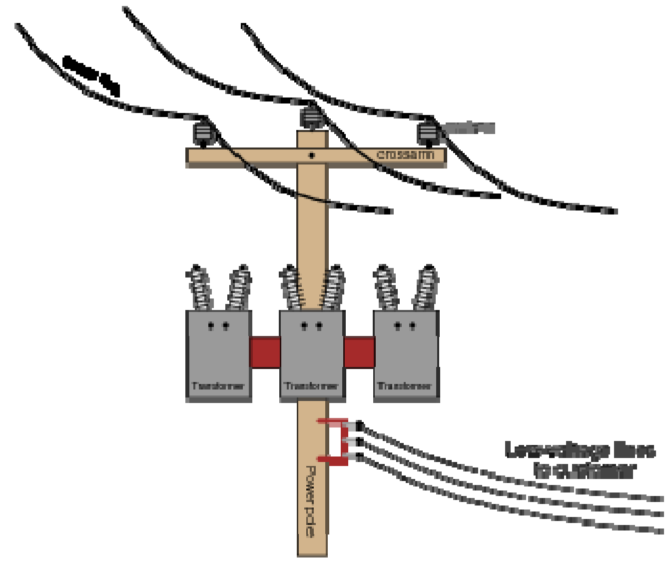
Identify the primary-secondary connection configuration of these three power transformers (i.e. Y-Y, Y-Delta, Delta-Y, etc.):



Reveal Answer

Question 12:

An electrical lineman is connecting three single-phase transformers in a Y(primary)-Y(secondary) configuration, for power service to a business. Draw the connecting wires necessary between the transformer windings, and between the transformer terminals and the lines:

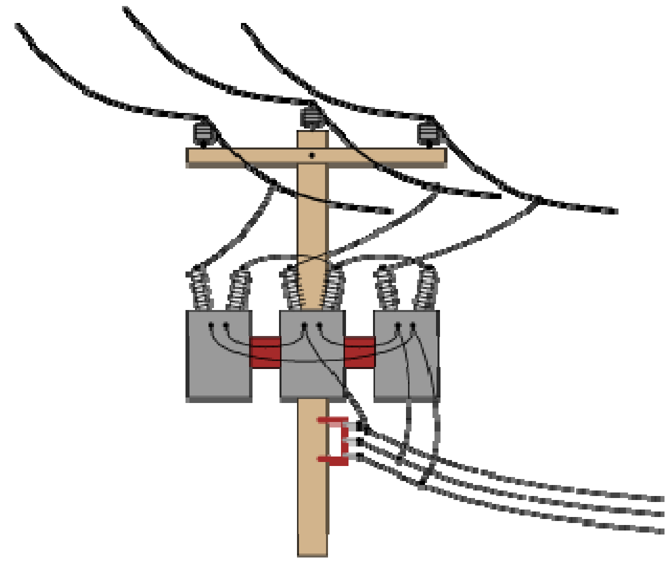


Note: fuses have been omitted from this illustration, for simplicity.

Reveal Answer

Question 13:

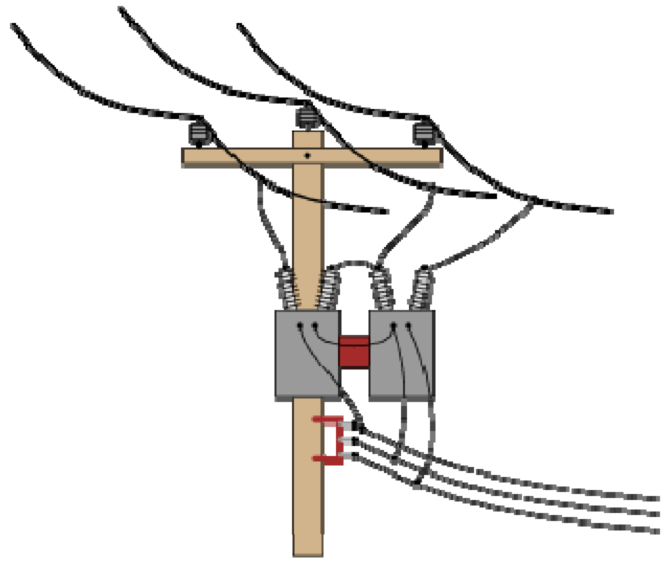
Identify the primary-secondary connection configuration of these pole-mounted power transformers (i.e. Y-Y, Y-Delta, Delta-Y, etc.):



Reveal Answer

Question 14:

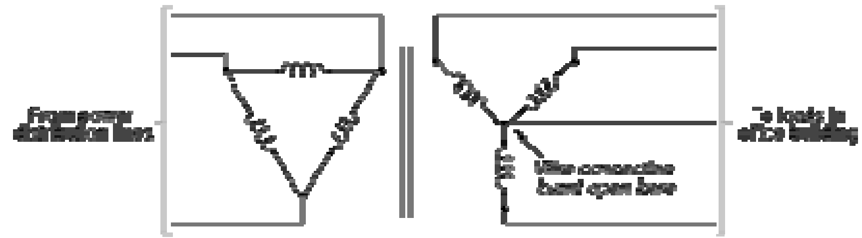
Identify the primary-secondary connection configuration of these pole-mounted power transformers (i.e. Y-Y, Y-Delta, Delta-Y, etc.):



Reveal Answer

Question 15:

One of the conductors connecting the secondary of a three-phase power distribution transformer to a large office building fails open. Upon inspection, the source of the failure is obvious: the wire overheated at a point of contact with a terminal block, until it physically separated from the terminal.



What is strange, though, is that the overheated wire is the *neutral* conductor, not any one of the "line" conductors. Based on this observation, what do you think caused the failure?
After repairing the wire, what would you do to verify the cause of the failure?

Basic Motor Formulas And Calculations

The formulas and calculations which appear below should be used for estimating purposes only. It is the responsibility of the customer to specify the required motor Hp, Torque, and accelerating time for his application. The salesman may wish to check the customers specified values with the formulas in this section, however, if there is serious doubt concerning the customers application or if the customer requires guaranteed motor/application performance, the Product Department Customer Service group should be contacted.

Rules Of Thumb (Approximation)

At 1800 rpm, a motor develops a 3 lb.ft. per hp
At 1200 rpm, a motor develops a 4.5 lb.ft. per hp
At 575 volts, a 3-phase motor draws 1 amp per hp
At 460 volts, a 3-phase motor draws 1.25 amp per hp
At 230 volts a 3-phase motor draws 2.5 amp per hp
At 230 volts, a single-phase motor draws 5 amp per hp
At 115 volts, a single-phase motor draws 10 amp per hp

Mechanical Formulas

$$\text{Torque in lb.ft.} = \frac{\text{HP x 5250}}{\text{rpm}} \qquad \text{HP} = \frac{\text{Torque x rpm}}{5250} \qquad \text{rpm} = \frac{\text{120 x Frequency}}{\text{No. of Poles}}$$

Temperature Conversion

Deg F = (Deg C x 9/5) + 32

High Inertia Loads

$$t = \frac{WK^2 \times rpm}{308 \times T\ av.}$$

$$T = \frac{WK^2 \times rpm}{308 \times t}$$

WK^2 = inertia in lb.ft.^{2}
t = accelerating time in sec.
T = Av. accelerating torque lb.ft..

$$\text{inertia reflected to motor} = \text{Load Inertia} \left(\frac{\text{Load rpm}}{\text{Motor rpm}} \right)^2$$

Synchronous Speed, Frequency And Number Of Poles Of AC Motors

$$n_s = \frac{120 \times f}{P} \qquad f = \frac{P \times n_s}{120} \qquad P = \frac{120 \times f}{n_s}$$

Relation Between Horsepower, Torque, And Speed

$$HP = \frac{T \times n}{5250} \qquad T = \frac{5250\ HP}{n} \qquad n = \frac{5250\ HP}{T}$$

Motor Slip

$$\%\ Slip = \frac{n_s - n}{n_s} \times 100$$

Code	KVA/HP		Code	KVA/HP		Code	KVA/HP		Code	KVA/HP

A	0-3.14		F	5.0 -5.59		L	9.0-9.99		S	16.0-17.99
B	3.15-3.54		G	5.6 -6.29		M	10.0-11.19		T	18.0-19.99
C	3.55-3.99		H	6.3 -7.09		N	11.2-12.49		U	20.0-22.39
D	4.0 -4.49		I	7.1 -7.99		P	12.5-13.99		V	22.4 & Up
E	4.5 -4.99		K	8.0 -8.99		R	14.0-15.99			

Symbols

I = current in amperes
E = voltage in volts
KW = power in kilowatts
KVA = apparent power in kilo-volt-amperes
HP = output power in horsepower
n = motor speed in revolutions per minute (RPM)
ns = synchronous speed in revolutions per minute (RPM)
P = number of poles
f = frequency in cycles per second (CPS)
T = torque in pound-feet
EFF = efficiency as a decimal
PF = power factor as a decimal

Equivalent Inertia

In mechanical systems, all rotating parts do not usually operate at the same speed. Thus, we need to determine the "equivalent inertia" of each moving part at a particular speed of the prime mover.

The total equivalent WK^2 for a system is the sum of the WK^2 of each part, referenced to prime mover speed.

The equation says:

$$WK^2_{EQ} = WK^2_{part} \left(\frac{N_{part}}{N_{prime\ mover}} \right)^2$$

This equation becomes a common denominator on which other calculations can be based. For variable-speed devices, inertia should be calculated first at low speed.

Let's look at a simple system which has a prime mover (PM), a reducer and a load.

$WK^2 = 100$ lb.ft.^{2}		$WK^2 = 900$ lb.ft.^{2} (as seen at output shaft)		$WK^2 = 27{,}000$ lb.ft.^{2}
PRIME MOVER		3:1 GEAR REDUCER		LOAD

The formula states that the system WK^2 equivalent is equal to the sum of WK^2_{parts} at the prime mover's RPM, or in this case:

$$WK^2_{EQ} = WK^2_{pm} + WK^2_{Red.} \left(\frac{\text{Red. RPM}}{P_M \text{ RPM}} \right)^2 + WK^2_{Load} \left(\frac{\text{Load RPM}}{\text{PM RPM}} \right)^2$$

Note: reducer RPM = Load RPM

$$WK^2_{EQ} = WK^2_{pm} + WK^2_{Red.} \left(\frac{1}{3} \right)^2 + WK^2_{Load} \left(\frac{1}{3} \right)^2$$

The WK^2 equivalent is equal to the WK^2 of the prime mover, plus the

WK^2 of the reducer times $(1/3)^2$, plus the WK^2 of the load times $(1/3)^2$.

This relationship of the reducer to the driven load is expressed by the formula given earlier:

$$WK^2_{EQ} = WK^2_{part} \left(\frac{N_{part}}{N_{prime\ mover}} \right)^2$$

In other words, when a part is rotating at a speed (N) different from the prime mover, the WK^2_{EQ} is equal to the WK^2 of the part's speed ratio squared.

In the example, the result can be obtained as follows:

The WK^2 equivalent is equal to:

$$WK^2_{EQ} = 100 \text{ lb.ft.}^2 + 900 \text{ lb.ft.}^2 \left(\frac{1}{3} \right)^2 + 27{,}000 \text{ lb.ft.}^2 \left(\frac{1}{3} \right)^2$$

Finally:

$$WK^2_{EQ} = \text{lb.ft.}^2_{pm} + 100 \text{ lb.ft.}^2_{Red} + 3{,}000 \text{ lb.ft}^2_{Load}$$

$$WK^2_{EQ} = 3200 \text{ lb.ft.}^2$$

The total WK^2 equivalent is that WK^2 seen by the prime mover at its speed.

Electrical Formulas

To Find	Alternating Current	
	Single-Phase	Three-Phase
Amperes when horsepower is known	$\frac{HP \times 746}{E \times Eff \times pf}$	$\frac{HP \times 746}{1.73 \times E \times Eff \times pf}$
Amperes when kilowatts are known	$\frac{Kw \times 1000}{E \times pf}$	$\frac{Kw \times 1000}{1.73 \times E \times pf}$
Amperes when kva are known	$\frac{Kva \times 1000}{E}$	$\frac{Kva \times 1000}{1.73 \times E}$
Kilowatts	$\frac{I \times E \times pf}{1000}$	$\frac{1.73 \times I \times E \times pf}{1000}$
Kva	$\frac{I \times E}{1000}$	$\frac{1.73 \times I \times E}{1000}$
Horsepower = (Output)	$\frac{I \times E \times Eff \times pf}{746}$	$\frac{1.73 \times I \times E \times Eff \times pff}{746}$

I = Amperes; E = Volts; Eff = Efficiency; pf = Power Factor; Kva = Kilovolt-amperes; Kw = Kilowatts

Locked Rotor Current (I_L) From Nameplate Data

Three Phase: $I_L = \frac{577 \times HP \times KVA/HP}{E}$

See: KVA/HP Chart

$$\text{Single Phase: } I_L = \frac{1000 \times HP \times KVA/HP}{E}$$

EXAMPLE: Motor nameplate indicates 10 HP, 3 Phase, 460 Volts, Code F.

$$I_L = \frac{577 \times 10 \times (5.6 \text{ or } 6.29)}{460}$$

I_L = 70.25 or 78.9 Amperes (possible range)

Effect Of Line Voltage On Locked Rotor Current (I_L) (Approx.)

$$I_L @ E_{LINE} = I_L @ E_{N/P} \times \frac{E_{LINE}}{E_{N/P}}$$

EXAMPLE: Motor has a locked rotor current (inrush of 100 Amperes (I_L) at the rated nameplate voltage ($E_{N/P}$) of 230 volts.

What is I_L with 245 volts (E_{LINE}) applied to this motor?

I_L @ 245 V. = 100 x 254V/230V

I_L @ 245V. = 107 Amperes

Basic Horsepower Calculations

Horsepower is work done per unit of time. One HP equals 33,000 ft-lb of work per minute. When work is done by a source of torque (T) to produce (M) rotations about an axis, the work done is:

radius x 2 πx rpm x lb. or 2 πTM

When rotation is at the rate N rpm, the HP delivered is:

$$HP = \frac{\text{radius x } 2\pi \text{ x rpm x lb.}}{33{,}000} = \frac{TN}{5{,}250}$$

For vertical or hoisting motion:

$$HP = \frac{W \times S}{33{,}000 \times E}$$

Where:

W = total weight in lbs. to be raised by motor
S = hoisting speed in feet per minute
E = overall mechanical efficiency of hoist and gearing. For purposes of estimating
E = .65 for eff. of hoist and connected gear.

For fans and blowers:

$$HP = \frac{\text{Volume (cfm) x Head (inches of water)}}{\text{6356 x Mechanical Efficiency of Fan}}$$

Or

$$HP = \frac{\text{Volume (cfm) x Pressure (lb. Per sq. ft.)}}{\text{3300 x Mechanical Efficiency of Fan}}$$

Or

$$HP = \frac{\text{Volume (cfm) x Pressure (lb. Per sq. in.)}}{\text{229 x Mechanical Efficiency of Fan}}$$

For purpose of estimating, the eff. of a fan or blower may be assumed to be 0.65.

Note: Air Capacity (cfm) varies directly with fan speed. Developed Pressure varies with square of fan speed. Hp varies with cube of fan speed.

For pumps:

$$HP = \frac{\text{GPM x Pressure in lb. Per sq. in. x Specific Grav.}}{\text{1713 x Mechanical Efficiency of Pump}}$$

Or

$$HP = \frac{\text{GPM x Total Dynamic Head in Feet x S.G.}}{\text{3960 x Mechanical Efficiency of Pump}}$$

where Total Dynamic Head = Static Head + Friction Head

For estimating, pump efficiency may be assumed at 0.70.

Accelerating Torque

The equivalent inertia of an adjustable speed drive indicates the energy required to keep the system running. However, starting or accelerating the system requires extra energy.

The torque required to accelerate a body is equal to the WK^2 of the body, times the change in RPM, divided by 308 times the interval (in seconds) in which this acceleration takes place:

$$\text{ACCELERATING TORQUE} = \frac{WK^2N \text{ (in lb.ft.)}}{308t}$$

Where:

- N = Change in RPM
- W = Weight in Lbs.
- K = Radius of gyration
- t = Time of acceleration (secs.)
- WK^2 = Equivalent Inertia
- 308 = Constant of proportionality

Or

$$T_{Acc} = \frac{WK^2N}{308t}$$

The constant (308) is derived by transferring linear motion to angular motion, and considering acceleration due to gravity. If, for example, we have simply a prime mover and a load with no speed adjustment:

Example 1

PRIME LOADER		LOAD
$WK^2 = 200$ lb.ft.^{2}		$WK^2 = 800$ lb.ft.^{2}

The WK^2_{EQ} is determined as before:

$WK^2_{EQ} = WK^2_{pm} + WK^2_{Load}$

$WK^2_{EQ} = 200 + 800$

$WK^2_{EQ} = 1000$ ft.lb.^{2}

If we want to accelerate this load to 1800 RPM in 1 minute, enough information is available to find the amount of torque necessary to accelerate the load.

The formula states:

$$T_{Acc} = \frac{WK^2_{EQ}N}{308t} \text{ or } \frac{1000 \times 1800}{308 \times 60} \text{ or } \frac{1800000}{18480}$$

$T_{Acc} = 97.4$ lb.ft.

In other words, 97.4 lb.ft. of torque must be applied to get this load turning at 1800 RPM, in 60 seconds.

Note that T_{Acc} is an average value of accelerating torque during the speed change under consideration. If a more accurate calculation is desired, the following example may be helpful.

Example 2

The time that it takes to accelerate an induction motor from one speed to another may be found from the following equation:

$$t = \frac{WR^2 \text{ x change in rpm}}{308 \text{ x } T}$$

Where:

T = Average value of accelerating torque during the speed change under consideration.

t = Time the motor takes to accelerate from the initial speed to the final speed.

WR_2 = Flywheel effect, or moment of inertia, for the driven machinery plus the motor rotor in lb.ft.^{2} (WR^2 of driven machinery must be referred to the motor shaft).

The Application of the above formula will now be considered by means of an example. Figure A shows the speed-torque curves of a squirrel-cage induction motor and a blower which it drives. At any speed of the blower, the difference between the torque which the motor can deliver at its shaft and the torque required by the blower is the torque available for acceleration. Reference to Figure A shows that the accelerating torque may vary greatly with speed. When the speed-torque curves for the motor and blower intersect there is no torque available for acceleration. The motor then drives the blower at constant speed and just delivers the torque required by the load.

In order to find the total time required to accelerate the motor and blower, the area between the motor speed-torque curve and the blower speed-torque curve is divided into strips, the ends of which approximate straight lines. Each strip corresponds to a speed increment which takes place within a definite time interval. The solid horizontal lines in Figure A represent the boundaries of strips; the lengths of the broken lines the average accelerating torques for the selected speed intervals. In order to calculate the total acceleration time for the motor and the direct-coupled blower it is necessary to find the time required to accelerate the motor from the beginning of one speed interval to the beginning of the next interval and add up the incremental times for all intervals to arrive at the total acceleration time. If the WR^2 of the motor whose speed-torque curve is given in Figure A is 3.26 ft.lb.^{2} and the WR^2 of the blower referred to the motor shaft is 15 ft.lb.^{2}, the total WR^2 is:

$15 + 3.26 = 18.26$ ft.lb.^{2},

And the total time of acceleration is:

$$\frac{WR^2}{308}\left[\frac{rpm_1}{T_1} + \frac{rpm_2}{T_2} + \frac{rpm_3}{T_3} + \text{- - - - - - - - - -} + \frac{rpm_9}{T_9}\right]$$

Or

$$t = \frac{18.26}{308}\left[\frac{150}{46} + \frac{150}{48} + \frac{300}{47} + \frac{300}{43.8} + \frac{200}{39.8} + \frac{200}{36.4} + \frac{300}{32.8} + \frac{100}{29.6} + \frac{40}{11}\right]$$

$t = 2.75$ sec.

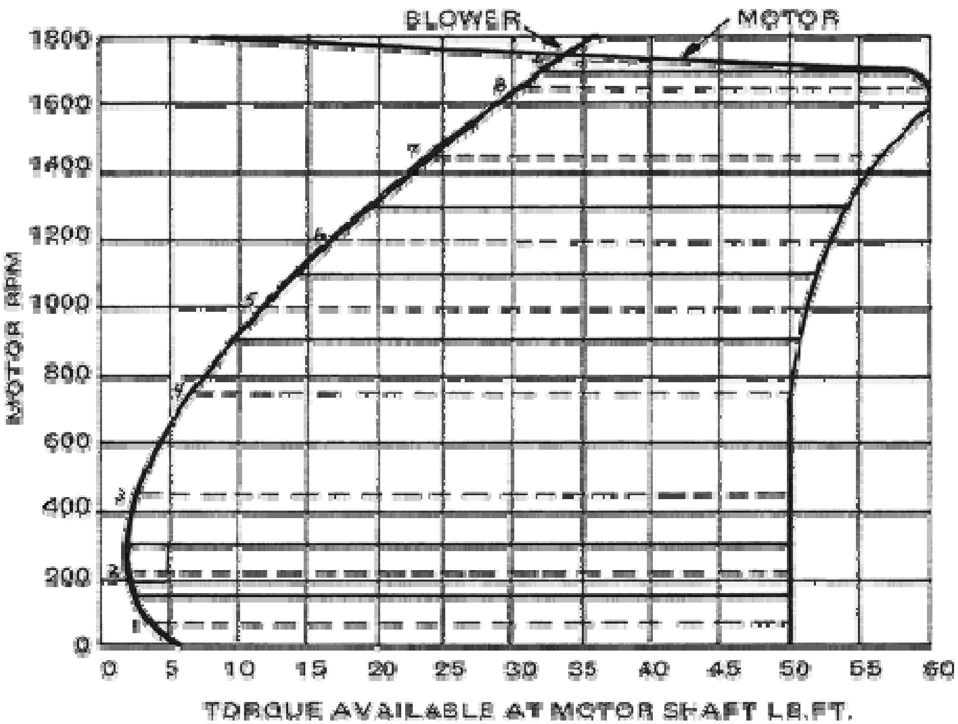
Figure A

Curves used to determine time required to accelerate induction motor and blower

Accelerating Torques

$T_1 = 46$ lb.ft. $T_4 = 43.8$ lb.ft. $T_7 = 32.8$ lb.ft.

T_2 = 48 lb.ft. T_5 = 39.8 lb.ft. T_8 = 29.6 lb.ft.
T_3 = 47 lb.ft. T_6 = 36.4 lb.ft. T_9 = 11 lb.ft.



Duty Cycles

Sales Orders are often entered with a note under special features such as:

"Suitable for 10 starts per hour"
Or
"Suitable for 3 reverses per minute"
Or
"Motor to be capable of accelerating 350 lb.ft.^{2}"
Or

"Suitable for 5 starts and stops per hour"

Orders with notes such as these can not be processed for two reasons.

1. The appropriate product group must first be consulted to see if a design is available that will perform the required duty cycle and, if not, to determine if the type of design required falls within our present product line.
2. None of the above notes contain enough information to make the necessary duty cycle calculation. In order for a duty cycle to be checked out, the duty cycle information must include the following:
    a. Inertia reflected to the motor shaft.
    b. Torque load on the motor during all portions of the duty cycle including starts, running time, stops or reversals.
    c. Accurate timing of each portion of the cycle.
    d. Information on how each step of the cycle is accomplished. For example, a stop can be by coasting, mechanical braking, DC dynamic braking or plugging. A reversal can be accomplished by plugging, or the motor may be stopped by some means then re-started in the opposite direction.
    e. When the motor is multi-speed, the cycle for each speed must be completely defined, including the method of changing from one speed to another.
    f. Any special mechanical problems, features or limitations.

Obtaining this information and checking with the product group before the order is entered can save much time, expense and correspondence.

Duty cycle refers to the detailed description of a work cycle that repeats in a specific time period. This cycle may include frequent starts, plugging stops, reversals or stalls. These characteristics are usually involved in batch-type processes and may include tumbling barrels, certain cranes, shovels and draglines, dampers, gate- or plow-positioning drives, drawbridges, freight and personnel elevators, press-type extractors, some feeders,presses of certain types, hoists, indexers, boring machines,cinder block machines, keyseating, kneading, car-pulling, shakers (foundry or car), swaging and washing machines, and certain freight and passenger vehicles. The list is not all-inclusive. The drives for these loads must be capable of absorbing the heat generated during the duty cycles. Adequate thermal capacity would be required in slip couplings, clutches or motors to accelerate or plug-stop these drives or to withstand stalls. It is the product of the slip speed and the torque absorbed by the load per unit of time which generates heat in these drive components. All the events which occur during the duty cycle generate heat which the drive components must dissipate.

Because of the complexity of the Duty Cycle Calculations and the extensive engineering data per specific motor design and rating required for the calculations, it is necessary for the sales engineer to refer to the Product Department for motor sizing with a duty cycle application

ELECTRICAL UNIT CONVERSIONS

The purpose of this document is to provide information, formulas and documentation to take certain electrical values and convert them into other electrical values. The formulas below are known and used universally but we use them here in association with computer, network, telecom and other IT equipment.

Background

It is often necessary to turn voltage, amperage and electrical "nameplate" values from computer, network and telecom equipment into kW, KVA and BTU information that can be used to calculate overall power and HVAC loads for IT spaces. The following describes how to take basic electrical values and convert them into other types of electrical values.

- NOTE #1:
  The informational nameplates on most pieces of computer or network equipment usually display electrical values. These values can be expressed in volts, amperes, kilovolt-amperes, watts or some combination of the foregoing.
- NOTE #2:
  If you are using equipment nameplate information to develop a power and cooling profile for architects and engineers, the total power and cooling values will exceed the actual output of the equipment. Reason: the nameplate value is designed to ensure that the equipment will energize and run safely. Manufacturers build in a "safety factor" when developing their nameplate data. Some nameplates display information that is higher than the equipment will ever need - often up to 20% higher. The result is that, in total, your profile will "over engineer" the power and cooling equipment. Electrical and mechanical engineers may challenge your figures citing that nameplates require more power than necessary.
- NOTE #3:
  Our advice: Develop the power and cooling profile using the nameplate information and the formulas below and use the resultant documentation as your baseline. Reasons: (1) it's the best information available without doing extensive electrical tests on each piece of equipment. Besides, for most projects, you are being asked to predict equipment requirements 3-5 years out when much of the equipment you will need hasn't been invented yet. (2) the engineers will not duplicate your work; they do not know what goes into a data center. They

will only challenge the findings if they appear to be to high. If the engineers want to challenge your figures, it's OK but have them do it in writing and let them take full responsibility for any modifications. If you must lower your estimates, do so. But, document everything. There will come a day in 3-5 years when you will need every amp of power you predicted. We've had projects where it was very evident within six months that what we predicted would come true - sometimes even earlier than we estimated.

- NOTE #4
  If you are designing a very high-density server room where you will have racks and racks (or cabinets and cabinets) of 1U and 2U servers tightly packed, you need to read our article entitled "IT Pros - Don't be Left in the Dust on IT Server Room Design".

To Find Watts

1. When Volts and Amperes are Known

POWER (WATTS) = VOLTS x AMPERES

- We have a small server with a nameplate shows 2.5 amps. Given a normal 120 Volt, 60 hz power source and the ampere reading from equipment, make the following calculation:

POWER (WATTS) = 120 * 2.5 ANSWER: 300 WATTS

To Find Volt-Amperes (VA)

1. Same as above. VOLT-AMPERES (VA) = VOLTS x AMPERES ANS: 300 VA

To Find kilovolt-Amperes (kVA)

1. SINGLE PHASE

KILOVOLT-AMPERES (kVA) = VOLTS x AMPERES
1000

Using the previous example: 120 * 2.5 = 300 VA 300 VA / 1000 = .3 kVA

2. 208-240 SINGLE-PHASE (2-POLE SINGLE-PHASE)

- Given: We have a Sun server with an amp rating of 4.7 and requiring a 208-240 power source. We'll use 220 volts for our calculations.

KILOVOLT-AMPERES (kVA) = VOLTS x AMPERES
1000

220 x 4.7 = 1034 1034 / 1000 = 1.034 kVA

3. THREE-PHASE

- Given: We have a large EMC Symmetrix 3930-18/-36 storage system with 192 physical volumes. EMC's website shows a requirement for a 50-amp 208 VAC receptacle. For this calculation, we will use 21 amps. Do not calculate any value for the plug or receptacle.

KILOVOLT-AMPERES (kVA) = VOLTS x AMPERES x 1.73
1000

208 x 21 x 1.73 = 7,556.64 7,556.64 / 1000 = 7.556 kVA

To Find Kilowatts

- Finding Kilowatts is a bit more complicated in that the formula includes a value for the "power factor". The power factor is a nebulous but required value that is different for each electrical device. It involves the efficiency in the use of of the electricity supplied to the system. This factor can vary widely from 60% to 95% and is never published on the equipment nameplate and further, is not often supplied with product information. For purposes of these calculations, we use a power factor of .85. This arbitrary number places a slight inaccuracy into the numbers. Its OK and it gets us very close for the work we need to do.

1. SINGLE PHASE

Given: We have a medium-sized Compaq server that draws 6.0 amps.

KILOWATT (kW) = VOLTS x AMPERES x POWER FACTOR
1000

120 * 6.0 = 720 VA 720 VA * .85 = 612 612 / 1000 = .612 kW

2. TWO-PHASE

- Given: We have a Sun server with an amp rating of 4.7 and requiring a 208-240 power source. We'll use 220 volts for our calculations.

KILOWATT (kW) = VOLTS x AMPERES x POWER FACTOR x 2
1000

220 x 4.7 x 2 = 2068 2068 x .85 = 1757.8 1757.8 / 1000 = 1.76 kW

3. THREE-PHASE

- Given: We have a large EMC Symmetrix 3930-18/-36 storage system with 192 physical volumes. EMC's website shows a requirement for a 50-amp 208 VAC receptacle. For this calculation, we will use 22 amps. Do not calculate the value of the plug or receptacle. Use the value on nameplate.

KILOWATT (kW) = VOLTS x AMPERES x POWER FACTOR x 1.73
1000

208x22x1.73 = 7,916.48 7,916.48 * .85 = 6,729.008 6,729.008/1000=6.729 kW

To Convert Between kW and kVA

- The only difference between kW and kVA is the power factor. Once again, the power factor, unless known, is an approximation. For purposes of our calculations, we use a power factor of .85. The kVA value is always higher than the value for kW.

kW to kVA kW / .85 = SAME VALUE EXPRESSED IN kVA
kVA TO kW kVA * .85 = SAME VALUE EXPRESSED IN kW

To Find BTUs From Electrical Values

- Known and Given: 1 kW = 3413 BTUs (or 3.413 kBTUs)
- The above is a generally known value for converting electrical values to BTUs. Many manufacturers publish kW, kVA and BTU in their equipment specifications. Often, dividing the BTU value by 3413 does not equal their published kW value. So much for knowns and givens. Where the information is provided by the manufacturer, use it. Where it is not, use the above formula.

Series Direct Current Circuit Rules

Rule #1: The same current flows through each part of a series circuit.

Rule #2: Total Resistance of a series circuit is equal to the sum of the individual resistances.

Rule #3: The total voltage across a series circuit is equal to the sum of the individual voltage drops.

Rule #4: The voltage drop across a resistor in a series circuit is proportional to the size of the resistor.

Rule #5: The total power dissipated in a series circuit is equal to the sum of the individual power dissapations.

SUMMARY OF OHMS LAW FORMULAS

$$\text{AMPERES} = \frac{\text{VOLTS}}{\text{RESISTANCE}}$$

$$\text{RESISTANCE} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

VOLTS = AMPERES x RESISTANCE

Parallel Direct Current Circuit Rules

Rule #1: **The same voltage exists across each branch of a parallel circuit and is equal to the source voltage.**

Rule #2: **The current through a branch of a parallel network is inversely proportional to the amount of resistance of the branch.**

Rule #3: **The total current of a parallel circuit is equal to the sum of the currents of the individual branches of the circuit.**

Rule #4: **The total resistance of a parallel circuit is equal to the reciprocal of the sum of the reciprocals of the individual resistances of the circuit.**

Rule #5: **The total power dissipated in a parallel circuit is equal to the sum of the individual power dissapations.**

SUMMARY OF PARALLEL CIRCUIT RULES

TOTAL VOLTAGE =E(1) = E(2) = E(3) ...etc.

$$\text{TOTAL RESISTANCE} = \frac{\text{VOLTS}}{\text{AMPERES}}$$

TO DETERMINE THE TOTAL RESISTANCE IN A PARALLEL CIRCUIT WHEN THE TOTAL CURRENT AND TOTAL VOLTAGE ARE UNKNOWN USE EITHER OF THE FOLLOWING FORMULAS:

$$RT = \frac{1}{\frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + \ldots etc}$$

FOR TWO RESISTORS IN PARALLEL USE THIS FORMULA CALLED THE "PRODUCT OVER THE SUM"

$$RT = \frac{R(1) * R(2)}{R(1) + R(2)}$$

POWER IN SINGLE PHASE RESISTIVE CIRCUITS

WHERE POWER FACTOR IS 100 PERCENT

(THESE FORMULAS ARE COMMONLY USED TO SOLVE MOST CIRCUIT POWER PROBLEMS ON TESTS)

TO DETERMINE THE POWER CONSUMED BY AN INDIVIDUAL RESISTOR IN A SERIES CIRCUIT USE THIS FORMULA:

$$POWER = I^2 \times R$$

TO DETERMINE THE POWER CONSUMED BY AN INDIVIDUAL RESISTOR IN A PARALLEL CIRCUIT USE THIS FORMULA:

$$\text{POWER} = \frac{E^2}{R}$$

TO DETERMINE THE TOTAL POWER CONSUMED BY AN INDIVIDUAL CIRCUIT USE THIS FORMULA:

POWER = E (TOTAL VOLTAGE) x I (TOTAL CURRENT)

RULES OF THUMB:

- **THE TOTAL RESISTANCE OF RESISTORS IN PARALLEL IS ALWAYS LESS THAN THE VALUE OF ANY ONE RESISTOR.**
- **THE TOTAL RESISTANCE OF PARALLEL RESISTORS THAT ARE ALL THE SAME VALUE IS THAT VALUE DIVIDED BY THE NUMBER OF RESISTORS.**
- **ALWAYS USE THE PRODUCT OVER SUM RULE TO BREAK DOWN TWO PARALLEL RESISTORS INTO ONE RESISTOR. THIS IS MUCH EASIER THAN TRYING TO SOLVE LARGE ALGEBRAIC EXPRESSIONS.**
- **746 WATTS IS EQUAL TO ONE HORSEPOWER**
- **EFFICIENCY IS EQUAL TO OUTPUT DIVIDED BY INPUT**
- **IN INDUCTIVE CIRCUITS CURRENT LAGS VOLTAGE.**
- **IN CAPACITIVE CIRCUITS CURRENT LEADS VOLTAGE.**
- **POWER FACTOR IS A MEASURE OF HOW FAR CURRENT LEADS OR LAGS VOLTAGE.**

POWER IN ALTERNATING CURRENT CIRCUITS WHERE POWER FACTOR IS NOT 100 PERCENT

POWER = E x I x POWER FACTOR (FOR SINGLE PHASE)

POWER = E x I x 1.732 X POWER FACTOR (FOR THREE PHASE)

THIS POWER IS ALSO CALLED TRUE POWER OR REAL POWER AS OPPOSED TO APPARENT POWER FOUND BY CALCULATING VOLT-AMPERES.

VOLT-AMPERES = E x I (FOR SINGLE PHASE)

VOLT-AMPERES = E x I x 1.732 (FOR THREE PHASE)

IT CAN READILY BE DETERMINED BY ALGEBRA THAT

$$\text{POWER FACTOR} = \frac{\text{TRUE POWER}}{\text{APPARENT POWER}}$$

MOTOR APPLICATION FORMULAS

HORSEPOWER (for three phase motors) $= \dfrac{1.732 \times \text{VOLTS} \times \text{AMPERES} \times \text{EFFICIENCY} \times \text{power factor}}{746}$

THREE PHASE AMPERES (for three phase motors) $= \dfrac{746 \times \text{HORSEPOWER}}{1.732 \times \text{VOLTS} \times \text{EFFICIENCY} \times \text{POWER FACTOR}}$

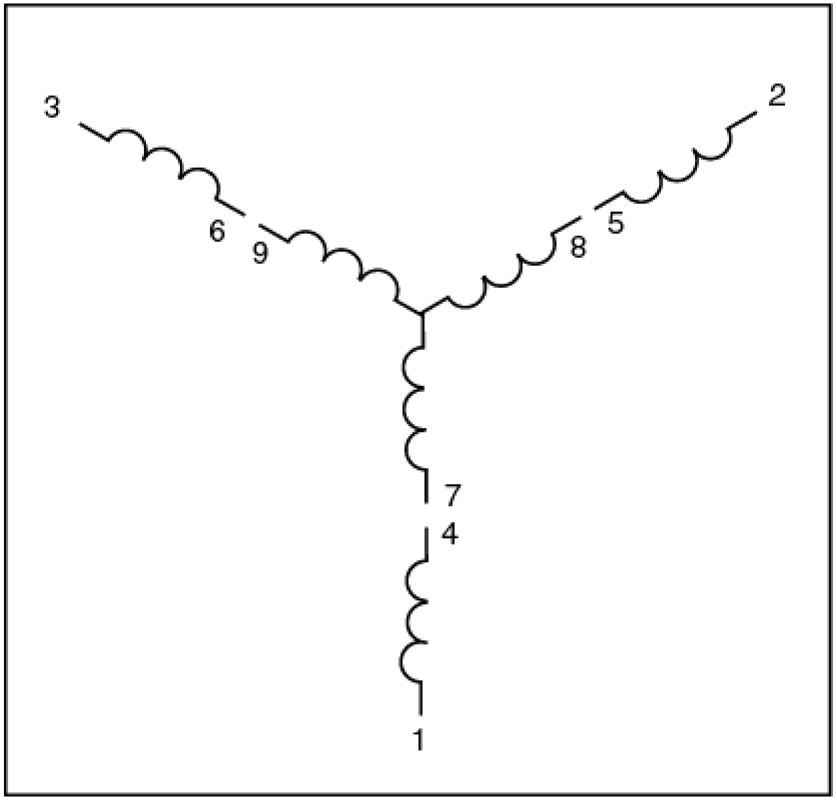
SYNCHRONOUS RPM $= \dfrac{\text{HERTZ} \times 120}{\text{NUMBER OF POLES}}$

MOTOR MARKINGS AND CONNECTIONS

CONNECTIONS FOR NINE LEAD

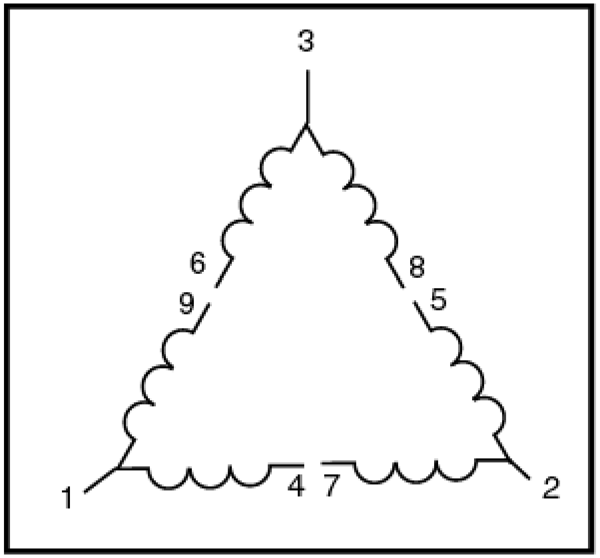
THREE PHASE MOTORS

THREE PHASE STAR OR Y



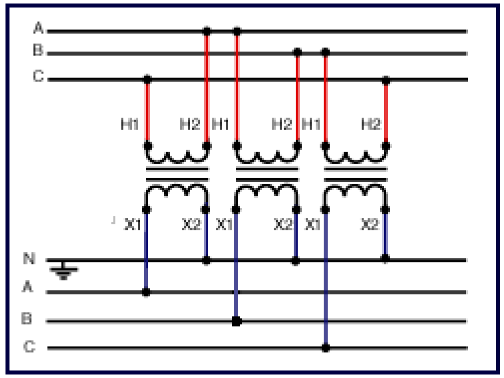
STAR CONNECTED				
Voltage	Line 1	Line 2	Line 3	Together
Low	1 & 7	2 & 8	3 & 9	4 & 5 & 6
High	1	2	3	4 & 7, 5 & 8, 6 & 9

THREE PHASE DELTA



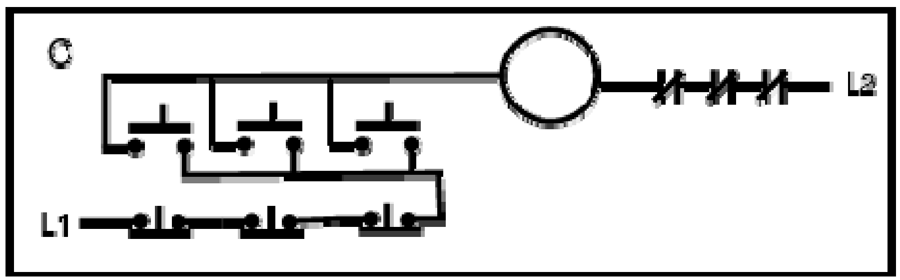
DELTA CONNECTED				
Voltage	Line 1	Line 2	Line 3	Together
Low	1 & 6 & 7	2 & 4 & 8	3 & 5 & 9	NONE
High	1	2	3	4 & 7, 5 & 8, 6 & 9

DELTA WYE HOOKUP FOR TRANSFORMER

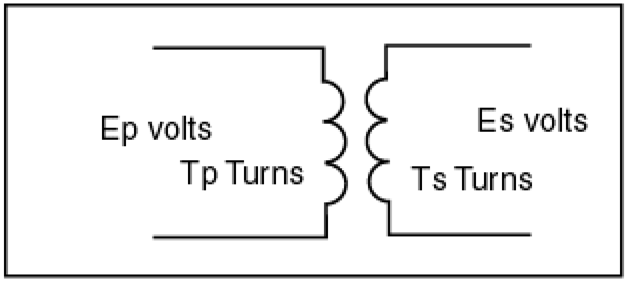


MOTOR CONTROLLER WITH THREE START STOP STATIONS

(HOLDING CONTACTS NOT SHOWN)



TRANSFORMER TURNS RATIO



$$\frac{Ep}{Es} = \frac{Tp}{Ts}$$

Where
Ep is primary voltage
Es is secondary voltage
Tp is number of turns in primary
Ts is number of turns in secondary

	Maximum Horsepower for NEMA-Rated Motor Starters			
	Single-Phase		**Three-Phase**	
NEMA Size	**115 Volt**	**230 Volt**	**208/230 Volt**	**460/575 Volt**

00	1/3	1	1.5	2
0	1	2	3	5
1	2	3	7.5	10
2	3	7.5	10/15	25
3			25/30	50
4			40/50	100
5			75/100	200

NEMA RATING FOR ENCLOSURES

NEMA and other organizations have established standards of enclosure construction for control equipment. In general, equipment would be enclosed by an Ottawa Electrician for one or more of the following reasons:

1. Prevent accidental contact with live parts by an Ottawa Electrician.
2. Protect the control from harmful environmental conditions.
3. Prevent explosion or fires which might result from the electrical arc caused by the control.

Common types of enclosures per NEMA classification numbers are:

NEMA I - GENERAL PURPOSE

The general purpose enclosure is intended primarily to prevent accidental contact with the enclosed apparatus by an Ottawa Electrician. It is suitable for general purpose applications indoors where it is not exposed to unusual service conditions. A NEMA I enclosure serves as protection against dust and light indirect splashing, but is not dusttight.

NEMA 3 - DUSTTIGHT, RAINTIGHT

This enclosure is intended to provide suitable protection against specified weather hazards. A NEMA 3 enclosure is suitable for application outdoors, on ship docks, canal and construction work, and for application in subways and tunnels by an Ottawa Electrician. It is also sleet-resistant.

NEMA 3R - RAINPROOF, SLEET RESISTANT

This enclosure protects against interference in operation of the contained equipment due to rain, and resists damage from exposure to sleet. It is designed with conduit hubs and external mounting by an Ottawa Electrician, as well as drainage provisions.

NEMA 4 - WATERTIGHT

A watertight enclosure is designed to meet the hose test described in the following note: "Enclosures shall be tested by subjection to a stream of water. A hose with a one inch nozzle shall be used and shall deliver at least 65 gallons per minute. The water shall be directed on the enclosure from a distance of not less than 10 feet and for a period of five minutes. During this period it may be directed in any one or more directions as desired. There shall be no leakage of water into the enclosure under these conditions."

A NEMA 4 enclosure is suitable for applications outdoors on ship docks and in dairies, breweries, etc.

NEMA 4X - WATERTIGHT, CORROSION-RESISTANT

These enclosures are generally constructed along the lines of NEMA 4 enclosures except they are made of a material that is highly resistant to corrosion. For this reason, they are ideal in applications such as paper mills, meat packing, fertilizer and chemical plants where contaminants would ordinarily destroy a steel enclosure over a period of time.

NEMA 7 - HAZARDOUS LOCATIONS - CLASS I

These enclosures are designed to meet the application requirements of the National Electrical Code for Class I hazardous locations. In this type of equipment, the circuit interruption occurs in air.

"Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures."

NEMA 9 HAZARDOUS LOCATIONS - CLASS II

These enclosures are designed to meet the application requirements of the National Electrical Code for Class II hazardous locations.

"Class II locations are those which are hazardous because of the presence of combustible dust."

The letter or letters following the type number indicates the particular group or groups of hazardous locations (as defined in the National Electrical Code) for which the enclosure is designed. The designation is incomplete without a suffix letter or letters.

NEMA 12 - INDUSTRIAL USE

The NEMA 12 enclosure is designed for use in those industries where it is desired to exclude such materials as dust, lint, fibers and flyings, oil see page or coolant see page. There are no conduit openings or knockouts in the enclosure, and mounting by an Ottawa Electrician is by means of flanges or mounting feet.

NEMA 13 - OILTIGHT, DUSTTIGHT

NEMA 13 enclosures are generally of cast construction, gasketed to permit use in the same environments as NEMA 12 devices. The essential difference is that, due to its cast housing, a conduit entry is provided as an integral part of the NEMA 13 enclosure, and mounting by an Ottawa Electrician is by means of blind holes, rather than mounting brackets.