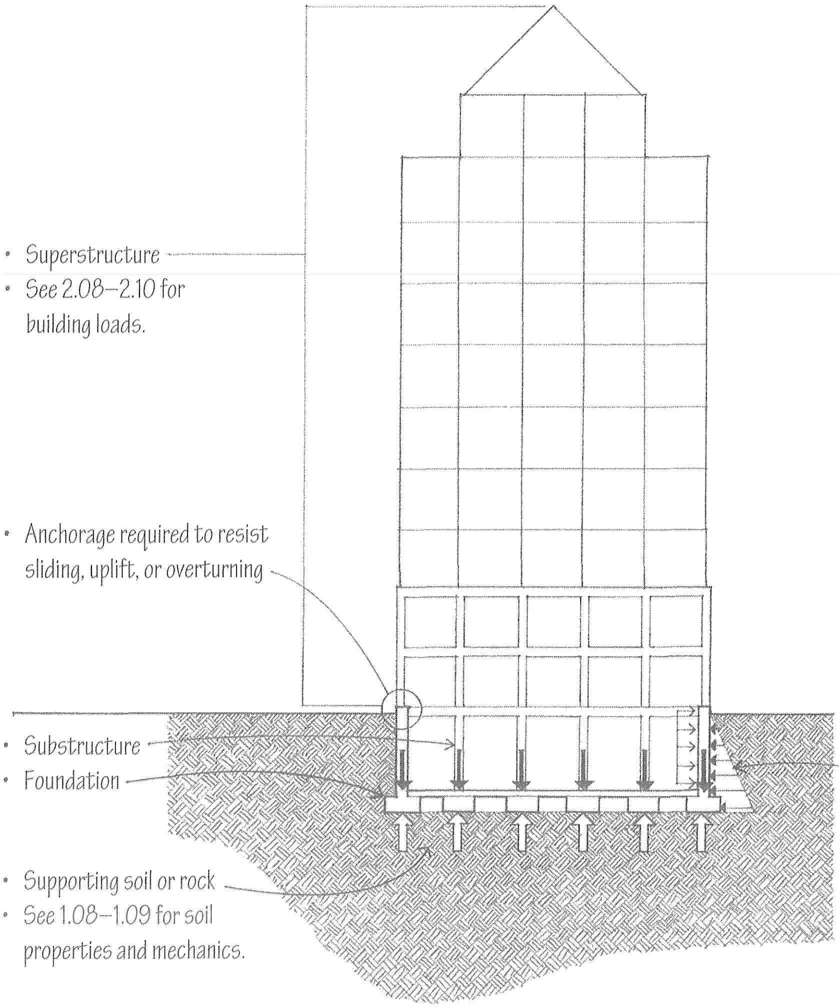
3

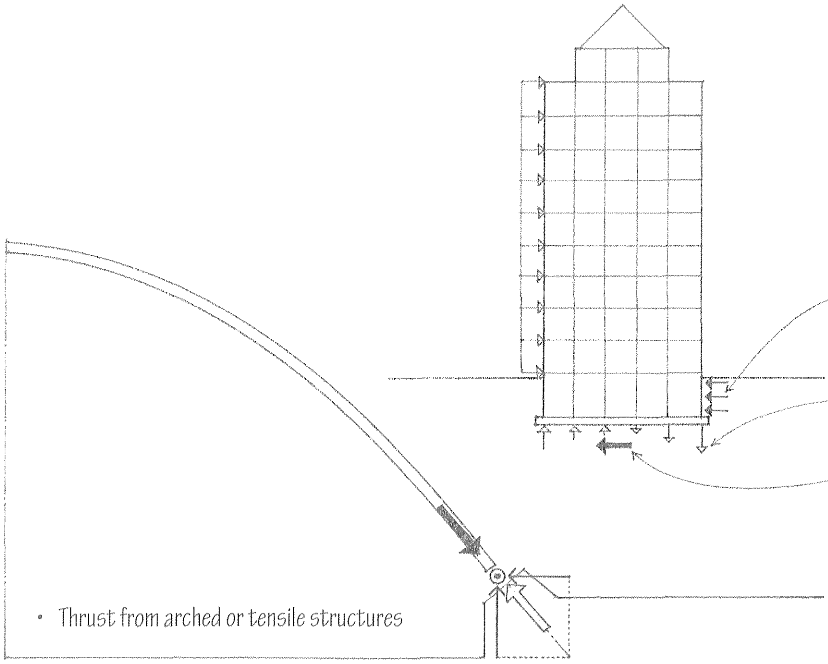
FOUNDATION SYSTEMS



The foundation is the lowest division of a building—its substructure—constructed partly or wholly below the surface of the ground. Its primary function is to support and anchor the superstructure above and transmit its loads safely into the earth. Because it serves as a critical link in the distribution and resolution of building loads, the foundation system must be designed to both accommodate the form and layout of the superstructure above and respond to the varying conditions of soil, rock, and water below.

The principal loads on a foundation are the combination of dead and live loads acting vertically on the superstructure. In addition, a foundation system must anchor the superstructure against wind-induced sliding, overturning, and uplift, withstand the sudden ground movements of an earthquake, and resist the pressure imposed by the surrounding soil mass and groundwater on basement walls. In some cases, a foundation system may also have to counter the thrust from arched or tensile structures.

• Active earth pressure exerted by a soil mass on a basement wall

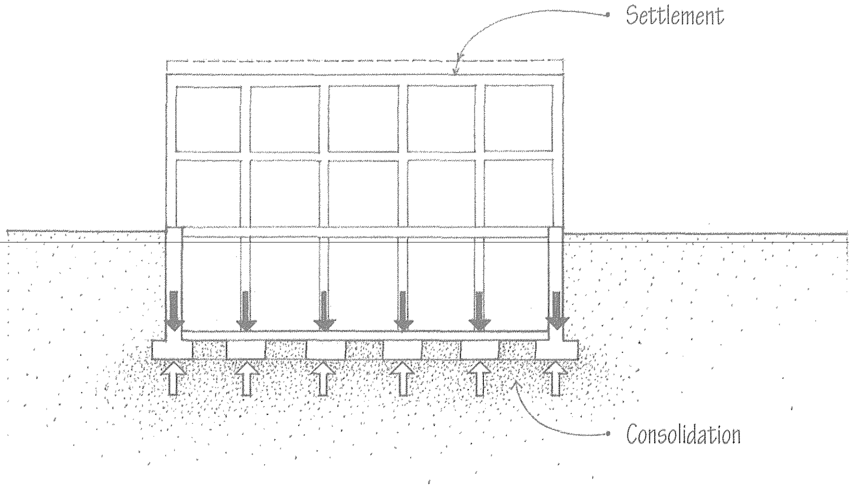


• Passive earth pressure is developed by a soil mass in response to the horizontal movement of a foundation.

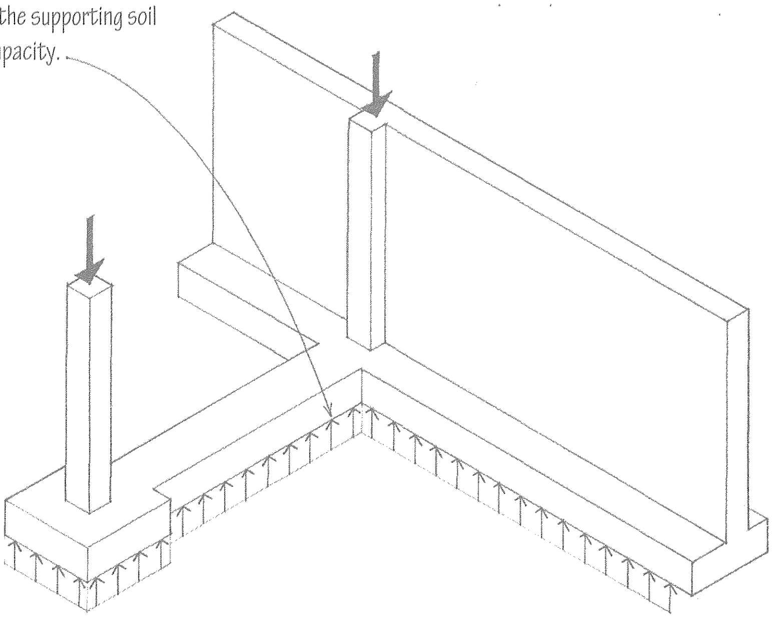
• Lateral forces can cause the foundation to impose nonuniform pressure on the supporting soil.

• Some shear resistance is provided by the friction between the foundation and the underlying soil.

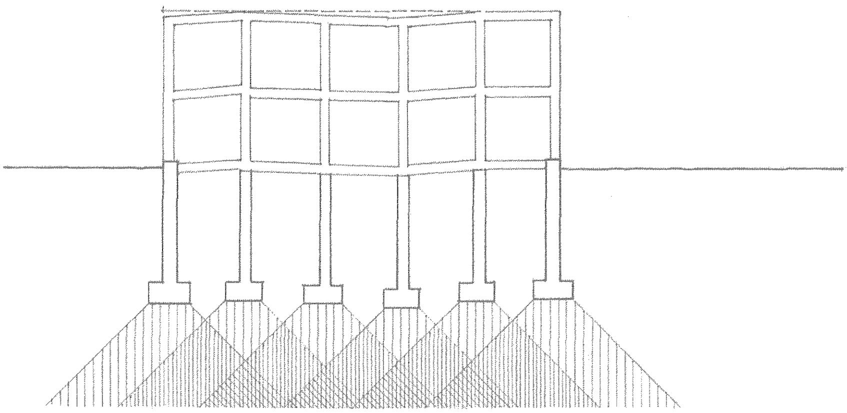
Settlement is the gradual subsiding of a structure as the soil beneath its foundation consolidates under loading. As a building is constructed, some settlement is to be expected as the load on the foundation increases and causes a reduction in the volume of soil voids containing air or water. This consolidation is usually slight and occurs rather quickly as loads are applied on dense, granular soils, such as coarse sand and gravel. When the foundation soil is a moist, cohesive clay, which has a scale-like structure and a relatively large percentage of voids, consolidation can be quite large and occur slowly over a longer period of time.



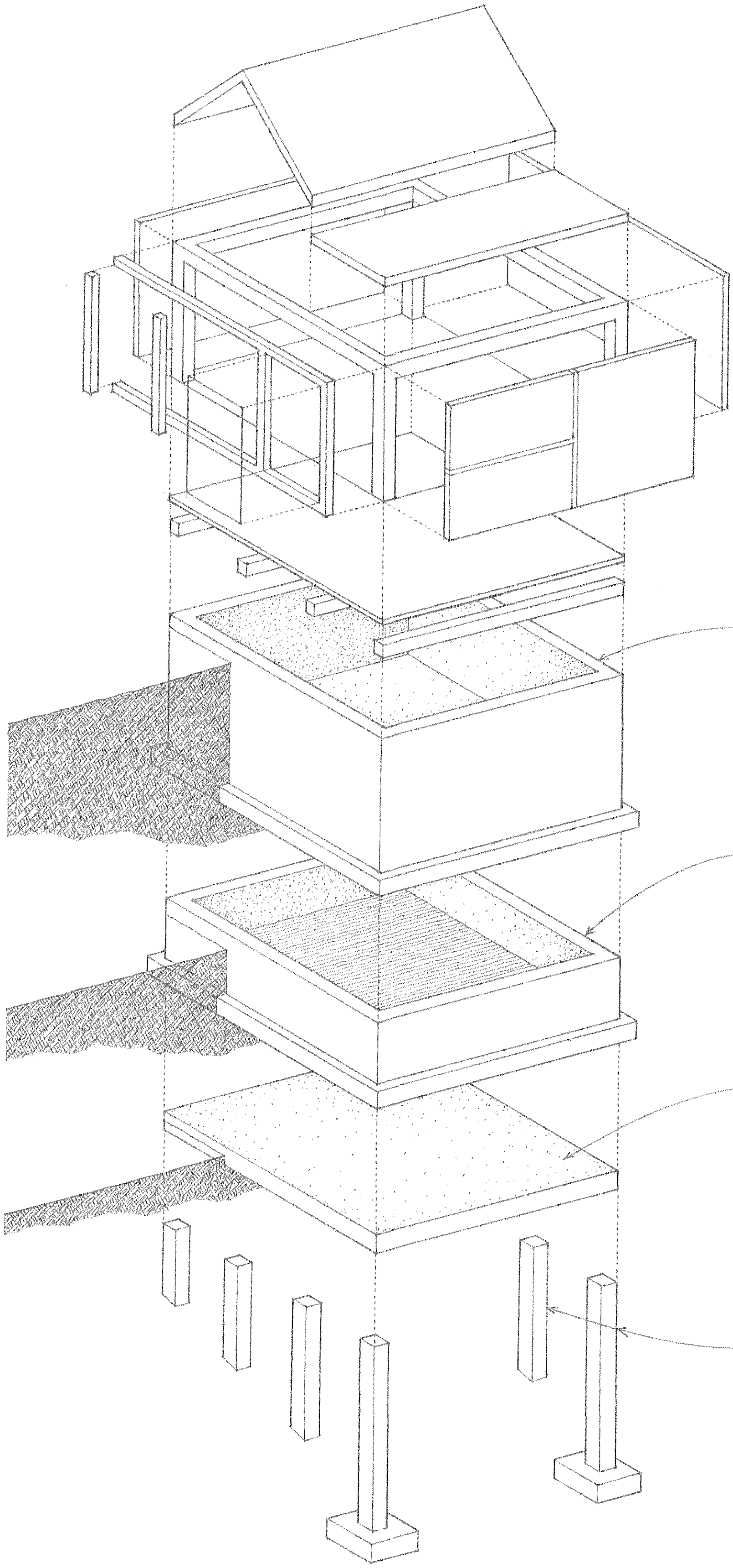
A properly designed and constructed foundation system should distribute its loads so that whatever settlement occurs is minimal or is uniformly distributed under all portions of the structure. This is accomplished by laying out and proportioning the foundation supports so that they transmit an equal load per unit area to the supporting soil or rock without exceeding its bearing capacity.



Differential settlement—the relative movement of different parts of a structure caused by uneven consolidation of the foundation soil—can cause a building to shift out of plumb and cracks to occur in its foundation, structure, or finishes. If extreme, differential settlement can result in the failure of the structural integrity of a building.



Foundations utilize a combination of bearing walls, columns, and piers to transmit building loads directly to the earth. These structural elements can form various types of substructures:



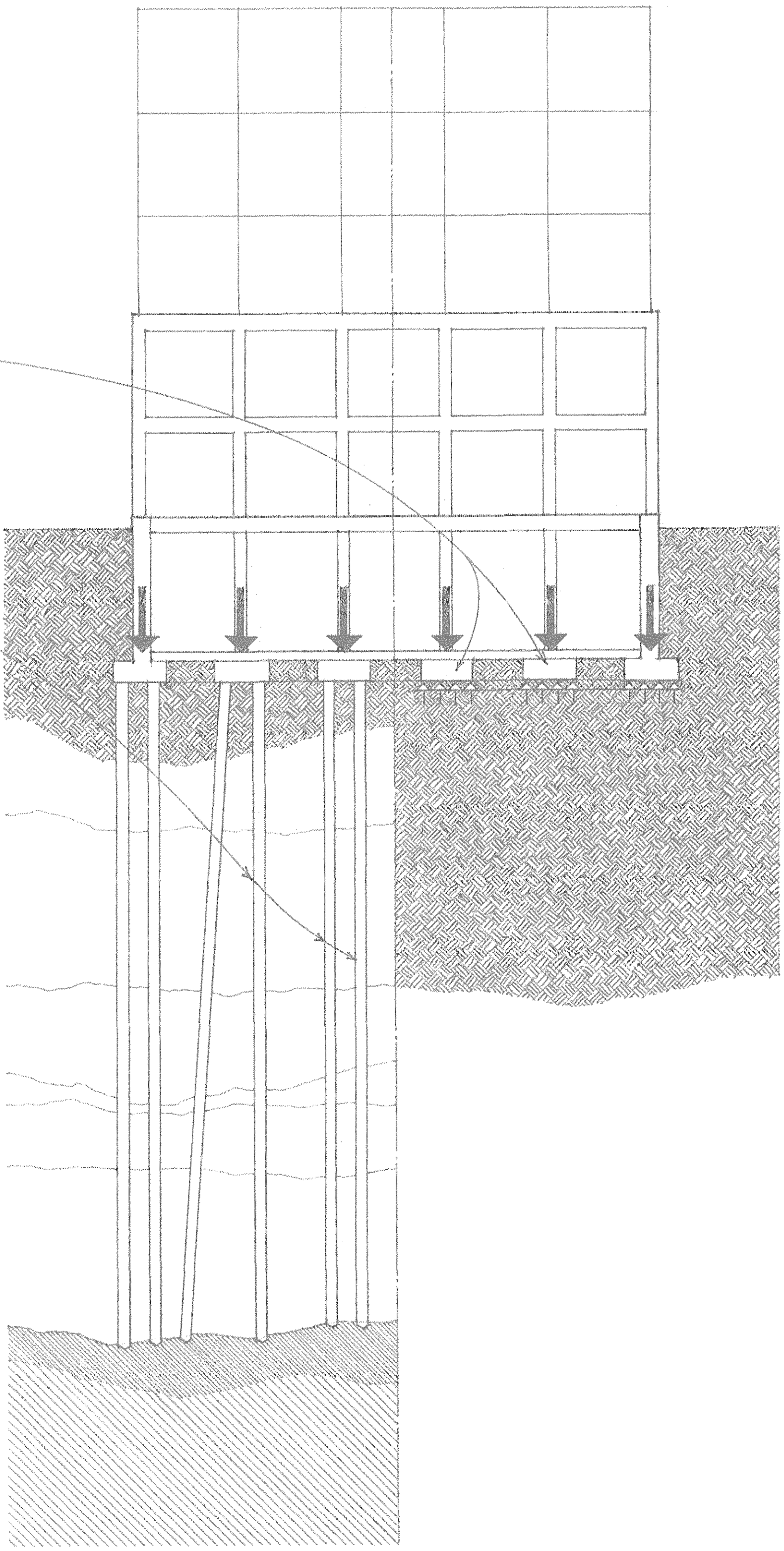
Basements wholly or partly below grade require a continuous foundation wall to hold back the surrounding earth and support the exterior walls and columns of the superstructure above.

Crawl spaces enclosed by a continuous foundation wall or piers provide space under a first floor for the integration of and access to mechanical, electrical, and plumbing installations.

Concrete slabs-on-grade supported directly by the earth and thickened to carry wall and column loads form an economical foundation and floor system for one- and two-story structures in climates where little or no ground frost occurs.

A grid of independent piers or poles can elevate the superstructure above the surface of the ground.

We can classify foundation systems into two broad categories—shallow foundations and deep foundations.



Shallow Foundations

Shallow or spread foundations are employed when stable soil of adequate bearing capacity occurs relatively near to the ground surface. They are placed directly below the lowest part of a substructure and transfer building loads directly to the supporting soil by vertical pressure.

Deep Foundations

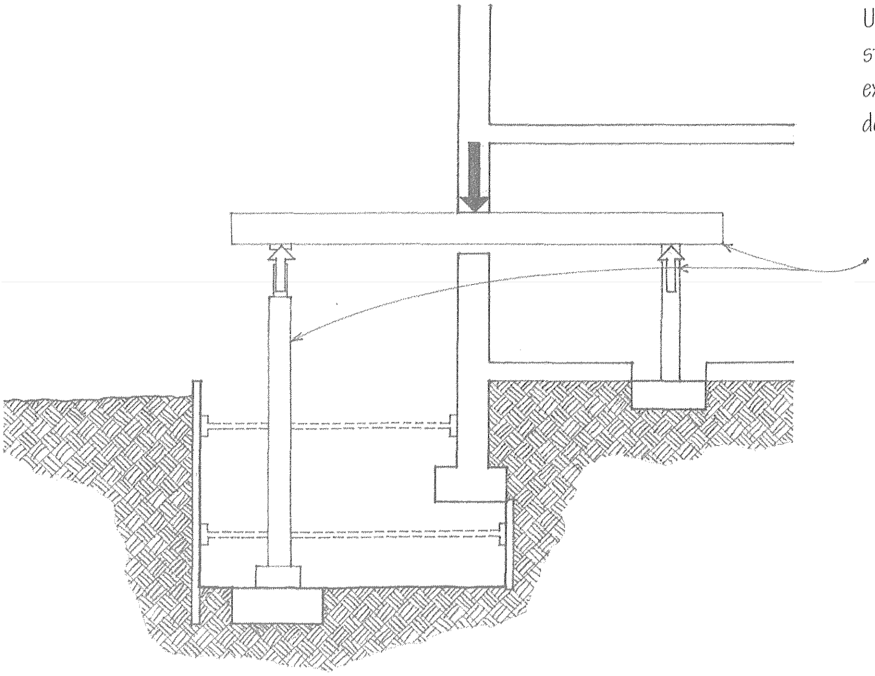
Deep foundations are employed when the soil underlying a foundation is unstable or of inadequate bearing capacity. They extend down through unsuitable soil to transfer building loads to a more appropriate bearing stratum of rock or dense sands and gravels well below the superstructure.

Factors to consider in selecting and designing the type of foundation system for a building include:

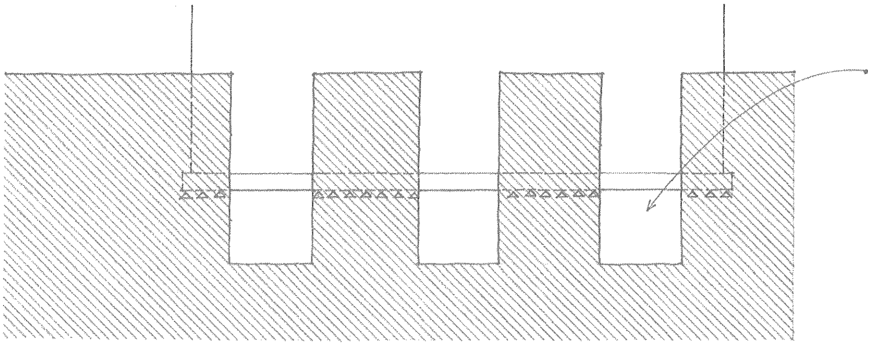
- Pattern and magnitude of building loads
- Subsurface and groundwater conditions
- Topography of the site
- Impact on adjacent properties
- Building code requirements
- Construction method and risk

The design of a foundation system requires professional analysis and design by a qualified structural engineer. When designing anything other than a single-family dwelling on stable soil, it is also advisable to have a geotechnical engineer undertake a subsurface investigation in order to determine the type and size of foundation system required for the building design.

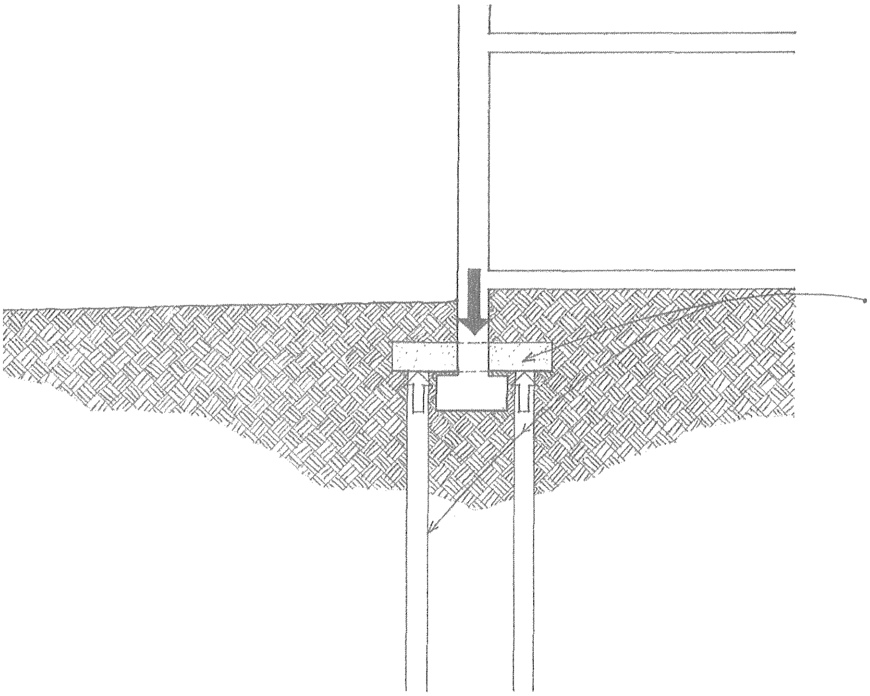
Underpinning refers to the process of rebuilding or strengthening the foundation of an existing building, or extending it when a new excavation in adjoining property is deeper than the existing foundation.



To provide temporary support while an existing foundation is repaired, strengthened, or deepened, needle beams are passed through the foundation wall and carried by hydraulic jacks and shores.



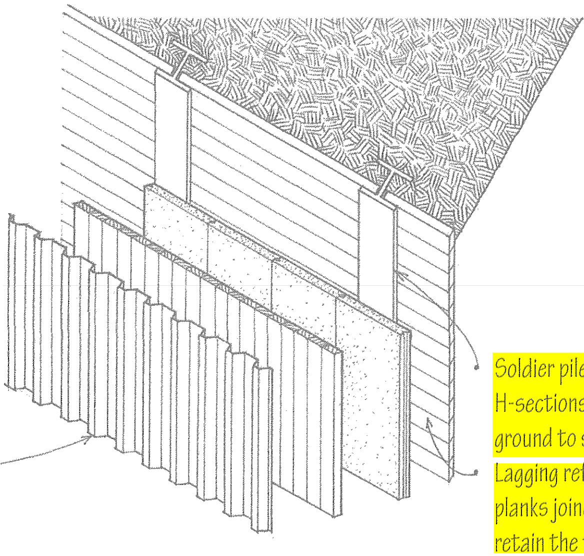
Another method for providing temporary support is to dig intermittent pits under the existing foundation down to the level of the new footings. After the new foundation wall and footing sections are placed, additional pits are dug until the entire wall has been deepened.



An alternative to extending a new foundation wall and placing new footings is to construct piles or caissons on either side of the existing foundation, remove a section of foundation wall, and replace the section with a reinforced concrete pile cap.

CSI MasterFormat 31 40 00 Shoring and Underpinning

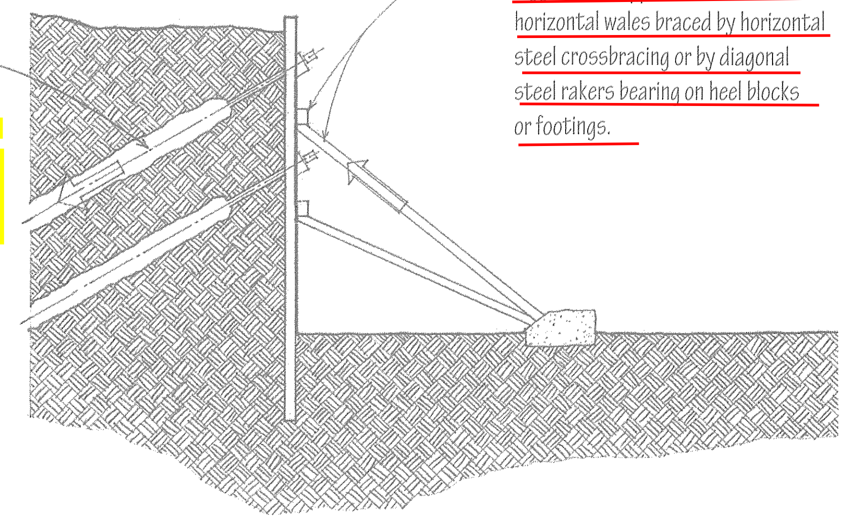
When the building site is sufficiently large that the sides of an excavation can be bench terraced or sloped at an angle less than the angle of repose for the soil, no supporting structure is necessary. When the sides of a deep excavation exceed the angle of repose for the soil, however, the earth must be temporarily braced or shored until the permanent construction is in place.



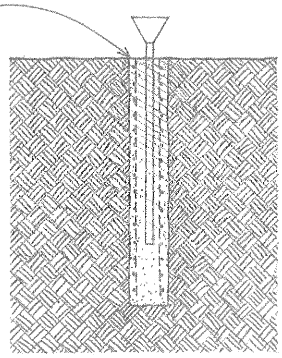
- Sheet piling consists of timber, steel, or precast concrete planks driven vertically side by side to retain earth and prevent water from seeping into an excavation. Steel and precast concrete sheet piling may be left in place as part of the substructure of a building.

- Soldier piles or beams are steel H-sections driven vertically into the ground to support horizontal lagging.
- Lagging refers to the heavy timber planks joined together side by side to retain the face of an excavation.

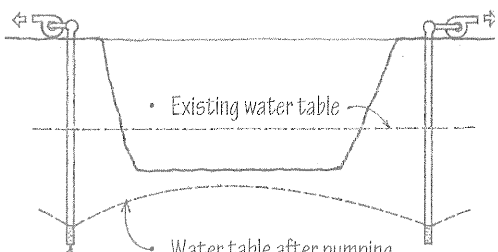
- Sheet piling and soldier beams with lagging are supported with continuous horizontal wales braced by horizontal steel crossbracing or by diagonal steel rakers bearing on heel blocks or footings.



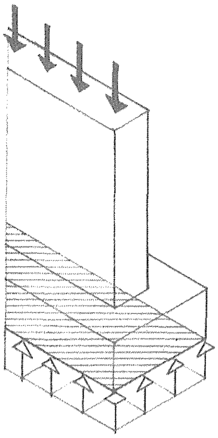
- Tiebacks secured to rock or soil anchors (CSI 31 51 00) may be used if crossbracing or rakers would interfere with the excavation or construction operation. The tiebacks consist of steel cables or tendons that are inserted into holes predrilled through the sheet piling and into rock or a suitable stratum of soil, grouted under pressure to anchor them to the rock or soil, and post-tensioned with a hydraulic jack. The tiebacks are then secured to continuous, horizontal steel wales to maintain the tension.

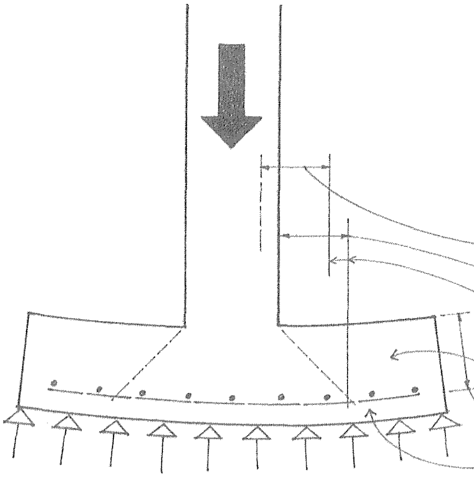


- A slurry wall (CSI 31 56 00) is a concrete wall cast in a trench to serve as sheeting and often as a permanent foundation wall. It is constructed by excavating a trench in short lengths, filling it with a slurry of bentonite and water to prevent the sidewalls from collapsing, setting reinforcement, and placing concrete in the trench with a tremie to displace the slurry.



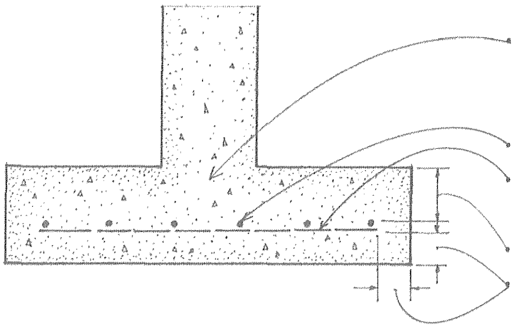
- Dewatering (CSI 31 23 19) refers to the process of lowering a water table or preventing an excavation from filling with groundwater. It is accomplished by driving perforated tubes called wellpoints into the ground to collect water from the surrounding area so it can be pumped away.



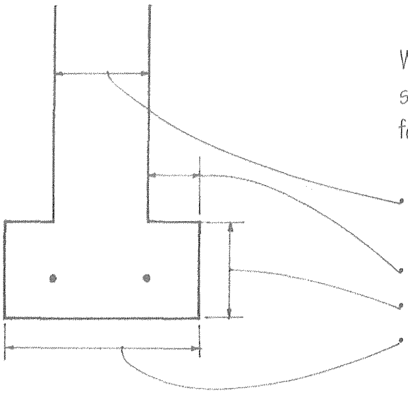


The lowest part of a shallow foundation are spread footings. They are extended laterally to distribute their load over an area of soil wide enough that the allowable bearing capacity of the soil is not exceeded. The contact area required is equal to the quotient of the magnitude of forces transmitted and the allowable bearing capacity of the supporting soil mass.

- d for unit masonry walls
- d for concrete walls
- Critical sections for shear
- Compression
- d = effective depth
- Tension

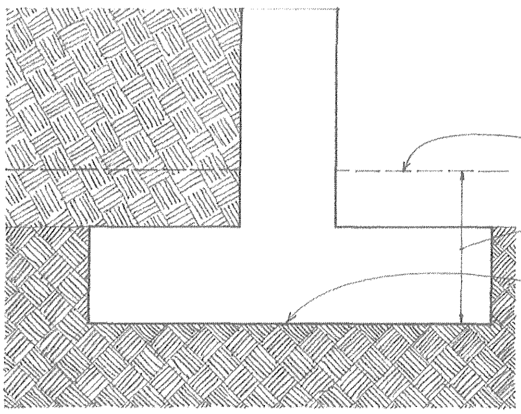


- Concrete having a minimum compressive strength of 2500 psi (17 kPa) at 28 days
- Longitudinal temperature reinforcement
- Tensile reinforcement is required when a spread footing projects more than half of the foundation wall thickness and is subject to bending.
- 6" (150) minimum above steel reinforcement
- 3" (75) minimum clearance between reinforcing bars and concrete surface



When footings for light frame construction bear on stable, noncohesive soil and transmit a continuous load of less than 2,000 pounds per lineal foot (29 kN/m), they may have the following cross-sectional proportions.

- Thickness (T) of concrete or unit masonry foundation wall supporting two floors: 8" (205) minimum
- Projection = 1/2 T
- Thickness of footing = T
- Width of footing = 2T



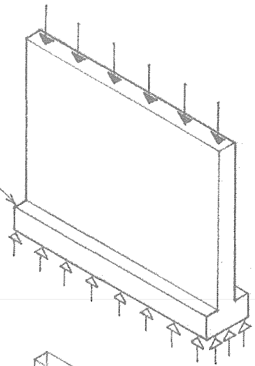
To minimize the effects of ground heaving when groundwater freezes and expands in cold weather, building codes require that footings be placed below the depth of frost penetration expected at the building site.

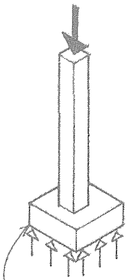
- Frostline is the average depth at which soil is frozen or frost penetrates the ground.
- 12" (305)

To minimize settlement, footings should always rest on stable, undisturbed soil free of organic material. When this is not possible, a specially engineered fill, compacted in 8" to 12" (205 to 305) layers at a controlled moisture content, can be used to make up the extra depth.

The most common forms of spread footings are strip footings and isolated footings.

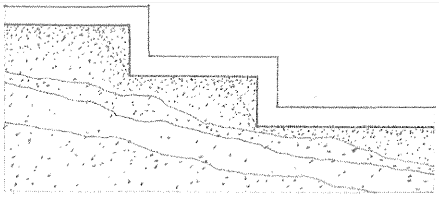
- Strip footings are the continuous spread footings of foundation walls.



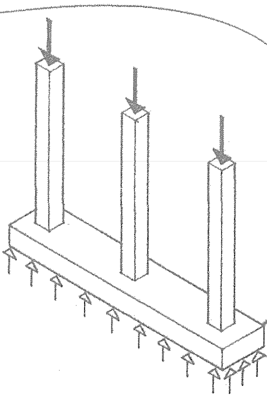


- Isolated footings are the individual spread footings supporting freestanding columns and piers.

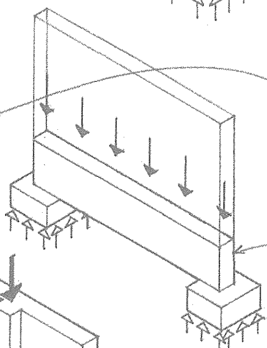
Other types of spread footings include the following:



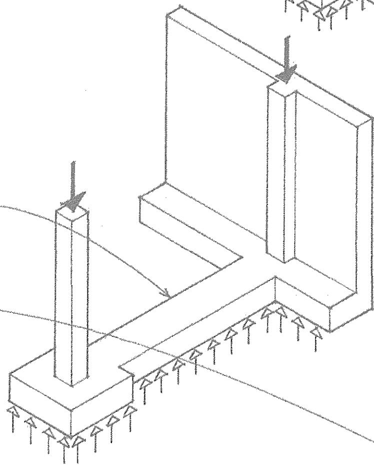
- Stepped footings are strip footings that change levels in stages to accommodate a sloping grade and maintain the required depth at all points around a building.

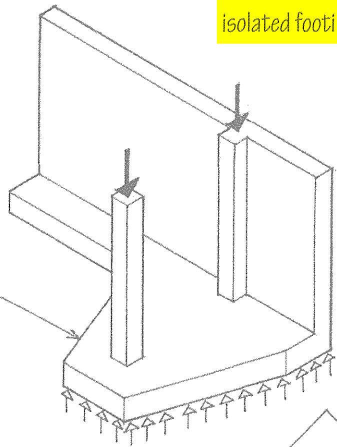


- A continuous footing is a reinforced concrete footing extended to support a row of columns.

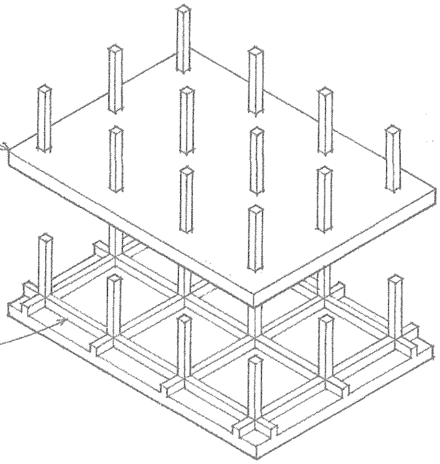


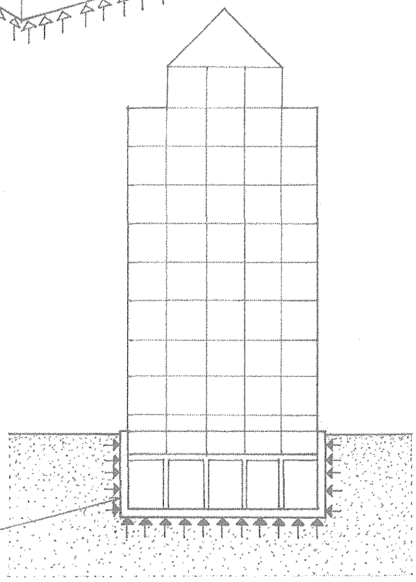
- A grade beam is a reinforced concrete beam supporting a bearing wall at or near ground level and transferring the load to isolated footings, piers, or piles.





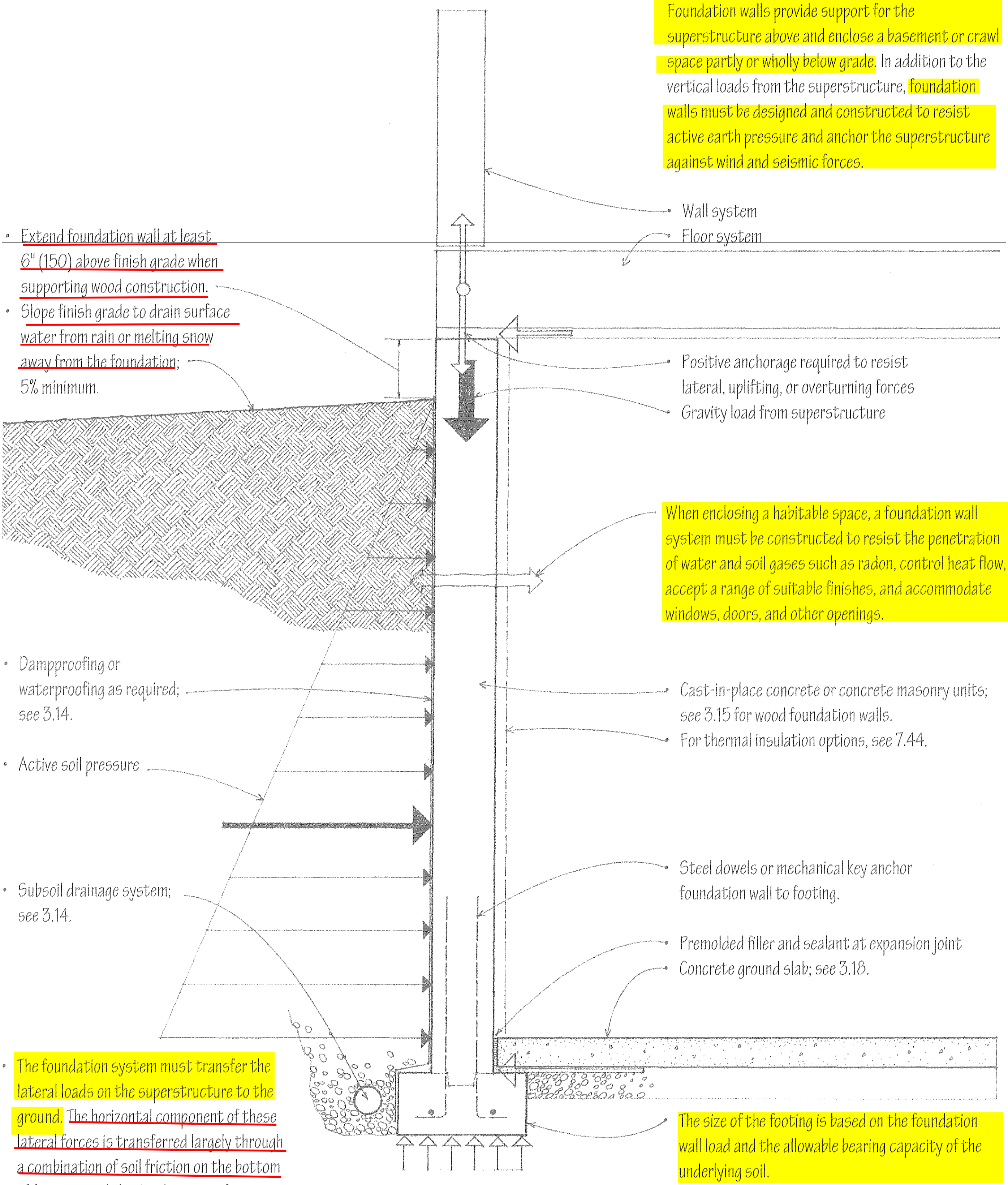
- A cantilever or strap footing consists of a column footing connected by a tie beam to another footing in order to balance an asymmetrically imposed load.
- A combined footing is a reinforced concrete footing for a perimeter foundation wall or column extended to support an interior column load.
- Cantilever and combined footings are often used when a foundation abuts a property line and it is not possible to construct a symmetrically loaded footing. To prevent the rotation or differential settlement that an asymmetrical loading condition can produce, continuous and cantilever footings are proportioned to generate uniform soil pressure.





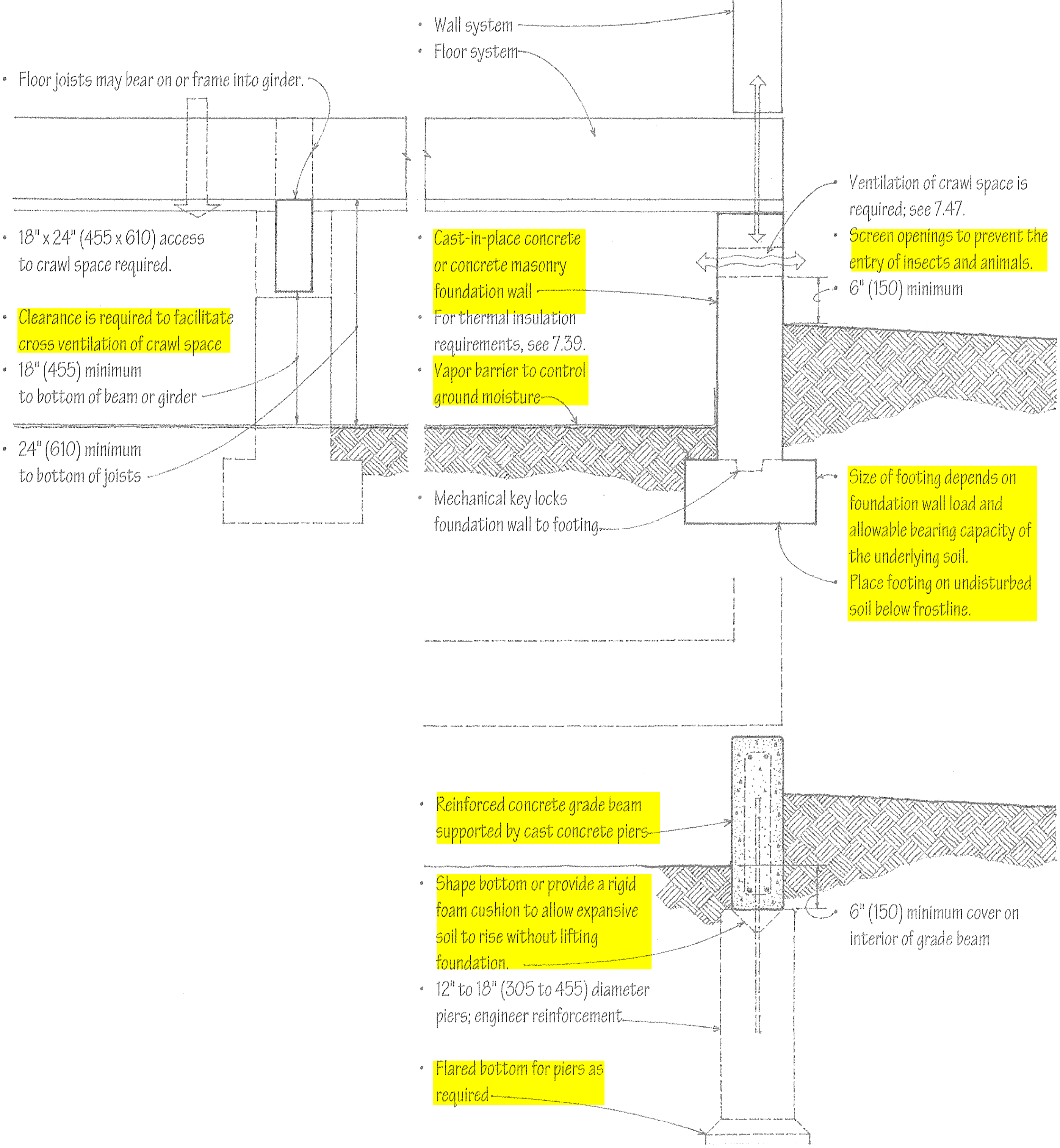
- A mat or raft foundation is a thick, heavily reinforced concrete slab that serves as a single monolithic footing for a number of columns or an entire building. Mat foundations are used when the allowable bearing capacity of a foundation soil is low relative to building loads and interior column footings become so large that it becomes more economical to merge them into a single slab. Mat foundations may be stiffened by a grid of ribs, beams, or walls.
- A floating foundation, used in yielding soil, has for its footing a mat placed deep enough that the weight of the excavated soil is equal to or greater than the weight of the construction supported.

Foundation walls provide support for the superstructure above and enclose a basement or crawl space partly or wholly below grade. In addition to the vertical loads from the superstructure, foundation walls must be designed and constructed to resist active earth pressure and anchor the superstructure against wind and seismic forces.



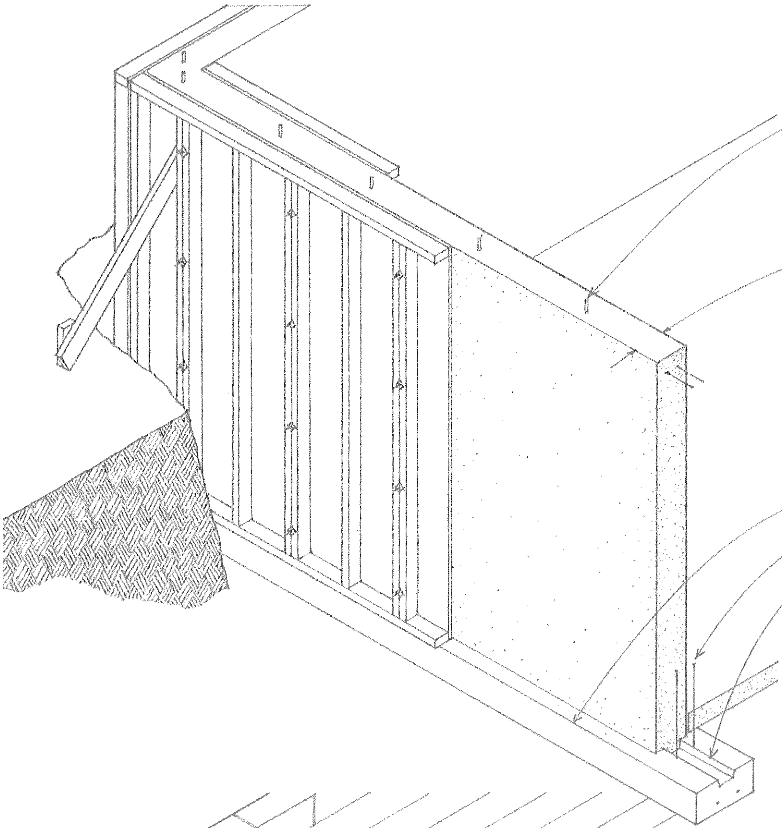
- Wall system
- Floor system
- Extend foundation wall at least 6" (150) above finish grade when supporting wood construction.
- Slope finish grade to drain surface water from rain or melting snow away from the foundation; 5% minimum.
- Positive anchorage required to resist lateral, uplifting, or overturning forces
- Gravity load from superstructure
- When enclosing a habitable space, a foundation wall system must be constructed to resist the penetration of water and soil gases such as radon, control heat flow, accept a range of suitable finishes, and accommodate windows, doors, and other openings.
- Dampproofing or waterproofing as required; see 3.14.
- Cast-in-place concrete or concrete masonry units; see 3.15 for wood foundation walls.
- For thermal insulation options, see 7.44.
- Active soil pressure
- Steel dowels or mechanical key anchor foundation wall to footing.
- Subsoil drainage system; see 3.14.
- Premolded filler and sealant at expansion joint
- Concrete ground slab; see 3.18.
- The foundation system must transfer the lateral loads on the superstructure to the ground. The horizontal component of these lateral forces is transferred largely through a combination of soil friction on the bottom of footings and the development of passive soil pressure on the sides of footings and foundation walls.
- The size of the footing is based on the foundation wall load and the allowable bearing capacity of the underlying soil.

Crawl spaces enclosed by a continuous foundation wall or piers provide space under a first floor for the integration of and access to mechanical, electrical, and plumbing installations.



Concrete Foundation Walls

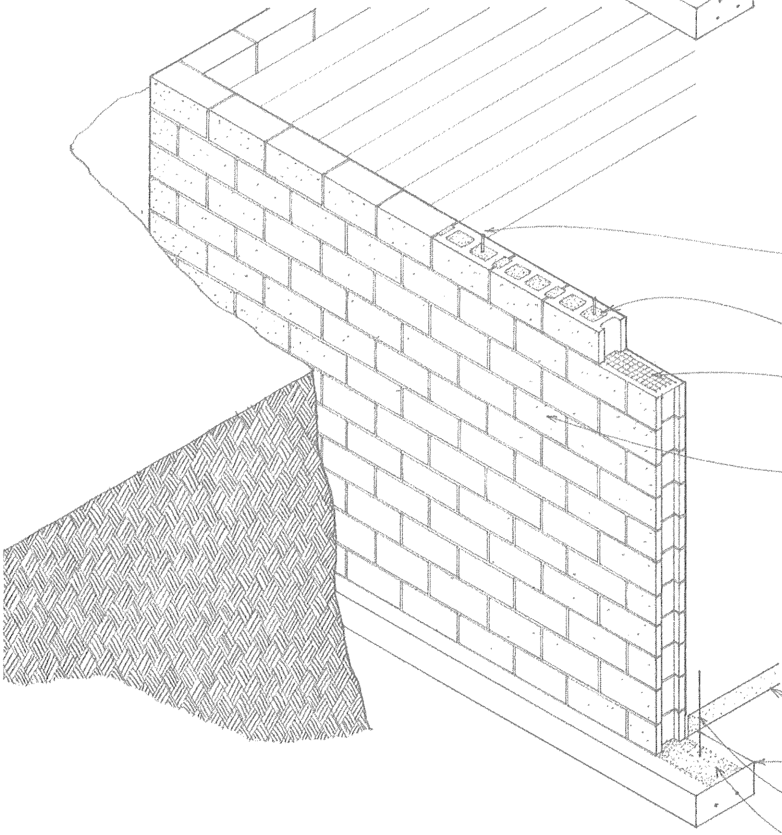
Cast-in-place concrete foundation walls require formwork and access to place the concrete.



- Anchor bolts for sill plates of light frame construction; see 3.13 and 4.28.
- 8" (205) minimum wall thickness
- Horizontal and vertical reinforcement as required by engineering analysis; see 5.06.
- Concrete ground slab; see 3.18.
- Concrete footing; see 3.08, 3.09.
- Steel dowels anchor foundation wall to footing.
- Key provides additional resistance to lateral slippage.

Concrete Masonry Foundation Walls

Concrete masonry foundation walls utilize easily handled small units and do not require formwork. Because concrete masonry is a modular material, all major dimensions should be based on the 8" (205) module of standard concrete block.

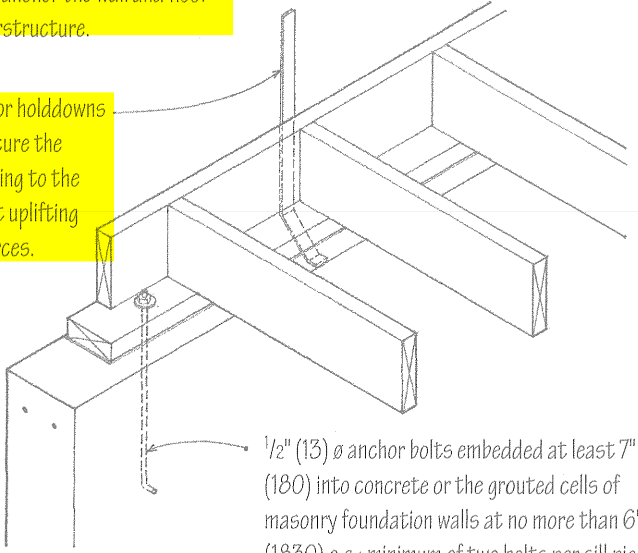


- Anchor bolts for sill plates of light frame construction; see 3.13 and 4.28.
- Fill cells in top course with grout.
- Screen to retain grout
- Masonry units laid in running bond with Type M or S mortar
- 8" (205) minimum nominal wall thickness
- Vertical reinforcement in grouted cells and horizontal bond beams as required by engineering analysis
- See 5.18 for reinforcement of masonry walls.
- Concrete ground slab; see 3.18.
- Concrete footing; see 3.08, 3.09.
- Steel dowels anchor foundation wall to footing.
- Full mortar joint on roughened footing

CSI MasterFormat 03 30 00 Cast-in-Place Concrete
CSI MasterFormat 04 20 00 Unit Masonry

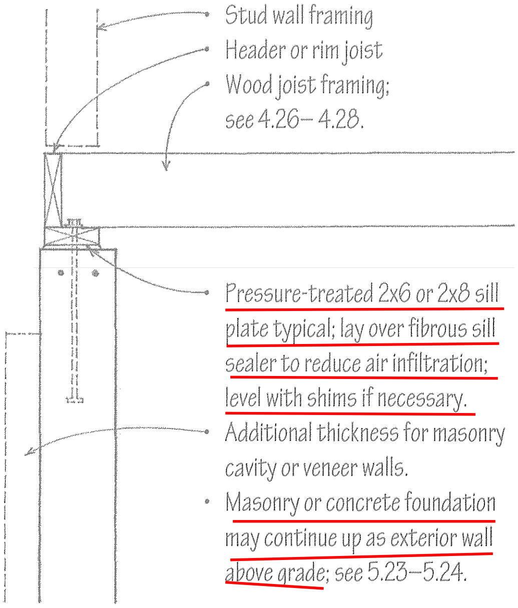
The top of a foundation wall must be prepared to receive, support, and anchor the wall and floor systems of the superstructure.

- Sill plate anchors or holddowns are required to secure the wall and floor framing to the foundation against uplifting wind or seismic forces.



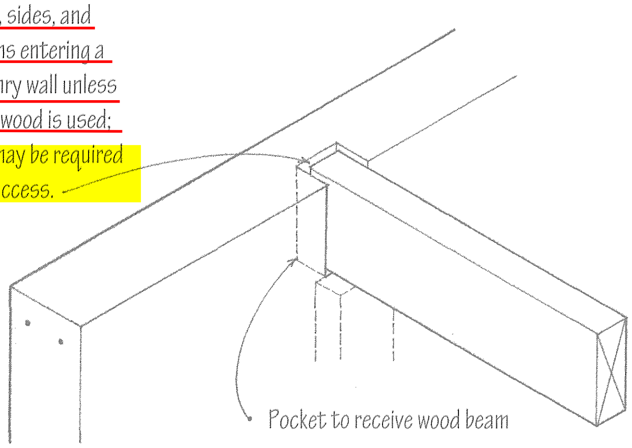
½" (13) ø anchor bolts embedded at least 7" (180) into concrete or the grouted cells of masonry foundation walls at no more than 6' (1830) o.c.; minimum of two bolts per sill piece w/ one within 12" (305) of each end; more stringent requirements exist for Seismic Zones 3 and 4.

Wood Joists



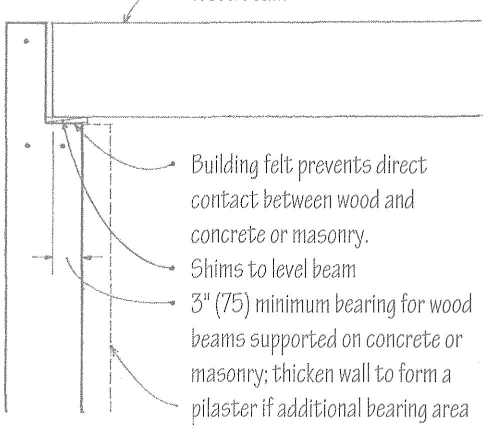
- Stud wall framing
- Header or rim joist
- Wood joist framing; see 4.26–4.28.
- Pressure-treated 2x6 or 2x8 sill plate typical; lay over fibrous sill sealer to reduce air infiltration; level with shims if necessary.
- Additional thickness for masonry cavity or veneer walls.
- Masonry or concrete foundation may continue up as exterior wall above grade; see 5.23–5.24.

- Provide ½" (13) minimum air space on the tops, sides, and ends of wood beams entering a concrete or masonry wall unless pressure-treated wood is used; additional space may be required for construction access.



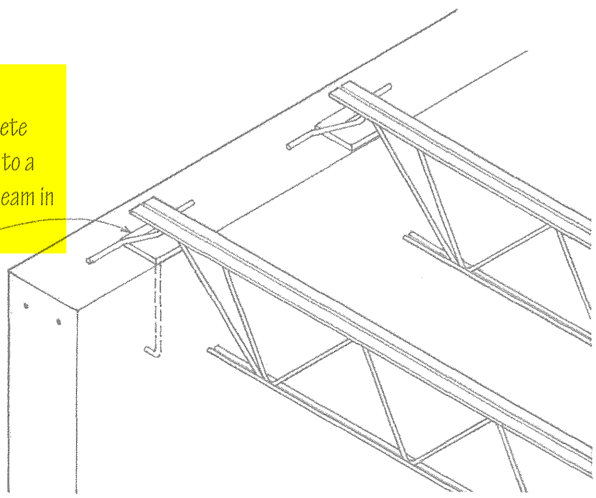
Pocket to receive wood beam

Wood Beams

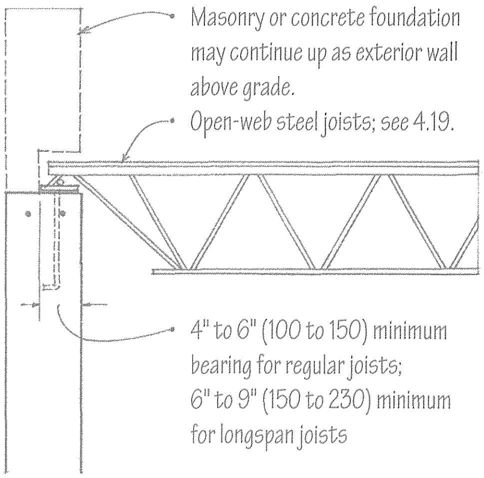


- Wood beam
- Building felt prevents direct contact between wood and concrete or masonry.
- Shims to level beam
- 3" (75) minimum bearing for wood beams supported on concrete or masonry; thicken wall to form a pilaster if additional bearing area is required.

- Steel base plates anchored to concrete foundation wall or to a continuous bond beam in masonry walls

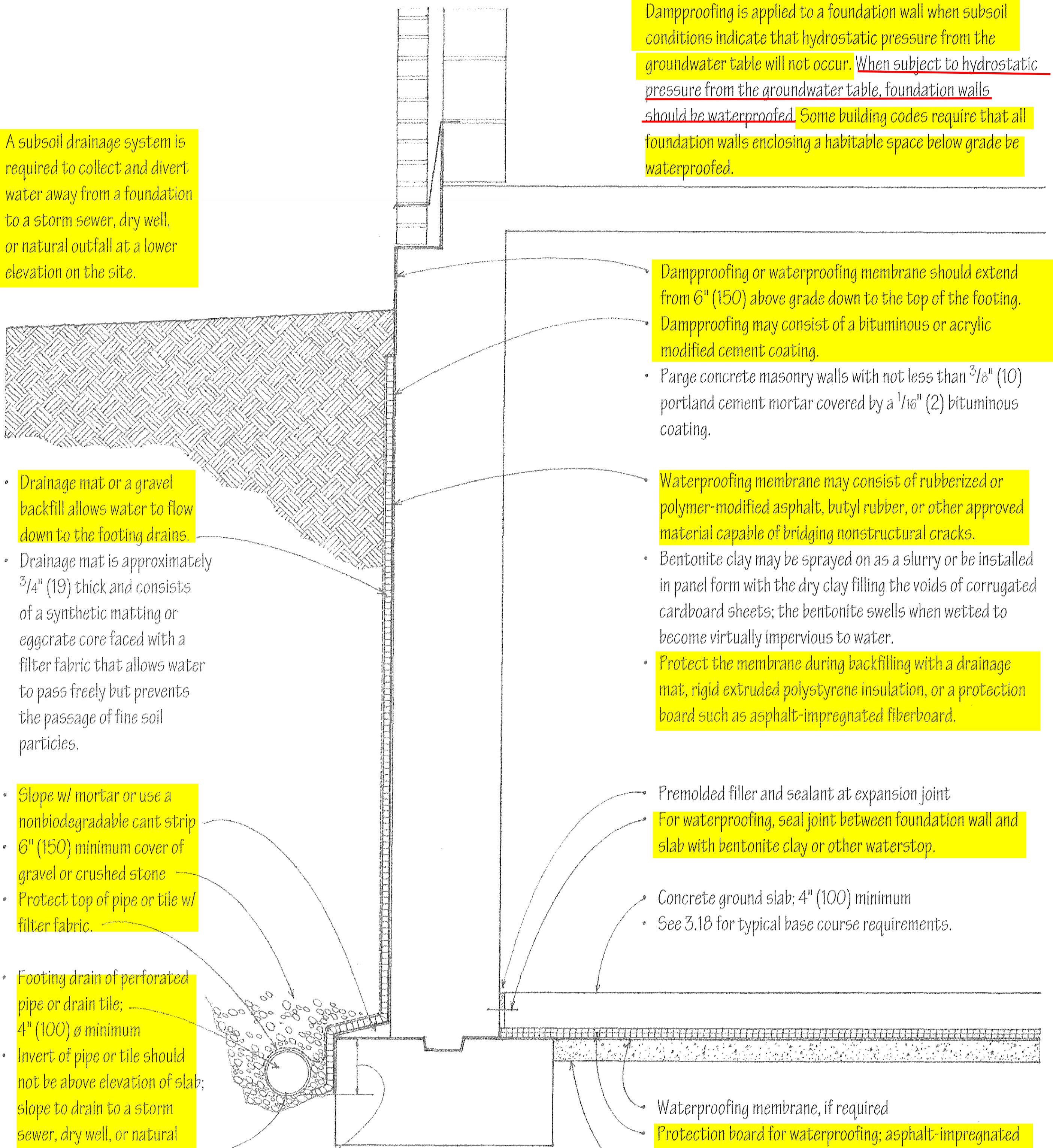


Open-Web Steel Joists



- Masonry or concrete foundation may continue up as exterior wall above grade.
- Open-web steel joists; see 4.19.
- 4" to 6" (100 to 150) minimum bearing for regular joists; 6" to 9" (150 to 230) minimum for longspan joists

3.14 FOUNDATION WALLS



Dampproofing is applied to a foundation wall when subsoil conditions indicate that hydrostatic pressure from the groundwater table will not occur. When subject to hydrostatic pressure from the groundwater table, foundation walls should be waterproofed. Some building codes require that all foundation walls enclosing a habitable space below grade be waterproofed.

A subsoil drainage system is required to collect and divert water away from a foundation to a storm sewer, dry well, or natural outfall at a lower elevation on the site.

- Dampproofing or waterproofing membrane should extend from 6" (150) above grade down to the top of the footing.
- Dampproofing may consist of a bituminous or acrylic modified cement coating.
- Parge concrete masonry walls with not less than 3/8" (10) portland cement mortar covered by a 1/16" (2) bituminous coating.

- Drainage mat or a gravel backfill allows water to flow down to the footing drains.
- Drainage mat is approximately 3/4" (19) thick and consists of a synthetic matting or eggcrate core faced with a filter fabric that allows water to pass freely but prevents the passage of fine soil particles.

- Waterproofing membrane may consist of rubberized or polymer-modified asphalt, butyl rubber, or other approved material capable of bridging nonstructural cracks.
- Bentonite clay may be sprayed on as a slurry or be installed in panel form with the dry clay filling the voids of corrugated cardboard sheets; the bentonite swells when wetted to become virtually impervious to water.
- Protect the membrane during backfilling with a drainage mat, rigid extruded polystyrene insulation, or a protection board such as asphalt-impregnated fiberboard.

- Slope w/ mortar or use a nonbiodegradable cant strip
- 6" (150) minimum cover of gravel or crushed stone
- Protect top of pipe or tile w/ filter fabric.

- Premolded filler and sealant at expansion joint
- For waterproofing, seal joint between foundation wall and slab with bentonite clay or other waterstop.

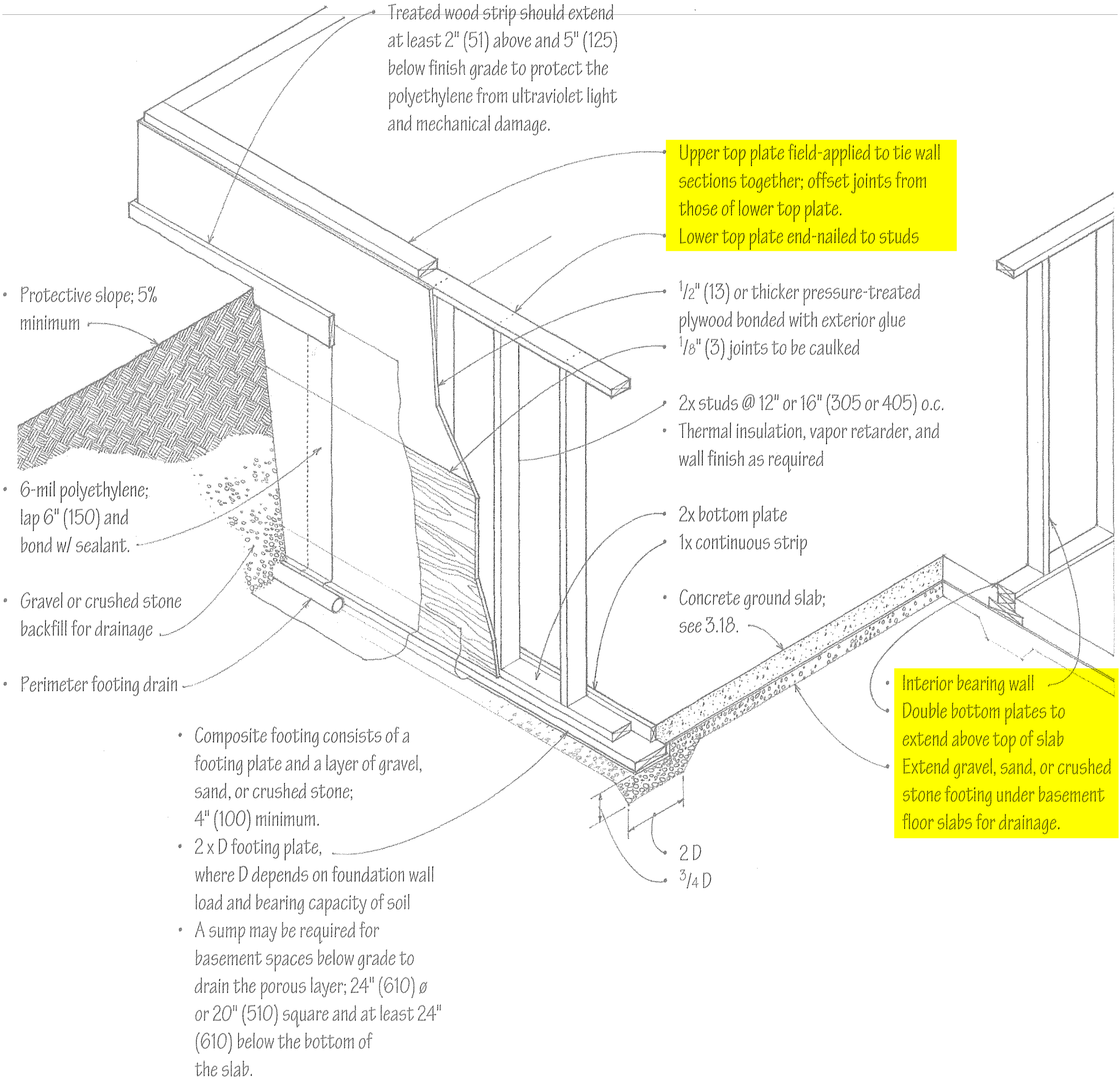
- Concrete ground slab; 4" (100) minimum
- See 3.18 for typical base course requirements.

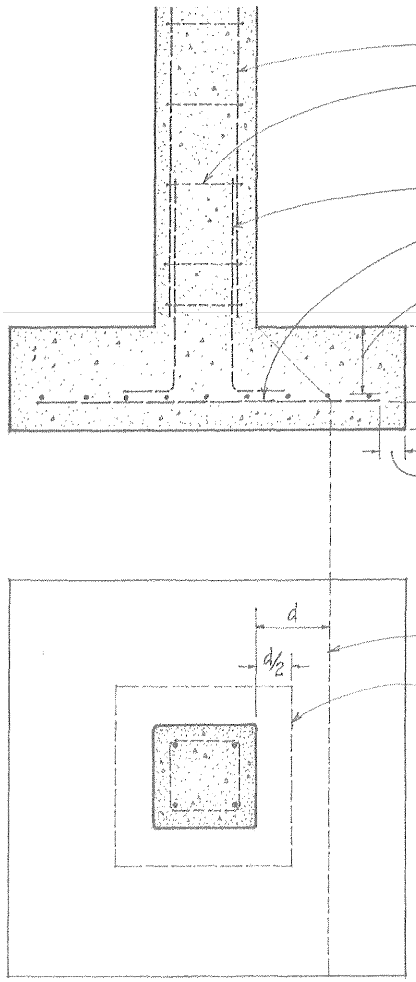
- Footing drain of perforated pipe or drain tile; 4" (100) ø minimum
- Invert of pipe or tile should not be above elevation of slab; slope to drain to a storm sewer, dry well, or natural outfall on site.
- 2" (51) minimum

- Waterproofing membrane, if required
- Protection board for waterproofing; asphalt-impregnated fiberboard or extruded polystyrene
- A mudslab of unreinforced concrete is used when the waterproofing membrane continues under the ground slab or to provide a working surface on unstable soil.

CSI MasterFormat 07 10 00 Dampproofing & Waterproofing
CSI MasterFormat 33 46 13 Foundation Drainage

Treated wood foundation systems can be used for both basement and crawl space construction. The wall sections may be built on-site or be factory-fabricated to reduce erection time. All wood and plywood used to fabricate a foundation system must be pressure-treated with a preservative approved for ground contact use; all field cuts should be treated with the same preservative. All metal fasteners should be of stainless steel or hot-dipped zinc-coated steel.

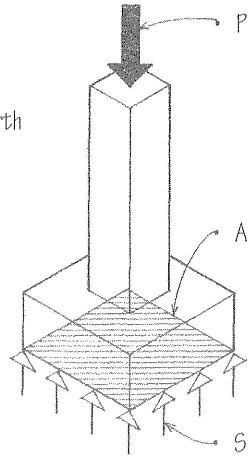




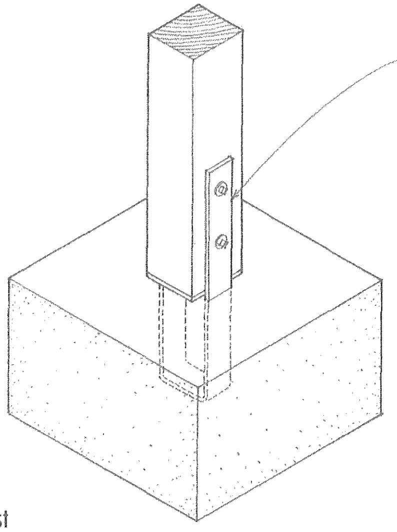
- Vertical reinforcement
- Lateral reinforcement
- See also 5.04 for concrete column details.
- Steel dowels anchor column to footing
- Two-way reinforcement uniformly spaced
- 6" (150) minimum above steel reinforcement
- d = effective depth
- 3" (75) minimum cover for steel reinforcement when concrete is cast against and permanently exposed to earth
- Critical section for one-way shear
- Critical section for two-way shear

Reinforced Concrete Column

A = P/S where:

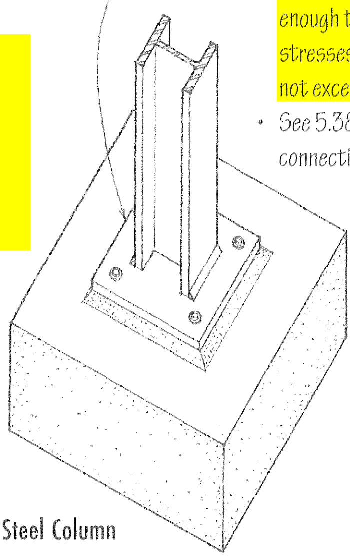


- P = Column load in pounds
- A = Contact area of footing
- S = Soil bearing capacity in psf; 1 psf = 0.0479 kPa



- A variety of proprietary post bases are available. Consult manufacturer for allowable loads and installation details. Post bases can also be fabricated to satisfy specific design conditions.
- See 5.50 for wood column base connections.

Wood Post



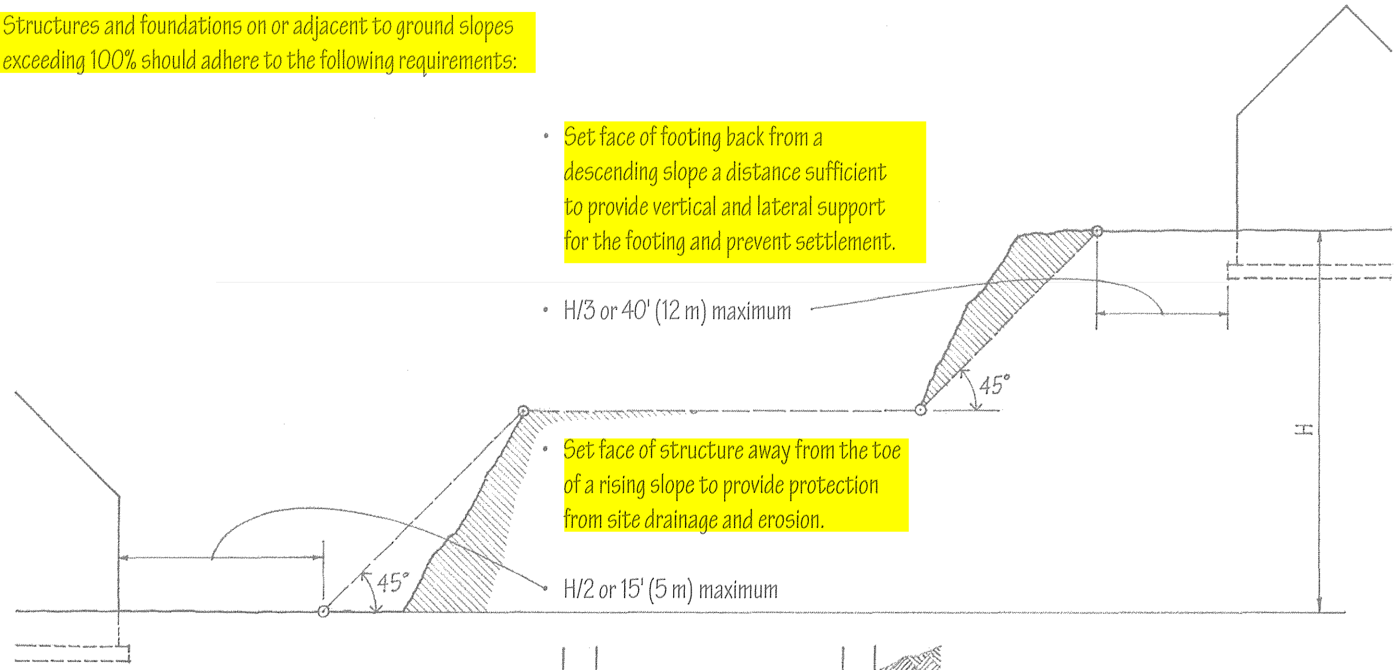
- A steel base plate is necessary to distribute the column load over an area wide enough that the allowable stresses in the concrete are not exceeded.
- See 5.38 for steel base plate connections.

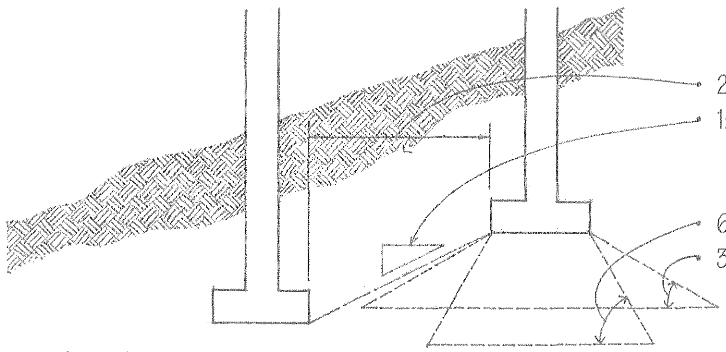
Steel Column

CSI MasterFormat 03 30 00 Cast-in-Place Concrete
CSI MasterFormat 03 31 00 Structural Concrete

Structures and foundations on or adjacent to ground slopes exceeding 100% should adhere to the following requirements:

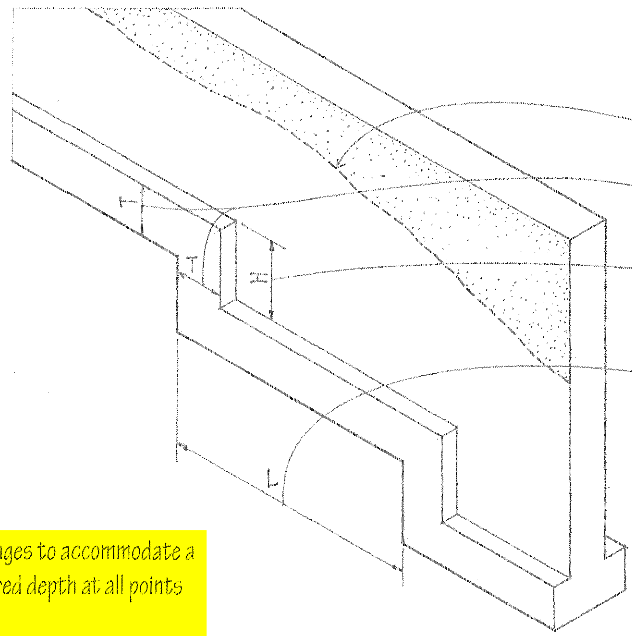
- Set face of footing back from a descending slope a distance sufficient to provide vertical and lateral support for the footing and prevent settlement.
- Set face of structure away from the toe of a rising slope to provide protection from site drainage and erosion.





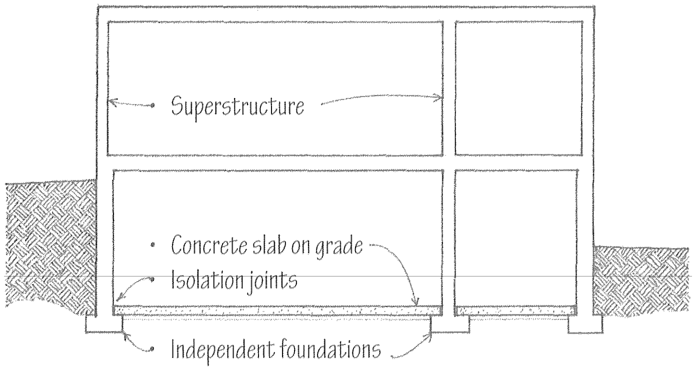
Closely spaced footings or adjacent footings located at different levels can cause overlapping soil stresses.

- Ground surface should not encroach on bearing prism of soil or rock.



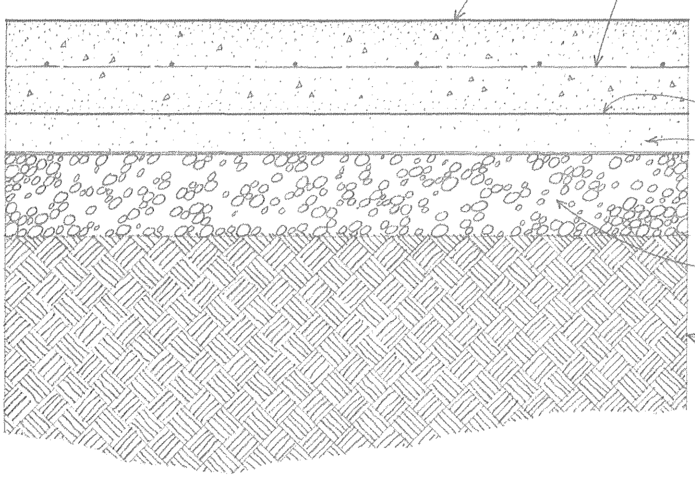
- Utilize modular dimensions for concrete masonry walls.

Stepped footings change levels in stages to accommodate a sloping grade and maintain the required depth at all points around a building.

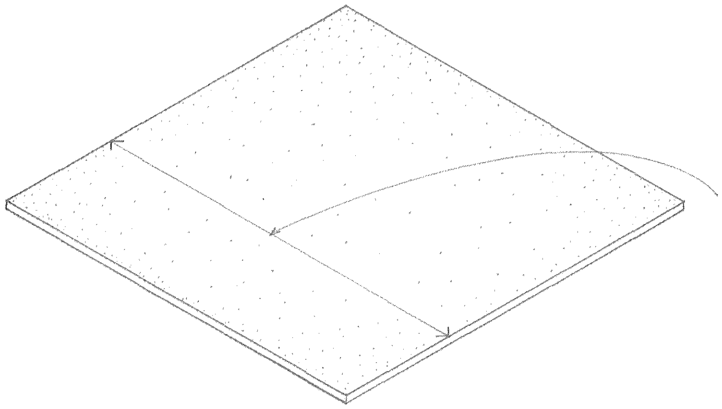


A concrete slab may be placed at or near grade level to serve as a combined floor and foundation system. The suitability of a concrete slab for such use depends on the geographic location, topography, and soil characteristics of the site, and the design of the superstructure.

Concrete slabs on grade require the support of a level, stable, uniformly dense or properly compacted soil base containing no organic matter. When placed over soil of low bearing capacity or over highly compressible or expansive soils, a concrete ground slab must be designed as a mat or raft foundation, which requires professional analysis and design by a qualified structural engineer.



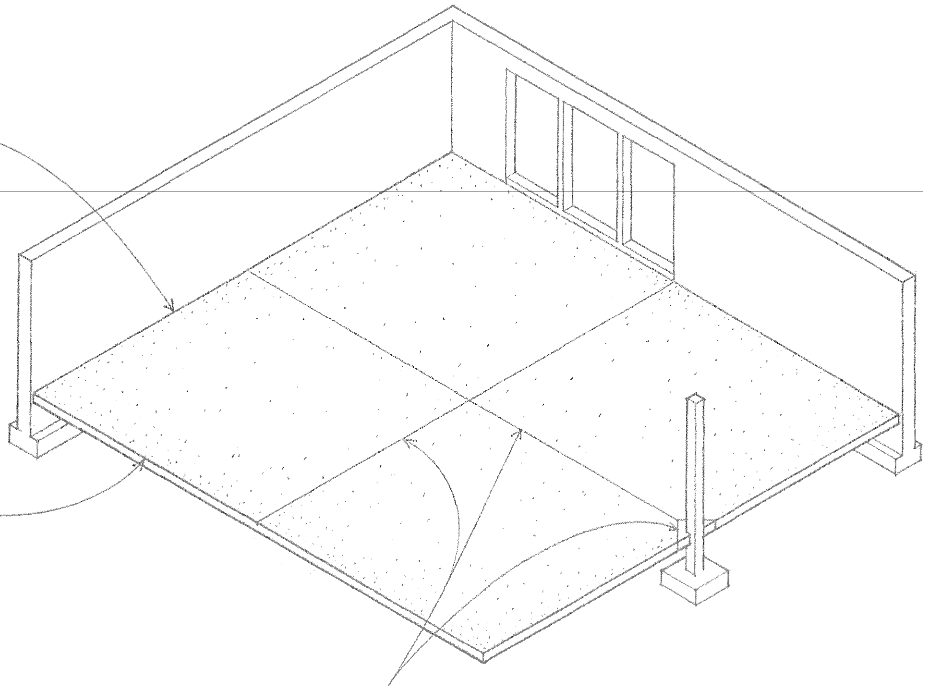
- 4" (100) minimum slab thickness; thickness required depends on expected use and load conditions.
- Welded wire fabric reinforcement set at or slightly above the mid-depth of the slab controls thermal stresses, shrinkage cracking, and slight differential movement in the soil bed; a grid of reinforcing bars may be required for slabs carrying heavier-than-normal floor loads.
- Admixture of glass, steel, or polypropylene fibers may be added to concrete mix to reduce shrinkage cracking.
- Concrete additives can increase surface hardness and abrasion resistance.
- 6-mil (0.15 mm) polyethylene moisture barrier
- The American Concrete Institute recommends a 2" (51) layer of sand be placed over the moisture barrier to absorb excess water from the concrete during curing.
- Base course of gravel or crushed stone to prevent the capillary rise of groundwater; 4" (100) minimum
- Stable, uniformly dense soil base; compaction may be required to increase soil stability, loadbearing capacity, and resistance to water penetration.



Maximum Slab Dimensions feet (m)	Wire Spacing inches (mm)	Wire Size (number)
Up to 45 (14)	6 x 6 (150 x 150)	W1.4 x W1.4
45–60 (14–18)	6 x 6	W2.0 x W2.0
60–75 (18–22)	6 x 6	W2.9 x W2.9

CSI MasterFormat 03 30 00 Cast-in-Place Concrete
CSI MasterFormat 03 31 00 Structural Concrete

Three types of joints may be created or constructed in order to accommodate movement in the plane of a concrete slab on grade—isolation joints, construction joints, and control joints.

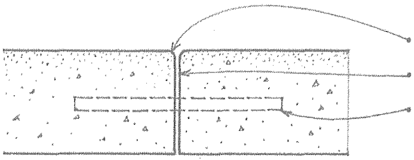


Isolation Joints

Isolation joints, often called expansion joints, allow movement to occur between a concrete slab and adjoining columns and walls of a building.

Construction Joints

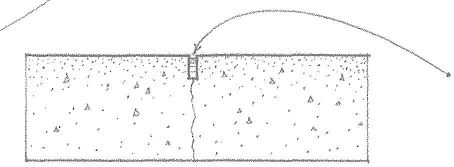
Construction joints provide a place for construction to stop and then continue at a later time. These joints, which also serve as isolation or control joints, can be keyed or doweled to prevent vertical differential movement of adjoining slab sections.



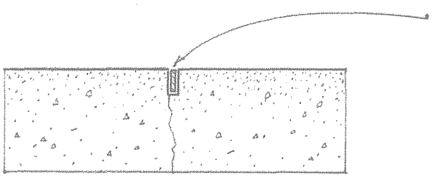
1/8" (3) radius
Prevent bond
Coated dowels or a keyed joint if required to prevent vertical differential movement

Control Joints

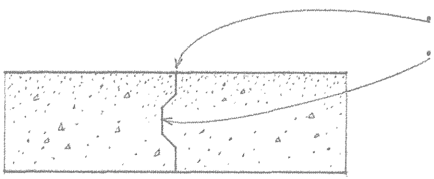
Control joints create lines of weakness so that the cracking that may result from tensile stresses occurs along predetermined lines. Space control joints in exposed concrete 15' to 20' (4570 to 6100) o.c., or wherever required to break an irregular slab shape into square or rectangular sections.



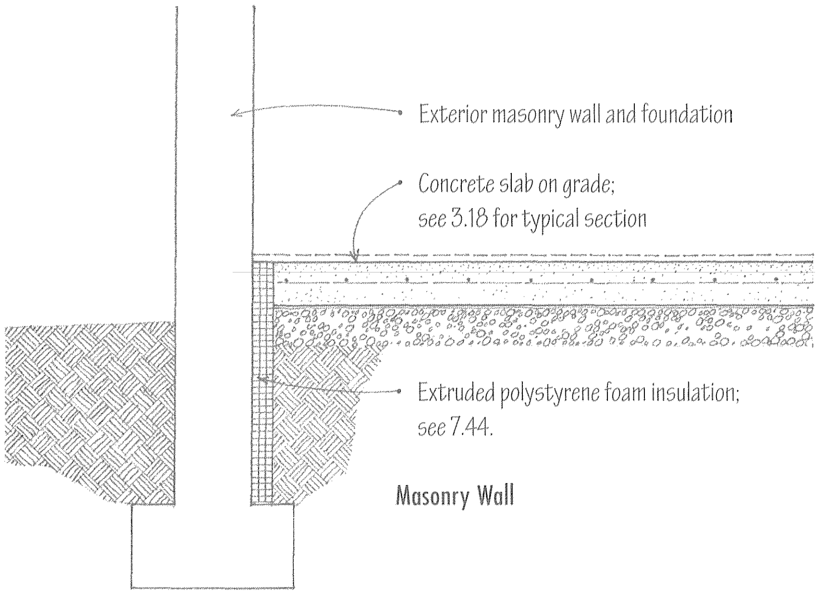
Sawn joint 1/8" (3) wide and 1/4 of slab depth; fill w/ joint filler.



1/8" (3) premolded or metal strip inserted when concrete is placed; finish flush with surface.

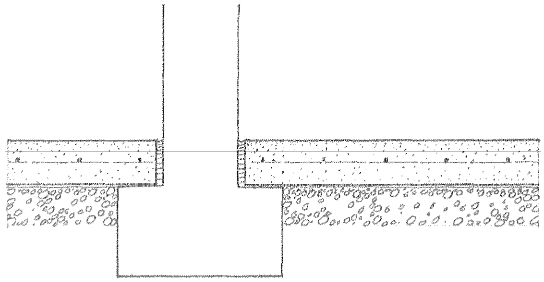


Keyed joint
Prevent bond by using a preformed metal or plastic joint material, or by applying curing compound to one side before other side is placed.

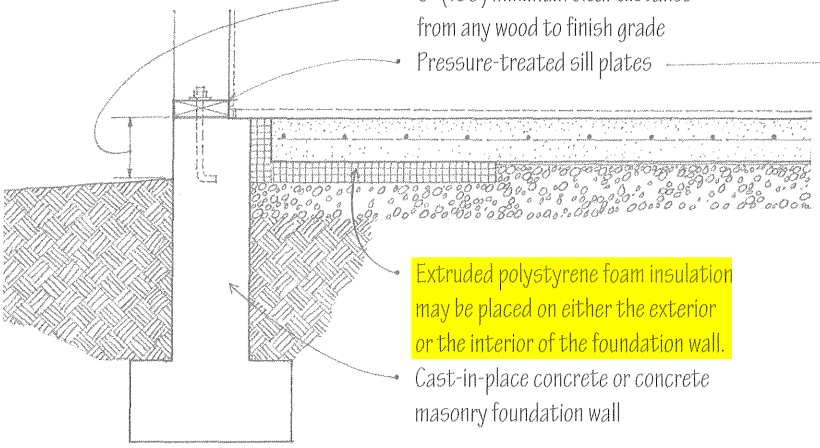


Masonry Wall

Isolated or integral footings are required to transmit loads from the superstructure above to the foundation soil.

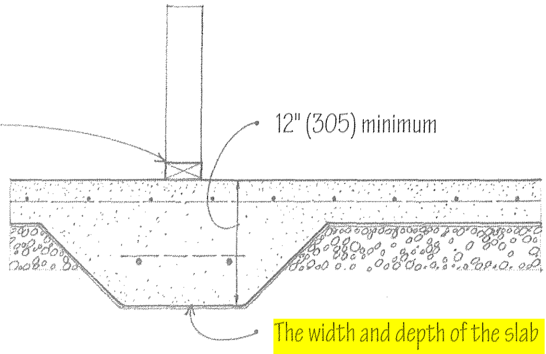


- An independent footing should be used when a bearing wall or column transmits a heavy or concentrated load.



- Extruded polystyrene foam insulation may be placed on either the exterior or the interior of the foundation wall.

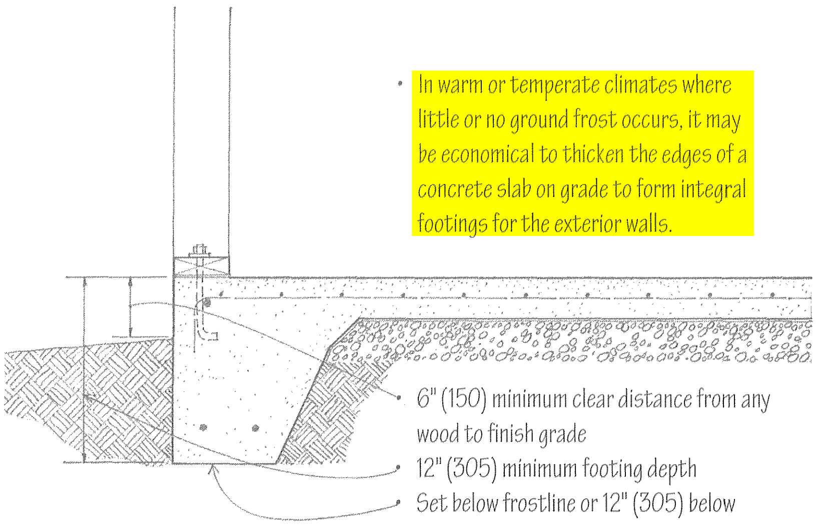
Stud Wall



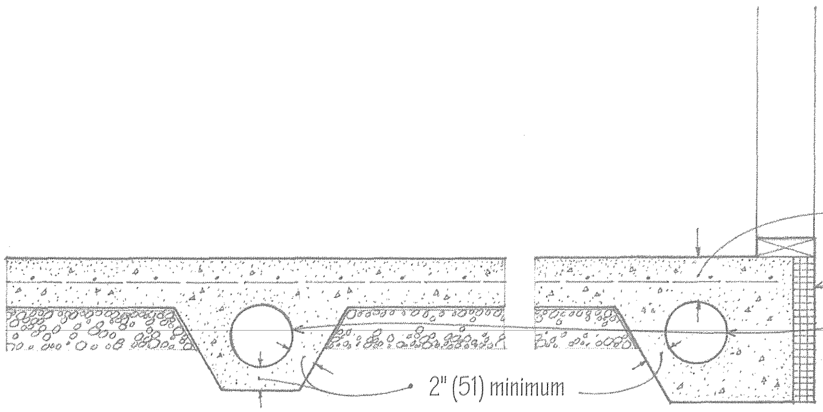
The width and depth of the slab footing are determined by the magnitude of the load and the bearing capacity of the soil.

- A concrete ground slab may be thickened to support a interior bearing partition or post and transmit the load to the underlying soil.

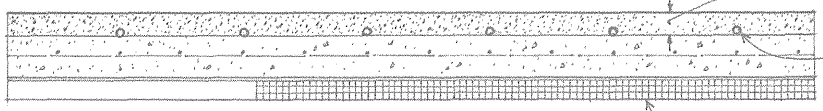
- In warm or temperate climates where little or no ground frost occurs, it may be economical to thicken the edges of a concrete slab on grade to form integral footings for the exterior walls.



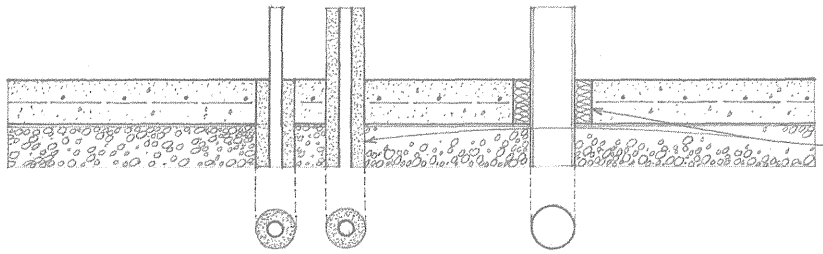
Thickened Edge Slab



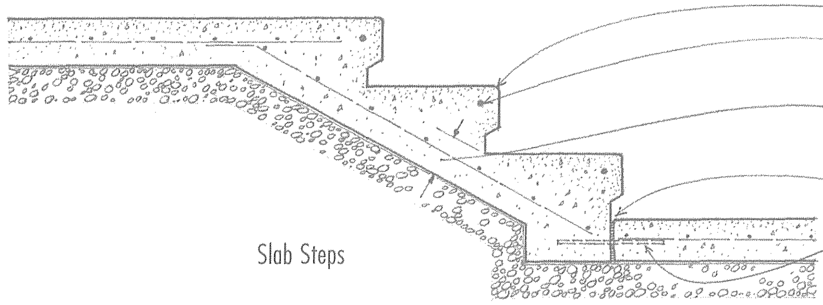
Heating Ducts



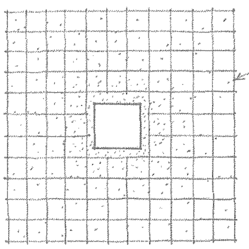
Embedded Heating Pipes



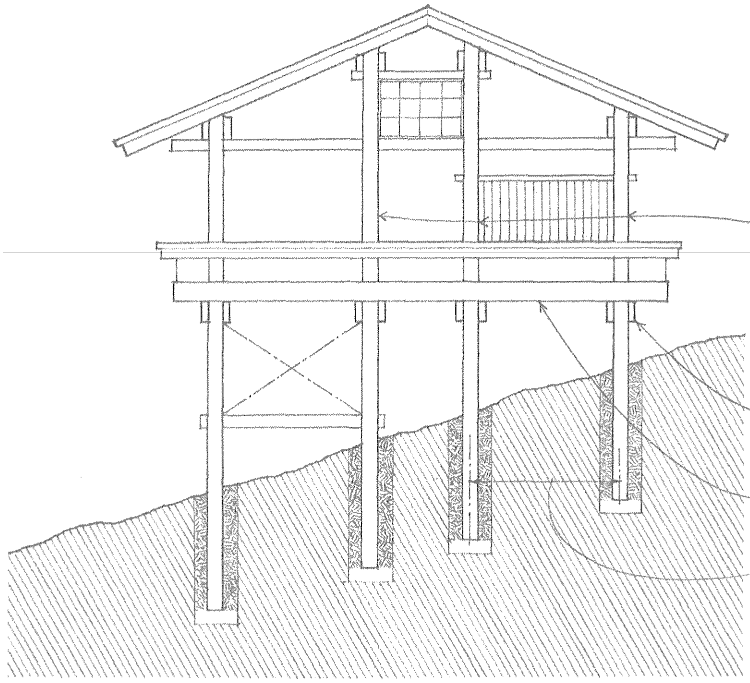
Pipe Penetrations



Slab Steps



Slab Openings



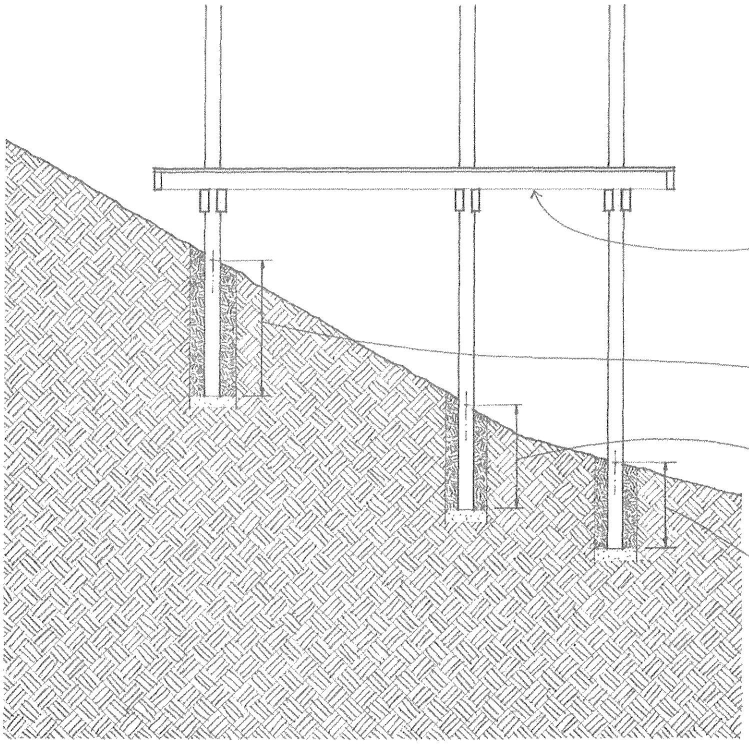
Pole foundations elevate timber structures above the ground plane, require minimal excavation, and preserve the natural features and existing drainage patterns of a site. They are particularly useful when building on steep slopes and in areas subject to periodic flooding.

The treated poles are usually laid out along a grid defined by the beam-and-joist framing pattern. Their spacing determines both the beam-and-joist spans and the vertical loads they must support.

- Poles 6" to 12" (150 to 305) in diameter; treat with a preservative to protect against decay and insect infestation. The treated poles may extend vertically to form the loadbearing frame of the superstructure or terminate at the first-floor level to support a conventional platform frame.
- Solid, built-up, or spaced wood beams; limit overhangs to 1/4 of the backspan.
- Insulate floors, walls, and roof according to local climatic conditions.
- Poles are spaced 6' to 12' (1830 to 3660) apart to support floor and roof areas up to 144 sf (13.4 m^2)

Poles are set in holes dug by hand or by a power auger. Adequate embedment length, suitable backfilling, and proper connections are required for a pole structure to develop the necessary rigidity and resistance to lateral wind and seismic forces. The required embedment length varies according to:

- Slope of the site
- Subsurface soil conditions
- Pole spacing
- Unsupported height of the poles
- Seismic zone



- Floors should be designed and constructed as a diaphragm to transfer the rigidity of uphill poles to the rest of the structure.

Embedment Length for Steep Slopes

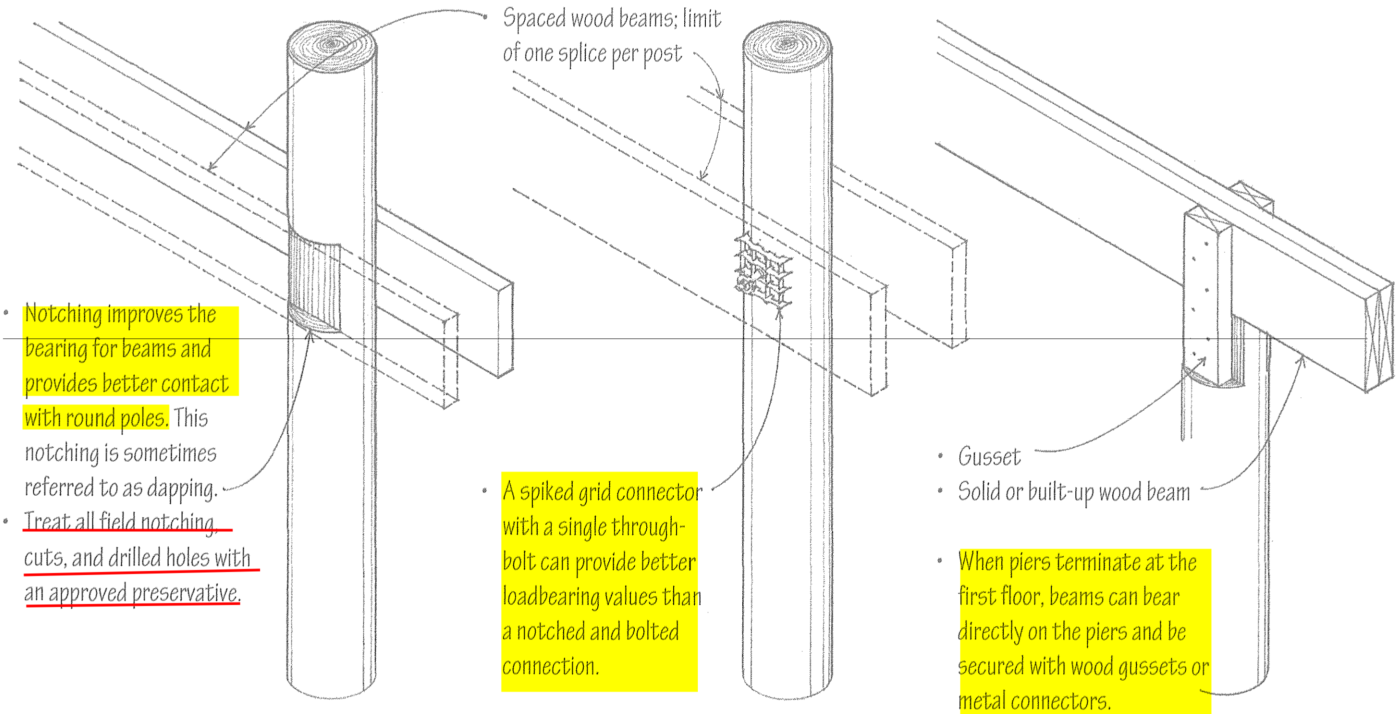
- 5' to 8' (1525 to 2440) for uphill poles; uphill poles have shorter unsupported heights but require deeper embedment in order to provide the necessary rigidity for the structure.
- 4' to 7' (1220 to 2135) for downhill poles

Embedment Length for Flat Slopes

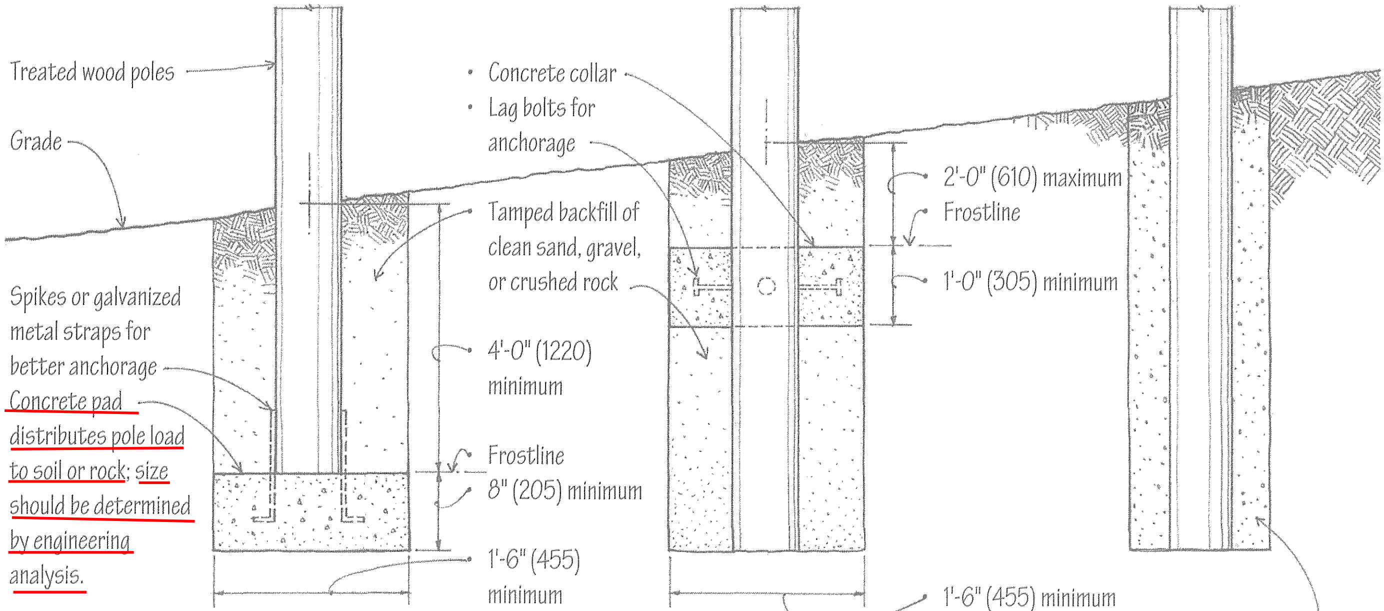
- 4' to 5' (1220 to 1525)

When the necessary embedment is not possible, such as on a rocky slope, steel rod crossbracing with turnbuckles or shear walls of concrete or masonry can be used to provide lateral stability.

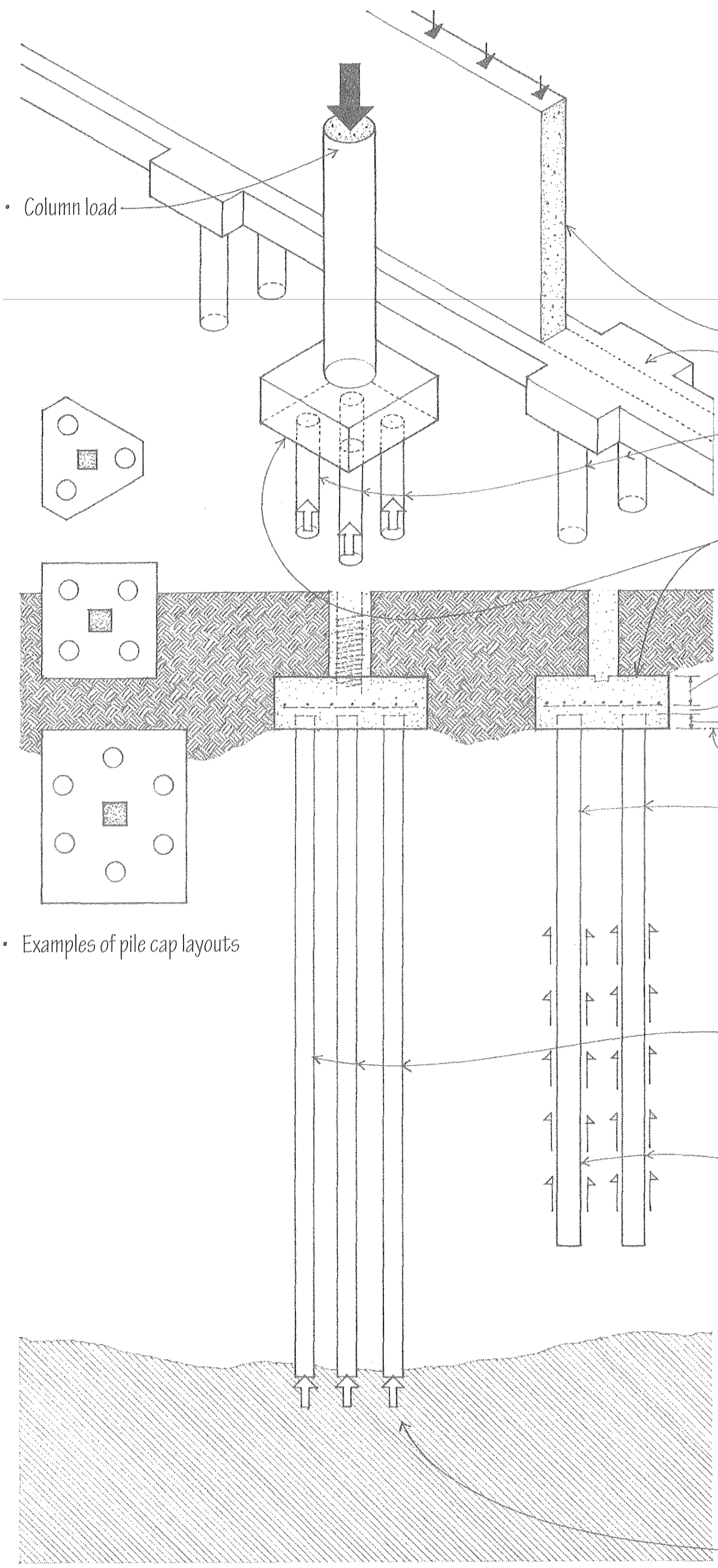
- Consult a qualified structural engineer when designing and constructing a pole structure, especially when building on a steeply sloping site subject to high winds or flooding.



Spaced beams are through-bolted to the sides of the treated poles, which then continue up to form the loadbearing frame for the superstructure.



Poles may distribute their loads with a concrete footing or necklace or by bearing directly on rock. Concrete pads and collars increase the contact area of the poles with the soil and distribute their loads over a larger area.



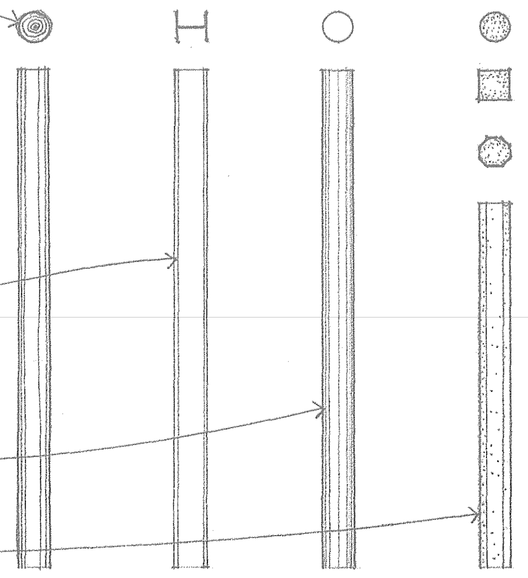
Deep foundations extend down through unsuitable or unstable soil to transfer building loads to a more appropriate bearing stratum of rock or dense sands and gravels well below the superstructure. The two principal types of deep foundations are pile foundations and caisson foundations.

A pile foundation is a system of end-bearing or friction piles, pile caps, and tie beams for transferring building loads down to a suitable bearing stratum.

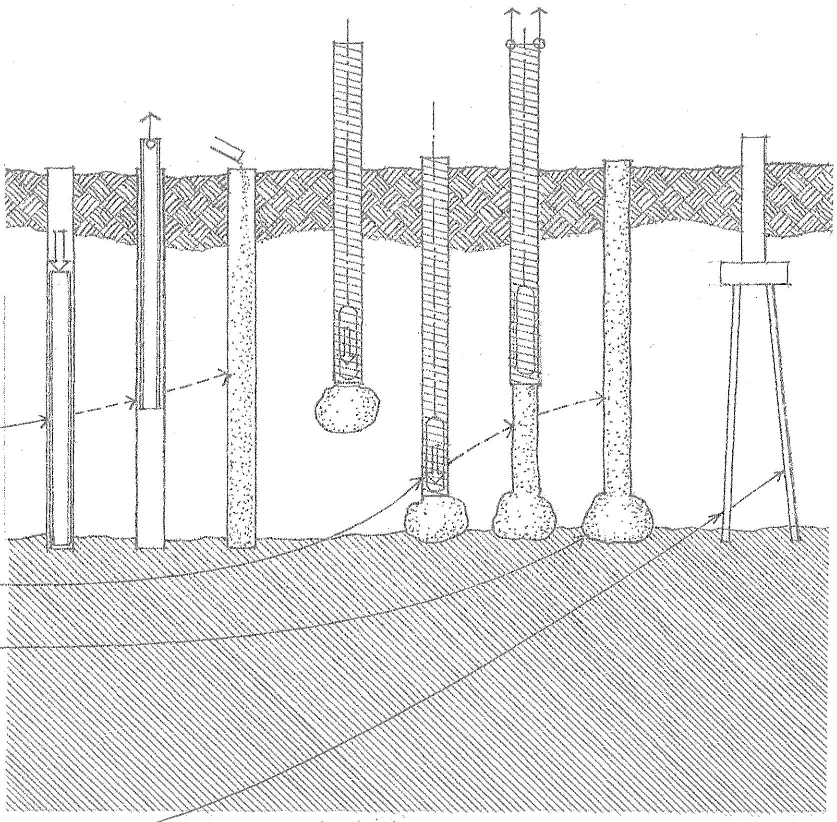
- Loadbearing wall
- Reinforced concrete grade or tie beam with integral pile caps
- Piles are usually driven in clusters of two or more, spaced 2'-6" to 4'-0" (760 to 1220) o.c.
- A reinforced concrete pile cap joins the heads of a cluster of piles in order to distribute the load from a column or grade beam equally among the piles.
- Varies with column load; 12" (305) minimum
- 3" (75)
- 6" (150)
- Place below frostline
- Piles may be of treated timber poles, but for large buildings, steel H-sections, concrete-filled pipes, or precast reinforced or prestressed concrete are more common.
- Piles are driven into the earth by a pile driver, composed of a tall framework supporting machinery for lifting the pile in position before driving, a driving hammer, and vertical rails or leads for guiding the hammer.
- End-bearing piles depend principally on the bearing resistance of soil or rock beneath their feet for support. The surrounding soil mass provides a degree of lateral stability for the long compression members.
- Friction piles depend principally on the frictional resistance of a surrounding earth mass for support. The skin friction developed between the sides of a pile and the soil into which the pile is driven is limited by the adhesion of soil to the pile sides and the shear strength of the surrounding soil mass.
- The allowable pile load is the maximum axial and lateral loads permitted on a pile, as determined by a dynamic pile formula, a static load test, or a geotechnical investigation of the foundation soil.
- Pile eccentricity, the deviation of a pile from its plan location or from the vertical, can result in a reduction of its allowable load.
- Bearing stratum of soil or rock

CSI MasterFormat 31 60 00 Special Foundations and Load-Bearing Elements

- Timber piles are logs driven usually as a friction pile. They are often fitted with a steel shoe and a drive band to prevent their shafts from splitting or shattering.
- Composite piles are constructed of two materials, such as a timber pile having a concrete upper section to prevent the portion of the pile above the water table from deteriorating.
- H-piles are steel H-sections, sometimes encased in concrete to a point below the water table to prevent corrosion. H-sections can be welded together in the driving process to form any length of pile.
- Pipe piles are heavy steel pipes driven with the lower end either open or closed by a heavy steel plate or point and filled with concrete. An open-ended pipe pile requires inspection and excavation before being filled with concrete.
- Precast concrete piles have round, square, or polygonal cross sections and sometimes an open core. Precast piles are often prestressed.



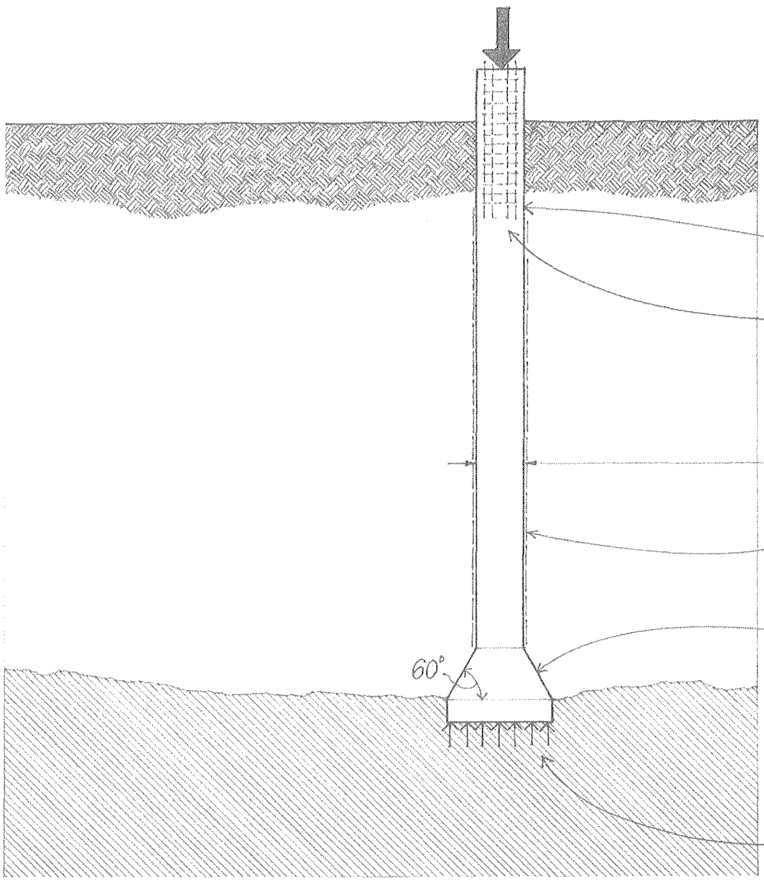
- Cast-in-place concrete piles are constructed by placing concrete into a shaft in the ground. The concrete piles may be cased or uncased.
- Cased piles are constructed by driving a steel pipe or casing into the ground until it meets the required resistance and then filling it with concrete. The casing is usually a cylindrical steel section, sometimes corrugated or tapered for increased stiffness. A mandrel consisting of a heavy steel tube or core may be inserted into a thin-walled casing to prevent it from collapsing in the driving process, and then withdrawn before concrete is placed in the casing.
- Uncased piles are constructed by driving a concrete plug into the ground along with a steel casing until it meets the required resistance, and then ramming concrete into place as the casing is withdrawn.
- A pedestal pile is an uncased pile that has an enlarged foot to increase the bearing area of the pile and strengthen the bearing stratum by compression. The foot is formed by forcing concrete out at the bottom of the casing into the surrounding soil.



- Micropiles are high capacity, small diameter [5" to 12" (125 to 305)], drilled and grouted in-place piles that are typically reinforced. They are often used for foundations in urbanized areas or in locations with restricted access, and for underpinning or emergency repairs because they can be installed in virtually any ground condition with minimal vibration and disturbance to existing structures.

CSI MasterFormat 31 62 00 Driven Piles
CSI MasterFormat 31 63 00 Bored Piles

Caissons are cast-in-place, plain or reinforced concrete piers formed by boring with a large auger or excavating by hand a shaft in the earth to a suitable bearing stratum and filling the shaft with concrete. For this reason, they are also referred to as drilled piles or piers.



Caisson

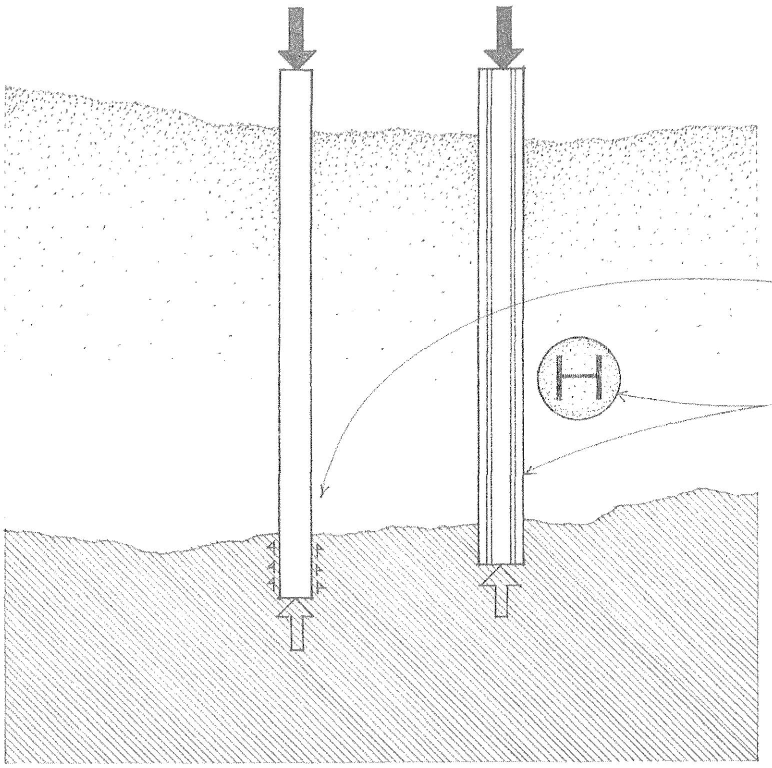
Reinforcement in upper part of shaft provides additional resistance to bending caused by lateral forces or eccentric column loading.

The boring is often 2'-6" (760) or larger in diameter to permit inspection of the bottom.

A temporary casing may be required to seal out water, sand, or loose fill from the shaft during excavation.

The base of a caisson may be enlarged into a bell shape to increase its bearing area and resist uplift from soil expansion. The bell may be excavated by hand or be formed by a bucket attachment to an earth auger that has a set of retractable blades.

Suitable bearing stratum of soil or rock



Socketed caissons are drilled into a stratum of solid rock in order to gain additional frictional support.

Rock caissons are socketed caissons that have a steel H-section core within a concrete-filled pipe casing.